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Total Mercury in the Night Shark, *Carcharhinus signatus* in the Western Equatorial Atlantic Ocean

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ABSTRACT

Mercury is the only element capable to biomagnificate along the food chain, and carnivorous fish tend to accumulate high concentrations of this element. Total mercury in muscle tissue of Carcharhinus signatus sampled along the western equatorial Atlantic Ocean was measured by atomic emission spectrophotometry with ICP/AES. The average total mercury concentrations were consistently greater than the maximum limit for human consumption established by the Brazilian Health Ministry for carnivorous fishes (1000 µg. kg-1 w.w.). Therefore, an average consumption of 0.1 kg/day of C. signatus would result in an average daily ingestion of 174.2 µg of Hg, more than five times the 30 µg/day intake established by the World Health Organization. In the range of lengths studied, body length could not be used as an indicator of the Hg contamination degree for C. signatus. Also, sex cannot be considered a determining factor in the total mercury accumulation in C. signatus.

Key words: Mercury, shark, Carcharhinus signatus, southwestern Atlantic Ocean

INTRODUCTION

Mercury contamination is generally related to point and non-point sources from natural and anthropogenic causes. Surface runoff, atmospheric deposition and mainly fluvial transport are prominent pathways in the mercury transport from continents to coastal areas (Hanten el al., 1998; Pinho, 1998). Several studies have already shown that mercury can bioaccumulate in muscle tissues of fish, mainly in the methylated form. Mercury concentrations in fish generally present a positive correlation with size and age (Neumann and Ward, 1999; Ward and Neumann, 1999; Lacerda et al., 2000).

Considering that mercury is the only element capable to biomagnificate along the food chain, carnivorous fish tend to accumulate high concentrations of this element. For this reason apex predator fishes may become the main pathway for human contamination through the consumption of contaminated specimens (Monteiro et al., 1996; Paz et al., 1997). In fact, many studies of marine fishes in Brazilian waters have revealed mercury concentrations above (0.5 $\mu g.g^{-1}$) the limit for human consumption established by the Brazilian Health Ministry (Aizpurúa et al., 1997; Pinho, *op. cit.*; Lacerda et al., *op. cit.*).

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Although several studies have been carried out on mercury concentration in fish captured in coastal environments, information from oceanic environments is scarce (but, see Pinho, *op. cit.*). This is possibly due to difficulties in obtaining samples of apex marine predator fishes, such as sharks from oceanic areas. In this study, we were able to analyze mercury concentrations of the Night shark *Carcharhinus signatus* captured in an oceanic area. The Night shark is one of the most abundant shark species in the western equatorial Atlantic Ocean. It occurs along the outer continental shelf and insular shelves, preferentially at 50 to 100 meters depth. It feeds on benthic bony fishes as scombrids and sea bass (Compagno, 1984; Hazin et al., 2000).

Night shark meat is used for human consumption (Compagno, 1984; Hazin et al., 2000), and may therefore represent an important model for understanding the role of mercury in oceanic environments and the possible intake of mercury from these environments by human populations. The objective of the present work was to determine the total mercury concentration in muscular tissue of *C. signatus* sampled from the western equatorial Atlantic Ocean, and to identify any correlation between mercury levels and shark body length.

MATERIAL AND METHODS

As part of the Brazilian Program for the Assessment of Living Resources in the Economic Exclusive Zone (REVIZEE), specimens of *C. signatus* were collected from November 1995 to November 1999 from landings of commercial vessels in Natal, Rio Grande do Norte State, Brazil. Sharks were caught in the area made up of deep (Aracati, Dois Irmãos, Fundo, Sirius) and shallow (Pequeno, Leste and Sueste) seamounts with depths at the summits between 38 to 370 m.

Commercial vessels were equipped with ~30 Km Japanese-style multifilament longline gear (Suzuki et al., 1977). On average, each vessel used 970-980 hook.day^{-1}, with mainline-set beginning at ~ 02:00 h and ending ~ 06:00 h. The retrieval was started at noon and accomplished by dusk. The Brazilian sardine (*Sardinella brasiliensis)*, flying fish *(Cypselurus cyanopterus)* and squids (*Loligo* sp.) were commonly used as bait (Hazin et al., 1998). Landed dressed carcasses of *C. signatus* were identified using the standards described by Compagno (1984). Each individual's sex and the interdorsal width (IW) (mm), defined as the distance between the posterior base of the first dorsal fin and the anterior base of the second dorsal fin, were recorded.

Approximately 50 g of muscular tissue of each individual were extracted using a stainless steel scalpel. Samples were kept on ice for transportation to the laboratory, and stored at -18° C until mercury concentration analyses were performed.

Total mercury was determined using a modified version of the methodology described by Bastos et al. (1998), where 1.0 g of wet weight fish tissue was heated on a hot plate for four hours at 60ºC with 1 ml H_2O_2 and 3 mL of an acid mixture (1 H_2SO_4:1 HNO_3). After cooling, 5 mL of $KMnO_4$ 5% were added and the sample was heated again for 30 minutes at 60 ºC.

Drops of 12 % $NH_2OH.HC$ were added after cooling and the extracts were then filtered and gauged to 25 mL with distilled water. The Hg was measured by atomic emission spectrophotometry with induced coupled plasma (ICP/AES Varian model Liberty II) with vapor generating accessory (VGA 77). The accuracy of the analytical method was verified by analyzing standard certified material - DORM 1 (*Squalus acanthias* muscular tissue) from the Marine Analytical Chemistry Standard Programs, Canada. The method presented an average recovery of 98.92%.

Total length (TL) was estimated from interdorsal space (IS), using the equation described by Hazin et al. (2000) for the *C. signatus* population in the southwestern equatorial Atlantic Ocean: IS = -3.46 + 0.26TL. Mature and immature specimens were identified based on the estimated total length.

A Kolmogorov-Smirnov test was used to test the normality of the total mercury distribution. As the mercury concentrations were not normal distributed ($p<0.05$), non-parametric statistical analyses were used for data analyses. A regression test was performed to verify the significance of the correlation between the total length and mercury concentration. Furthermore, ANOVA was used to test for a significant correlation between the observed mercury concentration and sex and maturity of *C. signatus* individuals. The significance level adopted on all analyses was $p<0.05$.

RESULTS AND DISCUSSION

The total sample of 38 *C. signatus* individuals was composed of 19 males (9 adults) and 19 females (10 adults). There was no significant difference (p=0.274) between the mercury concentrations of males and females (Table 1). Also, there was no significant difference between maturity stages (p=0.134). These results suggested that the intake and retention of Hg in *C. signatus* in the western equatorial Atlantic Ocean was independent of both sex and maturity (adults or juveniles). Walker (1976) also observed no significant difference in Hg concentrations between sexes of adult *Galeorhinus australis* and *Mustelus antarcticus* from Australian Coast. However, unlike the present study, he observed significant difference in juveniles of these two species.

Table 1 - Total length and mercury concentrations in muscular tissue of different shark species.

Species	Total Length (cm)			n	Hg (µg/kg w.w)			Studied area	Source
	Max	Min	Aver.		Max.	Min.	Aver.		
Carcharhinus signatus (male)	225	139	183	19	3479	327	1787	SW Equatorial Atlantic	Present study
C. signatus (female)	244	152	197	19	2775	1144	1697	SW Equatorial Atlantic	Present study
C. signatus	179	129	-	06	2570	1090	1777	Central Brazilian Coast	Pinho 1998
Rhizoprionodon lalandei	49	23	-	45	280	215	74.6	SE Brazilian Coast	Lacerda et al 2000
Isurus oxyrhinchus	393	165	-	90	5580	590	2115	South African Coast	Watling et al 1981
Galeorhinus galeus	-	-	108	244	4900	10	640	SE Australian Coast	Walker 1988
Carcharhinus brevipinna	-	-	240	08	610	2100	1480	SE Australian Coast	Walker 1988
Carcharhinus brachyurus	-	-	183	07	1200	230	600	SE Australian Coast	Walker 1988

Specimens of *C. signatus* collected showed reduced size range (Table 1). This could also explain the similar Hg concentrations between juveniles and adults observed in *C. signatus*, although a more detailed study would be needed in order to verify this hypothesis, including growth rates and length-at-age data.

The similarity of our results to those of Pinho (1998) indicated that *C. signatus* from the central Brazilian Coast and western equatorial Atlantic Ocean had similar rates of Hg accumulation, though Pinho's small sample size (n=6) reduced confidence in this assumption (Table 1). Indeed, it was also possible that these individuals composed a single population and consequently had the same migration routes and feeding habits, thus sharing environmental conditions and mercury sources throughout its range.

Walker (1988) analyzed mercury concentration of 27 elasmobranch species sampled along the southeastern Australian Continental Shelf at depths greater than 75 m. His results revealed higher Hg concentrations in deep water pelagic and demersal species (Table 1). According to Walker, these values could be associated with the predominantly piscivorous feeding habits of the studied species. The Hg concentrations observed in Australian shark species and Atlantic *C. signatus* corroborated the hypothesis that Hg concentrations could be related to diet and depth because *C. signatus* was a semi-pelagic species that inhabits environments deeper than 100 m and feeds mainly on demersal teleost fish.

Lacerda et al. (2000) found lower Hg concentration values for the coastal shark species *Rhizoprionodon lalandei*, *R. porosus* and *Mustelus higmani* from the north coast of Rio de Janeiro State, Brazil (Table 1). The lower Hg concentrations could be due to aspects of the three species' life-histories, including living at shallower depths on coastal environments, smaller body size (23-100 cm), and different feeding habits compared to *C. signatus*. Differences in these characteristics were enough to result in major differences in Hg accumulation rates in different fish species (Bidone et al., 1997; Doyon et al., 1998).

The average Hg concentration in *C. signatus* was 1742 µg/kg. This was above the maximum allowed for human consumption of carnivorous fish (1000 µg/kg w.w.) by the Brazilian Legislation (Brasil, 1975). Of the 38 *C. signatus* specimens analyzed in the present study, 32 (92%) had Hg concentrations above the maximum allowed. Some authors have reported similar results for both freshwater and marine coastal teleost fishes. This showed that the biomagnification phenomenon (*e.g.* a species from a higher trophic level presented higher Hg concentrations than the organism from the immediately inferior trophic level), was taking place not only in freshwater but also in marine ecosystems (Kehrig et al, 1998; Bidone et al, 1997). Ingestion of contaminated food has been the most significant Hg pathway to human populations, and an average ingestion of only 0.1 kg/day of muscular tissue of the *C. signatus* we sampled could result in a daily intake of 174.2 µg of Hg. This value was more than five times the 30 µg of Hg per day maximum intake concentration established by the World Health Organization (WHO). Results of this magnitude have already limited the human consumption of piscivorous species in the USA (Kannan et al., 1998) and Australia (Simpfendorfer and Donohue, 1998).

Higher Hg concentration in apex predator fish species is recognizably a problem associated with the biomagnification process Marcovecchio et al. (1991). Nevertheless, WHO (1989) observed that fish from non-impacted areas has Hg concentrations increased with age until, in theory, reaching a "homeostatic equilibrium" between Hg concentration in the organism (including the depuration capacity) and the bioavailable in the ecosystem. Therefore, more extensive studies with a larger size range, as well as the age determination will add more information in order to clarify the influence of these biotic factors on mercury distribution in C. signatus.

Regression between C. signatus total length and Hg concentration was low (r^2= 0.026) (Fig. 1), and the correlation between these variables was not significant (p=0.068). Similarly, an absence of significant correlation between length and Hg concentration was observed for other six shark species (Squatina argentina, Prionace glauca, Sphyrna sp, Carcharias taurus and Isurus oxyrinchus) from the southeastern Brazilian coast (Morales-Aizpurúa et al., 1999).

Thompson (1985) also observed a lack of correlation between total length and mercury concentration for several fish species distributed along the Tasmanian Continental Shelf. Thompson concluded that use of correlation to estimate mercury content and define human consumption limit for a given species could not be done without proper knowledge of the species biology and the particularities of each environment it inhabited.

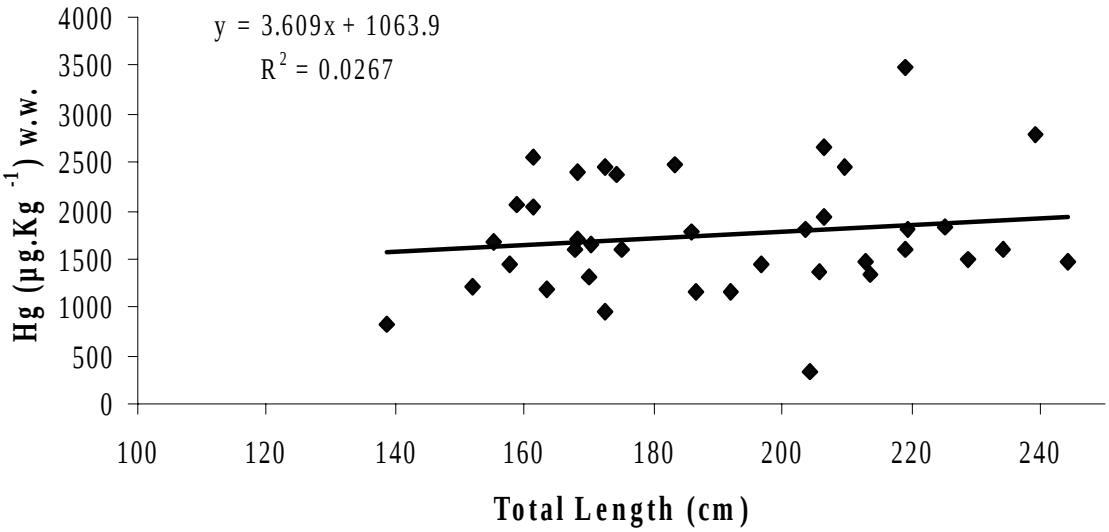

Figure 1 - Total mercury concentration by total length in *C. signatus* from the western equatorial Atlantic Ocean.

However, mercury concentration in the Mako shark (Isurus oxyrhinchus) from the coast of South Africa revealed a strong correlation between total length and mercury concentration (Watling et al., 1981). In this case, it was recommended that I. oxyrhinchus individuals greater than 2 m should not be commercially fished for human consumption. Notwithstanding, the same procedure could not be used for C. signatus because the mercury distribution was relatively consistent among the different studied lengths, thus not permitting the selection of a specific class size to be avoided.

CONCLUSIONS

The average total mercury concentrations in *C. signatus* sampled along the western equatorial Atlantic Ocean were consistently greater than the maximum limit for human consumption established by the Brazilian Health Ministry for carnivorous fishes (1000 µg/kg w.w.). Therefore, an average consumption of just 0.1 kg/day of *C. signatus*, could result in an average ingestion of 174.2 µg/day of Hg, more than five times the daily mercury intake limit of 30 µg/day established by the World Health Organization (WHO).

The present study's results indicated that in the range of lengths studied, body length could not be used as an indicator of the Hg contamination degree for *C. signatus* because there was not a significant difference in Hg concentration among the studied specimens. Also, sex could not be considered a determining factor in the total mercury accumulation in *C. signatus*, because there was no significant difference between male and female Hg levels.

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RESUMO

O mercúrio (Hg) é o único metal que comprovadamente biomagnifica através da cadeia alimentar, e sendo assim, espécies de peixes predadores tendem a apresentar altas concentrações deste metal. Porções de tecido muscular de *C. signatus* coletados na região oeste equatorial do oceano Atlântico foram submetidas a extração ácida e tiveram a concentração de mercúrio determinada com acessório gerador de vapor a frio acoplado a um ICP-AES. A concentração média de Hg apresentou valores acima do limite máximo permissível para consumo humano estabelecido pela legislação brasileira (1000 $\mu g.kg^{-1}$ de peso úmido). Conseqüentemente, um consumo médio de 0,1 $kg.dia^{-1}$ de *C. signatus* resultaria numa ingestão media de 174,2 µg de Hg, mais de cinco vezes o consumo máximo de 30 $\mu g.dia^{-1}$ estabelecido pela Organizacao Munidal da Saúde. Dentro das classes de tamanho analisadas, o comprimento total não pode ser utilizado como indicador do grau de contaminação por mercúrio em *C. signatus*. Ainda, o sexo não pode ser considerado um fator determinante na acumulação total de mercúrio em *C. signatus*.

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