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Original article

Assessment of mercury contamination in *Brycon falcatus* (Characiformes: Bryconidae) and human health risk by consumption of this fish from the Teles Pires River, Southern Amazonia

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Brycon falcatus is one of the most highly consumed species of fish within the region in the Teles Pires basin, and has great commercial importance in sport and professional artisanal fishing. The objective of this study was to analyze the presence and concentration of total mercury (THg) in the muscle, liver and gills of *B. falcatus*, and calculate the risk to human health of THg contamination from ingestion of the fish. THg concentrations were similar in the liver (0.076 mg kg^{-1}) and muscle (0.052 mg kg^{-1}), and higher than in the gills (0.009 mg kg^{-1}). The levels of HgT present in *B. falcatus* tissues did not influence weight gain and nutritional status. Based on the condition factor, weight and length ratio and hepatosomatic index, it seems that the concentrations of THg did not influence the health and well-being of *B. falcatus* collected in the Teles Pires River basin. THg concentrations in the muscle of *B. falcatus* are below the limit recommended by the World Health Organization for people who consume until 250 g of fish per week. The risk of deleterious effects on human health may exist if there is a greater consumption of *B. falcatus* such as 340 g/day, that is the mean of fish consumption by indigenous and riverine.

Keywords: Condition factor, Hepatosomatic index, Matrinxã, Tapajós basin, Weight-length relationship.

Brycon falcatus é um dos peixes mais consumidos na região da bacia do rio Teles Pires, tendo grande importância comercial na pesca esportiva e profissional artesanal. O objetivo deste estudo foi analisar a presença e concentrações de mercúrio total (HgT) no músculo, fígado e brânquias do peixe *B. falcatus*. Foi calculado o risco para a saúde humana de contaminação por Hg pela ingestão deste pescado. As concentrações de HgT foram similares no fígado (0,076 mg.kg^{-1}) e no músculo (0,052 mg.kg^{-1}) e maiores do que nas brânquias (0,009 mg.kg^{-1}). Os níveis de HgT presentes nos tecidos de *B. falcatus* não influenciaram no incremento de peso e estado nutricional. Com base no fator de condição, relação peso e comprimento e índice hepatossomático, aparentemente as concentrações de THg não influenciaram a saúde e o bem-estar de *B. falcatus* coletados na bacia do rio Teles Pires. As concentrações de THg no músculo de *B. falcatus* estão abaixo do limite recomendado pela Organização Mundial de Saúde para pessoas que consomem até 250 g de peixe por semana. O risco de efeitos deletérios para a saúde humana pode existir se houver um maior consumo de *B. falcatus*, como 340 g/dia, que é a média do consumo de peixe por indígenas e ribeirinhos.

Palavras-chave: Bacia do Tapajós, Fator de Condição, Índice hepatossomático, Matrinxã, Relação peso-comprimento.

Introduction

Cattle farming, agriculture and tannery operations are the current main economic activities within the Teles Pires River basin (Brazil). Trace elements such as Cu, Hg, and Cd are widely used in fungicides, fertilizers, bactericides and disinfectants in agricultural practices (Micaroni *et al*., 2000; Penteado, 2000; Grant, Sheppard, 2008; Sfredo, 2008). In the 1970s, intense logging activity began with consequent increases in deforestation, burning and erosion (Cordeiro *et al*., 2002). Forest burning, extensive cattle farming and soybean plantations led to the erosion of soils naturally rich in mercury (Lechler *et al*., 2000). Soils of the Amazon region present naturally high Hg concentrations, often higher than those observed globally (Roulet, Lucotte, 1995; Fadini, Jardim, 2001; Wasserman *et al*., 2003). In the Tapajos River basin an

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increase in the deposition of Hg in lacustrine sediments was observed in the 1970s (Roulet *et al*., 2000), coinciding with the beginning of intense colonization of the Amazon. These authors have suggested that the colonization of drainage basins and increased land exploration in the Amazon increased the leaching of naturally present mercury from the soil into rivers. In addition, intense gold prospecting activities occurred between the 1970s and 90s in northern Mato Grosso State (where the Teles Pires River basin is located), declining after this period due to the depletion of easily accessible gold deposits (Lobo *et al*., 2016). Subsequently, gold prospecting was replaced by agriculture and cattle farming, where fire was used as a way to open new areas for these activities (Cordeiro *et al*., 2002).

Among various pollutants, trace elements represent an important group of interest due to their bioaccumulation and toxicity in living organisms (Islam, Tanaka, 2004; Abdallah, 2008). Hg, in particular, is a trace element that biomagnifies along food chains, thus, it is worrying to top levels organisms as piscivorous fish and humans, for example. For teleost fish, the bioavailability of Hg depends not only on its total concentration in the environment but also its chemical species and capacity of absorption through different tissues of the fish (Sweet, Zelikoff, 2001). In the organs, Hg first crosses the epithelium to the blood, which transports it through the bloodstream to the tissues. The gills, the digestive system and, to a lesser extent, the skin, are the main sites of mercury capture in fish (Erickson *et al*., 2008). The primary target tissues of Hg are the central nervous system and the kidney, causing brain damage, abnormal motor coordination, behavioral changes, alterations that impair growth, reproduction and development of the fish (Clarkson *et al*., 2003). Mercury-induced toxicity in the liver can severely affect morphology and structure, impairing its functional role by interfering with key physiological and metabolic processes (Macirella *et al*., 2016). Some fish organs are commonly used to determine the bioaccumulation of total mercury (THg), such as the liver, as it plays vital roles in the accumulation, biotransformation and excretion of contaminants (Figueiredo-Fernandes *et al.*, 2006). The gills have a large surface area in contact with contaminants present in the water, therefore, they are an important route of exposure of the organism. High concentrations of Hg in the gills may reflect a transitory state before it is eliminated from that organ (Huang *et al*., 2012). Finally, evaluating the fish muscle helps determine the direct transfer of Hg to humans, as this is the most consumed part of the fish.

Fish are an important source of protein in the human diet, and represent one of the major sources of Hg ingestion via the food chain. High concentrations of Hg in humans can cause damage to the neurological and immunological systems, congenital malformations and teratogenic effects (Akagi *et al*., 1995). There are several studies in the Teles Pires River basin investigating Hg contamination in humans through fish consumption (Akagi *et al*., 1995; Malm *et al*., 1995; Malm *et al*., 1997; Hacon *et al*., 1997; Barbosa *et al*., 1997; Hacon *et al*., 2000; Dorea *et al*., 2005). However, these studies were performed at contaminated sites. From a food safety point of view, it is important for studies to focus on commonly consumed species of fish and popular fishing sites with professional and amateur fishermen (Kensová *et al*., 2012). The fish species *Brycon falcatus* (Müller & Troschel, 1844), commonly known as matrinxã, is one of the most highly consumed species in the region due to its excellent quality of meat.

Considering the current scenario of multiple uses of the Teles Pires River basin, and therefore potential mercury contamination, the objectives of this study were to evaluate: (1) the total concentration of THg in the muscle, gills and liver of *B. falcatus*, (2) whether THg contamination was interfering with the well-being of collected fish, and (3) the risk to human health associated with the consumption of THg in *B. falcatus* muscle tissue. Our hypotheses are: (1) Since the liver is an important organ of detoxification of contaminants, it will present higher THg levels when compared to the other tissues analyzed (gills and muscle); (2) Fish will present a strict correlation between THg contamination and its condition factor, weight and length ratio and hepatosomatic index, indicating that Hg exposure is interfering with their growth and sanity; (3) The *B. falcatus* specimens will present low levels of THg in the muscle since are omnivorores, representing a low risk to human health even at high rates of fish consumption in that region.

Material and Methods

Study area. The Teles Pires River basin is located in northern Mato Grosso State (Brazil), and is one of the main tributaries of the Tapajós River basin. Fish were collected from the Celeste River (12°24’56.00”S 55°31’28.00” W) in the municipality of Vera, the Verde River (11°4’1.99”S 55°34’17.00”W) in the municipality of Sorriso, and from the Teles Pires River (11°34’48.00” S and 55°39’5.00” W) in the municipality of Sinop (Fig. 1). There is no history of gold prospecting activities within the studied areas, however the soil is subject to intense use, primarily through cattle farming, agriculture and tannery activities.

Fish collection and biometrics. Fish samples were collected from November 2014 to October 2016 using fishing rods and artificial bait. Five specimens were collected on the Celeste river, 33 on the Teles Pires River and 7 on the Verde River. After capture, fish were euthanized with a dose of 287 mg L^{-1} of Eugenol® for approximately 600 s (American Veterinary Medical Association, 2001; Vidal *et al*., 2008), then submerged in ice and packed in plastic bags. Samples were transported to the laboratory where total length, standard length and weight were measured for each specimen. The liver, gills and dorsolateral muscle (region below the dorsal fin and above the lateral line) were removed. These three tissues were stored at -20°C until analysis for THg concentration. *Brycon falcatus* specimens were catalogued at the Universidade Estadual de Campinas museum (ZUEC 9190) and the Acervo Biológico da Amazônia Meridional of the Universidade Federal de Mato Grosso (Núm. catalogo?).

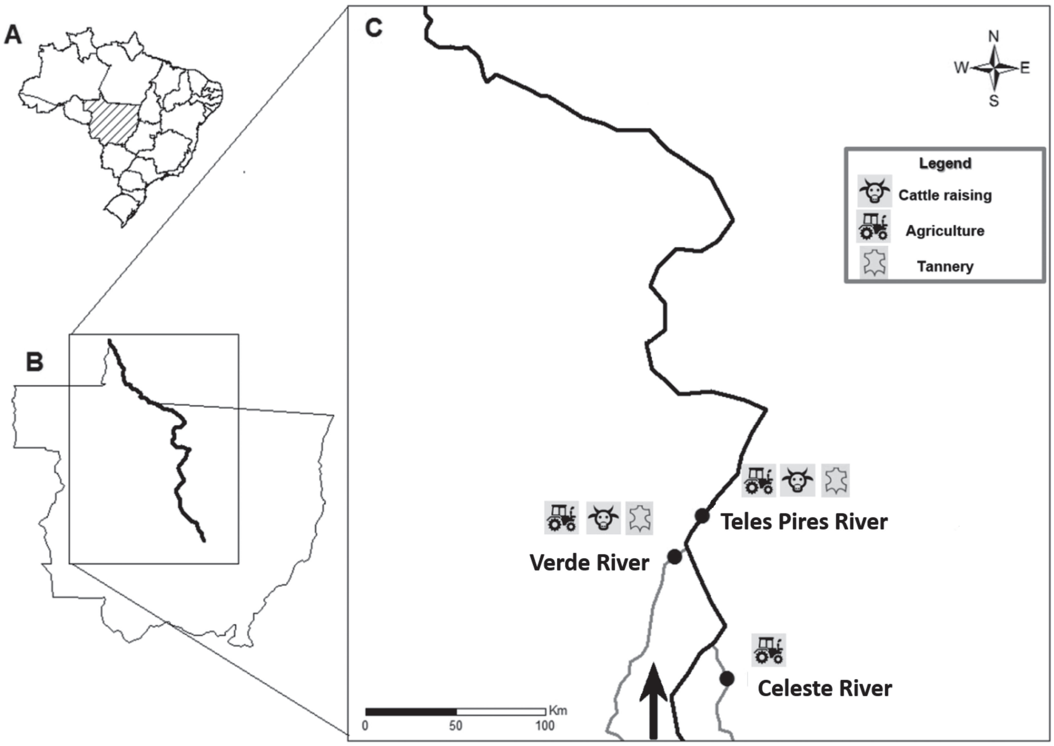

Fig. 1. a. Brazil, with the state of Mato Grosso marked as stripes. **b.** The state of Mato Grosso with the Teles Pires River shown in bold. **b.** *Brycon falcatus* sample collection sites (black circles), accompanied by pictographs of the main human activities found at each site. The black arrow indicates the flow direction of rivers. The specimens were collected from November 2014 to October 2016.

THg analysis. Tissue samples were digested as described by Zhou, Wong (2000), with 8 ml of HNO_3:H_2SO_4 (2:1 v/v) solution at 25°C for 3 h, and then 60°C for 5 h. Five ml of 30% H_2O_2 were added and temperature maintained at 65°C until samples were light in color. Samples were added to 25 ml of distilled H_2O, and the determination of THg concentration was performed with a Cold Vapor Atomic Absorption Spectrometer (Spectrometer model AA 140, Varian).

Quality Assurance of Analyses. To verify the accuracy of the analytical method, a commercial certified sample (TORT-2 lobster hepatopancreas) provided by the National Research Council of Canada was analyzed. TORT-2 recovery was 81±6% for THg (n=2). *Spikes* were also made with muscle tissue samples, oven dried at 40ºC to a constant weight, macerated, mixed with 10 mg/L THg solution, oven dried and macerated a second time, weighed and then subjected to the same digestion process as the previous tissue samples. These *spikes* (n=4) showed a recovery of 91±3% for THg. The THg concentration of samples within this study represent the uncorrected analytical results for the observed recovery in *spikes* and/or TORT-2. Blank (n=10) were periodically analyzed to test for any memory effect in the analysis and to evaluate any possible contamination of glassware, reagents and the laboratory atmosphere itself. The detection limit corresponds to the mean concentration of blanks samples plus three times the standard deviation (Miller, Miller, 1994). The detection limit was 0.063 µg/L.

Weight-length relationship and condition factor. The condition factor (K) is often used as an indicator of the degree of a species' well-being. A K with values close to or greater than 1 generally indicates well-nourished and healthy fish, and K values below 0.8 indicate underweight fish (Cizdziel *et al*., 2002). The condition factor and weight-length relationship were analyzed according to Santos (1978) and Braga (1986). The allometric condition factor was calculated using the formula K = W/Lb, where W = weight, L = standard length and b = regression coefficient. The weight-length relationship was estimated using the expression $W = aL^b$, where W = weight, a = intercept, L = standard length, and b = angular coefficient (Le Cren, 1951). The parameters a and b were estimated after logarithmic transformation of the weight and length data and subsequent adjustment of the line of best fit using the least squares method (Vanzolini, 1993). Le Cren (1951) states that the *b* values range from 2.0 to 4.0, assuming the value 3.0 for an "ideal fish" which maintains the same shape during ontogenetic growth. Values less or greater than 3.0 indicate individuals that become "longer" or more "round" during growth, respectively. The degree of association between weight and standard length was measured by coefficient of determination (r^2).

Hepatosomatic Index (HSI). The HSI reflects a fish's metabolic energy demand and can be considered as a general indicator of the health of fish which are sensitive to environmental contaminants (Everaarts *et al*., 1993). An increase in liver weight may indicate an increase in the enzymatic detoxification process. In this way, the HSI can be used as a biomarker when fish are exposed to substances toxic to the liver (Haux, Larsson, 1984). The HSI was calculated using the formula described by Vazzoler (1981):

$$HSI = 100 \times (\text{liver weight (g)} / \text{total body weight (g)})$$

Estimated risk to human health. The human health risk assessment was performed in accordance with the United States Environmental Protection Agency (USEPA, 2000). We used an approach based on four different consumption rates of *B. falcatus*: average consumption for consumers in Mato Grosso, Brazil, Instituto Brasileiro de Geografia e Estatística (IBGE, 2011), average consumption for typical adults (USEPA, 2000), consumption for regular adult consumers (USEPA, 2000), and consumption for riverine and indigenous populations (Fréry *et al*., 2001). For each of the four rates, we calculated the mean daily human intake of THg using the specimens with the lowest and highest THg concentration. To calculate the level of THg exposure resulting from the consumption of fish muscle tissue (the most commonly consumed tissue), the mean daily THg intake (MDI) equation was calculated as follows:

$$MDI\ (\text{mg kg day}) = (C*CR)/(BW)$$

Where: C = concentration of THg in fish muscle tissue (mg kg^{-1}), CR = mean consumption rate: 0.030 kg day for typical adults, 0.142 kg day for regular adult consumers, 0.009 kg day for consumers in Mato Grosso (IBGE, 2011) and 0.340 kg day for indigenous and riverine populations (Fréry *et al*., 2001), BW = subject's body weight (70 kg was used).

The risk assessment was quantified by calculating the risk index (RI), which is expressed as the ratio between MDI and the oral reference dose (RfD) of mercury, and gives an idea of how many times above or below the recommended dose the population in question is being exposed to. The RI was calculated according to the following equation:

$$RI = MDI / RfD$$

Where RfD is the exposure to mercury to the human that is likely to be without noticeable risk to human health during a lifetime. The present work used RfD of 0.0001 mg kg^{-1} body weigth/day that is suggested by World Health Organization (WHO, 2008) for methylmercury (since almost all THg of muscle of fish is methylmercury) that includes the sensitive groups. Therefore, this RfD used intends to represents the worst scenario of mercury ingestion that should be considered when risk is assessed (the methylmercury ingestion by sensitive groups). Risk index values <1.0 indicate that population exposure is less than the acceptable dose and is likely to be without noticeable risk to human health (WHO, 2008). If the IR is ≥1.0, then population exposure is equal to or greater than the recommended acceptable dose, and the potential for adverse health effects increases.

Statistical analysis. Considering that *B. falcatus* is a migratory species, and that the distance between the three collection sites is no more than approximately 100 km, fish sampled from the three localities were analyzed collectively. Therefore, all data analyses cited above (weight-length relationship, K, HSI, MDI, RI) and subsequent analyses were performed by combining all specimens from the three locations.

Non-normality in the data distribution was verified through the Shapiro-Wilk test. As a result, a non-parametric Kruskal-Wallis test was used to test for differences in THg concentration between *B. falcatus* tissues. Spearman's correlation was used to verify any correlation between THg concentration in muscle tissue and condition factor, and between THg in the liver and the HSI. In a previous analysis we found that the variables weight and standard length were dependent, therefore to verify if THg concentration within the tissues was affecting the weight increase of fish, a multiple linear regression was used, using the following model:

lm(log(weight)~log(standard length) + THg concentration

All analyzes were performed using the Statistical Software R v. 3.3.2 (R Core Team, 2017).

Results

Forty-five *Brycon falcatus* individuals were collected and analyzed from the three collection sites within the Teles Pires river basin (Tab. 1). THg concentrations were higher in liver and muscle tissue than in the gills of fish ($p=5.96e^{-10}$, Kruskal-Wallis, level of 5% probability) (Tab. 2). THg concentration in the muscle tissue (the most commonly consumed part of the fish) was below the World Health Organization (WHO, 2008) recommended values for THg in fish intended for human consumption (Tab. 2). The RI values for *B. falcatus* muscle consumption ranged from 0.01 to 8.74 (Tab. 3).

Tab. 1. Mean and range of total length (TL), standard length (SL) and weight (g) of *Brycon falcatus* specimens from rivers in the Teles Pires River basin collected from November 2014 to October 2016.

River	N	TL (mm)	SL (mm)	Weight (g)
Celeste	5	430 (285-565)	345 (225-450)	1740 (330-3600)
Teles Pires	33	292 (101-558)	247 (79-455)	1161 (13-3920)
Verde	7	484 (370-600)	396 (300-480)	2170 (810-4320)

Tab. 2. THg concentration (mean ± standard deviation, in mg kg^{-1} wet weight) in tissues of *Brycon falcatus* collected from the Teles Pires River basin and the recommended limit of THg in fish for human consumption (WHO, 2008). Same letter indicates no statistical difference, while different letters indicate statistical difference ($p=5.96e^{-10}$, Kruskal-Wallis, level of 5% probability). The specimens were collected from November 2014 to October 2016.

Trace element	Tissue type			Recommended limit
	Gills	Liver	Muscle	
THg	0.009 ± 0.004[a]	0.076 ± 0.139[b]	0.052 ± 0.037[b]	0.500

Tab. 3. Range of average daily intake (MDI) and risk index of adverse health effects (RI) calculated based on four different rates of fish consumption (typical consumers, regular consumers, consumers in the state of Mato Grosso and indigenous and riverine frequent consumers; consumption rates described in Material and Methods). RfD = oral reference dose (0.0001 mg kg day) based on WHO (2008). The MDI and RI were calculated based on total mercury concentration observed in *Brycon falcatus* muscle tissue collected from the Teles Pires River basin (0.009 to 0.180 mg kg^{-1} wet weight). The specimens were collected from November 2014 to October 2016.

	Typical adult	Regular adult consumers	Mato Grosso (General population)	Indigenous and Riverine
MDI (mg/kg/d)	3.85E-06 - 7.71E-06	1.82E-05 - 3.65E-05	1.16E-06 - 2.31E-06	4.37E-05 - 8.74E-04
RI	0.038 - 0.771	0.182 - 3.651	0.011 - 0.231	0.437 - 8.742

Fish weight increased positively with standard length (r^2 = 0.914; p<0.001; *b* = 3.387; Fig. 2). The condition factor (K) was 1.025 and the HSI was 0.454 ± 0.286. There was no correlation between THg concentration in the muscle and condition factor (r = -0.073; p = 0.669), or THg in the liver and HSI (r = -0.03; p = 0.832).

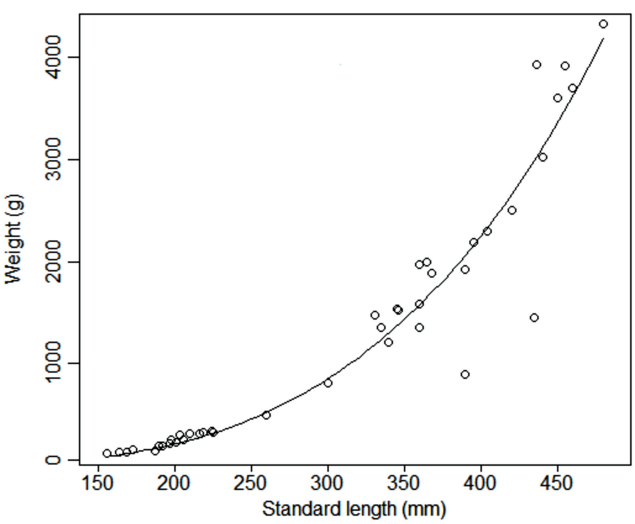

Fig. 2. Relationship between weight and standard length of *Brycon falcatus* collected from rivers of the Teles Pires River basin from November 2014 to October 2016.

THg concentration in muscle tissue was not related to standard length or weight (r^2 = 0.54; p>0.05).

Discussion

THg concentration in the liver and muscle tissue of *B. falcatus* was higher than that found in the gill tissue. The gills are in direct contact with the aquatic environment, and as they are responsible for the gas exchange process between the organism and environment, they are extremely irrigated by blood. Thus, the concentration levels in this organ reflect those of the external environment (river water) and the organism's blood. Other studies with fish have pointed to the liver as the organ with the highest accumulation of Hg (Havelková *et al*., 2008; Azevedo *et al*., 2012, Alvarez *et al*., 2012; Watanabe *et al*., 2012). In fish the Hg can be detoxified by the kidney, liver and, possibly, by the gills (Huang *et al*., 2012). Maulvault *et al.* (2016) reported that the liver presented the highest percentage of elimination of Hg (64%) in juveniles of *Dicentrarchus labrax* (perciform fish). In muscle, Hg normally binds to the protein sulfhydryl groups (Azevedo, 2003). The half-life of Hg in this tissue tends to be higher, therefore, it is extremely relevant to know its THg concentration as it integrates environmental concentration in time and space (especially for migratory fish such as *B. falcatus*). Therefore, liver and muscle tissues can have similar concentrations; however their significance and interpretation must be performed independently. Similar concentrations within these two tissues were also observed in omnivorous, carnivorous and detritivorous fish from the Vigário Reservoir (Rio de Janeiro, Brazil; Kasper *et al*., 2009).

Various anthropogenic impacts are known within the studied region such as tanneries and cattle farming, however agriculture is currently the most widely practiced human activity, and is thus responsible for the greatest impact. It has been shown that the various uses of the soil can be reflected in higher Hg concentrations in fish due to the direct increase of Hg from these activities (*e.g*., use of mercury fungicides), or through increased leaching of naturally occurring Hg within the soil. Roulet *et al*. (1999) observed that erosion resulting from deforestation carries mercury absorbed in soil particles to adjacent aquatic systems. Mercury deposition in the sediment of a Southern Amazonian lake increased with intensified deforestation and land use from activities such as road construction (Cordeiro *et al*., 2002). Fires caused cationic enrichment of the Tapajós river basin's soils, causing a change in cationic dynamics and consequent higher soil mercury loss due to leaching (Farella *et al*., 2006). Sampaio da Silva *et al*. (2009) studied the Tapajós river basin and suggested that land use in watersheds plays a key role in the Hg concentration of local ichthyofauna. Kütter *et al*. (2015) observed high mercury concentrations in the omnivorous *Astyanax* sp. in southern Brazil's rice plantations. Although within the region of focus of the present study, even with intense agricultural activity and agrochemical use (Pignati *et al*., 2007; Belo *et al*., 2012), our results showed that *B. falcatus* presented low concentrations of THg. Mercury is poorly absorbed through gills and skin of fish; the main route of exposure is through its diet (Erickson *et al.*, 2008). Top organisms in the aquatic food chain generally have higher THg concentrations than those at lower trophic levels even though they inhabit the same aquatic system (Voigt, 2004; Terra *et al*., 2008). *Brycon falcatus* has omnivorous food habit with a tendency to frugivory (Correa *et al.*, 2007). In the Teles Pires river basin, due to the great supply of *in natura* soybeans in attractants, the *B. falcatus* diet is mainly based on soybeans (Matos *et al*., 2016a). Thus, the low levels of THg in *B. falcatus* observed in the present study is probably due to its food habit.

The weight-length relationship in the present study revealed a positive allometric growth with a b value greater than 3.0, indicating that the increase in weight was greater than that of length for fish collected from the Teles Pires river basin. This positive allometric standard was also described for wild *B. falcatus* specimens (Giarrizzo *et al*., 2015), farmed *Brycon amazonicus* (Arias *et al*., 2006), wild *Brycon siebenthalae* (Arias, 1995) and wild *Brycon cephalus* (Zaniboni-Filho, 1985). According to Silva *et al*. (2015), when the value of b exceeds 3.0, the fish are fatter. Therefore, based on the *b* value, THg levels in collected *B. falcatus* did not influence weight gain. The condition factor is often used as an indicator of fish nutritional status, where a K value close to 1 generally indicates that fish are well nourished and healthy (Cizdziel *et al*., 2002). The condition factor of collected *B. falcatus* was 1.025, indicating that collected fish were healthy. In the present study there was no correlation between THg concentration in the muscle and K of collected *B. falcatus*. This indicates that THg levels in analyzed *B. falcatus* did not influence nutritional status. In addition, there are other factors besides well-being that were not analyzed in the present study, which can be affected even at low levels of mercury (such as, reproduction, gas exchange through gills and predator avoidance). Studies indicate that Hg affects the capture capacity of fish prey and makes them more susceptible to predation (Weis, Weis 1995a, 1995b; Smith, Weis, 1997). The contamination by Hg also can impair the hormone production in male and female fish, and decrease the quality and quantity of the production of sperm and eggs (Friedmann *et al*., 2002; Ebrahimi, Taherianfard, 2011). The gill epithelium of fish can be ruptured since Hg contamination, affecting the gas exchange and the permeability of cell membranes (Oliveira-Ribeiro *et al*., 2000), which may result in increased energy demands, change in gas exchange efficiency and increase the metabolic rate (Tatara *et al*., 2001).

Body indexes, such as the hepatosomatic index, have commonly been used for biomonitoring of environmental stress in fish health. An increase in the HSI may also be associated with increased detoxification activity in response to the presence of contaminants (Pereira, Kuch, 2005). However, a decreased HSI indicates that fish populations are under chemical stress and are using energy reserves (Kopecka *et al*., 2006). In farmed *Brycon*, a HSI of 0.96 was reported for *B. cephalus* (Monteiro *et al*., 2006) and 1.31 for *B. amazonicus* (Tavares-Dias *et al*., 2008). In wild *B. falcatus*, the HSI ranged from 0.166 to 0.390, reflecting stress induced by a low supply of fish food during the dry season, rather than contamination of the specimens (Matos *et al*., 2016b). In the present work, the mean HSI of analyzed fish was 0.454 ± 0.286, similar to that described by Matos *et al*. (2016b). Considering that this study analyzed wild specimens, where the food supply is likely lower than that in pisciculture, and that there was no correlation between THg concentration in the liver and the HSI, we can conclude that the low HSI does not reflect contamination of the specimens, but rather the specimens' nutritional status.

The THg levels in muscle tissue of the *B. falcatus* specimens evaluated in this study ranged from 0.009 to 0.180 $mg.kg^{-1}$ wet weight, below the value recommended for fish Hg content for human consumption by World Health Organization. This recommendation is based on a person weighing approximately 60 kg and having in his food about 400 g of fish per week (FAO, 1983). However, the RI calculated with different consumption rates of fish of the studied region presents some values greater than 1.0, indicating a potential risk of adverse effects on human health. The RfD used to calculate RI is an estimate of a daily exposure to the human population (including sensitive subgroups) that is unlikely to have a significant risk of deleterious effects during life. It is not a direct risk estimator, but rather a point of reference for assessing the potential effects. In increasing exposures to RfD, the potential for adverse health effects increases (USEPA, 2001). In the Tapajós basin, Bidone *et al*. (1997) and Castilhos *et al*. (1998) found similar levels of THg (0.050 $mg.kg^{-1}$) in matrinxã muscle. *Brycon falcatus* has excellent meat quality, and as a result is commonly consumed throughout the region, with the muscle flesh the part of the fish most commonly used for human consumption (Kosanovic *et al*., 2007). There are three indigenous ethnic groups (*mundurukus*, *kaiabis* and *apyakas*) within the Teles Pires river basin that consume the available fisheries resources (Ricardo, Fany, 2011; IBGE, 2016). In addition to the indigenous tribes, there is a fishing colony (named Z-16) with approximately 250 professional fishermen working in the Teles Pires river basin. In the Tapajós basin, researchers found trace element contamination in indigenous and riverine populations; where Barbosa *et al*. (1997) showed that 3% of the riverine population presented levels of mercury above 50 $mg.kg^{-1}$, Hacon *et al*. (1997) estimated a Risk Index of 9.3 for families of fishermen, and Brabo *et al*. (2000) concluded that while Hg levels in fish consumed by the *Sai Cinza* tribe were below the Brazilian limit for consumption, their high consumption rates of large quantities of fish make them highly susceptible to contamination. Considering that the diets of the local indigenous and riverine populations predominately consist of fish (the populations' main protein source), results in high susceptibility to the contaminants contained in consumed fish. According to Fréry *et al*. (2001), fish meat constitutes at least seven weekly meals for these populations, consuming approximately 340 g of fish per day. However, studies comparing contamination risks to the benefits provided by the consumption of omega-3 fatty acids have shown that the benefits outweigh the risks (Mozaffarian, Rimm, 2006; Mahaffey *et al*., 2011). To balance the risks and benefits of regular fish consumption, species choice, consumption frequency and portion size are essential aspects that need to be looked at (Domingo, 2007). Based on the data from our study, we conclude that it may be considered unlikely that the consumption of *B. falcatus* from the Teles Pires river basin for the general population, which consume about 30 g of matrinxã per day or about of 250 g/week, presents a risk for health. However, those who have a high consumption of fish, such as indigenous and riverine people, it is adequate to eat more herbivorous fish (pacu, tambaqui, pirapitinga, jatuarana, piau and others) since they probably have low Hg levels. It is especially important for the fish consumption by children, pregnant and lactating because they are nurturing a nervous system in formation, and, therefore, the most vulnerable life stages.

We summarize that by the condition factor, weight and length ratio and hepatosomatic index analyses the concentrations of THg probably did not influence the health and well-being of *B. falcatus* collected in the Teles Pires river basin. Liver and muscle tissues presented similar levels of THg, but their significance and interpretation should be performed independently. Regarding the consumption of the *B. falcatus*, we conclude that the concentrations of THg are within the limit recommended for those that have lower consumption rates of the studied region. The risk of deleterious effects on human health may exist in those that have a greater consumption of *B. falcatus* because the consumer will be exposed to higher loads of mercury (including the sensitive groups). With the implementation of the Sinop Hydroelectric Power Plant, which it is planned to operates from 2019, future studies on fish assessment should be carried out since the creation of the reservoir may increase the bioaccumulation of Hg in fish, as already seen in many tropical and temperate reservoirs (*e.g*., Schetagne, Verdon, 1999; Hylander *et al*., 2006; Porvari, 1995).

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