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Mercury concentration of the whitecheek shark, *Carcharhinus dussumieri* (Elasmobranchii, Chondrichthyes), and its relation with length and sex

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Abstract. This study was conducted to assess the total mercury (THg) concentration in muscle, liver and fin tissues of the whitecheek shark, *Carcharhinus dussumieri*, caught in three stations of the Persian Gulf. Approximately 96% of captured sharks had total mercury concentrations less than 0.6 mg/kg of wet weight (w.w.), while only 4% of all specimens had a concentration higher than 0.8 mg/kg w.w. There were no significant differences in total mercury concentrations between sexes ($p>0.05$). In all stations, muscle tissue showed the highest mercury levels (0.73 mg/kg in males and 0.77 mg/kg in females), followed by liver (0.28 mg/kg w.w. in males and 0.29 mg/kg w.w. in females) and fins (0.13 mg/kg w.w. in males and 0.16 mg/kg w.w. in females). There were significant positive relationships between total shark length and total mercury concentration in muscle, fins, and livers. These results imply that a daily consumption of less than 0.1 kg of whitecheek shark muscle could result in a weekly intake of 525 μg mercury, which is near to two times the maximum intake concentration established by the World Health Organization (WHO).

Keywords: total mercury, bioaccumulation, heavy metal, muscle, Persian Gulf

Resumen. Concentración de mercurio del tiburón *Carcharhinus dussumieri* (Elasmobranchii, Chondrichthyes) y su relación con el tamaño y el sexo. En este trabajo se evaluó la concentración de mercurio total en el tejido muscular, hepático y de las aletas del tiburón *Carcharhinus dussumieri*, capturado en tres estaciones del Golfo Pérsico. Aproximadamente, el 96% de los tiburones capturados tenía concentraciones de mercurio menores a 0,6 mg/kg en peso húmedo (p.h.), mientras sólo el 4% tenía una concentración mayor al 0,8% mg/kg p.h. No hubo diferencias significativas en la concentración de mercurio total entre sexos ($p>0,05$). En todas las estaciones, el tejido muscular tuvo los niveles más altos de mercurio (0,73 mg/kg en machos, 0,77 mg/kg en hembras), seguido por el tejido hepático (0,28 mg/kg p.h. en machos, 0,29 mg/kg p.h. en hembras) y el de las aletas (0,13 mg/kg p.h. en machos, 0,16 mg/kg p.h. en hembras). Se encontraron relaciones positivas significativas entre la longitud total de los tiburones y la concentración de mercurio en el músculo, aletas e hígado. Estos resultados implican que un consumo diario de menos de 0,1 kg de músculo de *C. dussumieri* resultaría en una ingesta de 525 μg de mercurio, lo que equivale a casi dos veces la ingesta máxima establecida por la Organización Mundial de la Salud.

Palabras clave: mercurio total, bioacumulación, metales pesados, músculo, Golfo Pérsico

Introduction

Mercury (Hg) contamination is of great concern because its toxicity poses health hazards for humans and wildlife in many coastal ecosystems (Ruelas-Inzunza & Paez-Osuna 2005, Tessier *et al*. 2007, Saniewska *et al*. 2010). Monomethyl mercury

(CH_3Hg^+) is the most toxic form of the mercury compounds, accounting for more than 95% of organic mercury in aquatic organisms (Branco *et al*. 2004, García-Hernández *et al*. 2007, Liu *et al*. 2012). The main routes of acute and chronic mercury exposure include inhalation, ingestion, and dermal absorption (Solis *et al*. 2000, Moreno *et al*. 2005, Harper & Harris 2008, Al-Saleh *et al*. 2009). Effects such as malformations, growth reduction, neurological deficiency in levels of certain enzymes, and renal failure are examples of toxicity by mercury exposure (Loumbourdis & Danscher 2004, Bose-O'Reilly *et al*. 2010, Rani *et al*. 2011).

The World Health Organization (WHO) estimates that around 10^7 kg of mercury are annually released worldwide (WHO 1989). About 50 percent of this amount is transported from the mainland to coastal areas through surface runoff, atmospheric deposition, fluvial transport, and natural weathering processes (Babiarz *et al*. 2003, Carvalho *et al*. 2008, Stern *et al*. 2012). Recently, public health concerns over mercury toxicity have focused on the potential risk associated with relatively low doses of mercury in the environment (Hsiao *et al*. 2010, Fang *et al*. 2011). Several studies have shown that mercury mainly bioaccumulates as methylated forms, in the muscle tissues of aquatic organisms (USEPA 2001, Cai *et al*. 2007, Negrete *et al*. 2008).

Because of their predatory behavior, long life, and higher trophic levels, sharks exhibit higher mercury concentrations than other marine fishes (Da Silva *et al*. 2005, Endo *et al*. 2008). The whitecheek shark, *Carcharhinus dussumieri*, is one of the most common sharks of the Persian Gulf, where inhabits in coastal ecosystems with many point human sources of mercury (Compagno 1984, Moore *et al*. 2012). This ecologically and economically important species, as presently known, is distributed in the northern Indian Ocean from the Persian Gulf to India at depth of less than 100 m (White 2012).

Meat and fins of whitecheek shark are used for human consumption and could consequently represent a health hazard because of the possible intake of mercury by human populations (Ferreira et al. 2004). Accordingly, the objective of the present study was to analyze the total mercury concentration in muscle, liver and fin tissues of the whitecheek shark from the Iranian coastal waters of the Persian Gulf. Relationships between body length and total mercury levels in muscle, liver, and fin of the sharks were also considered to assess risks associated with whitecheek shark consumption.

Materials and Methods

Sample preparation

Fish sampling was performed within 20 km of the shoreline in three stations: Genaveh (29° 25´ N; 50° 25' E), Boushehr (28° 45' N; 50° 41' E) and Dayer (27° 50' N; 51° 12' E) located off the north coast of the Persian Gulf (Fig. 1). A total of 149 whitecheek sharks were captured by a local trawl-fishing boat, from November to December 2011. All sharks were individually weighed, their total length measured, and then frozen for preservation before being transported to the laboratory.

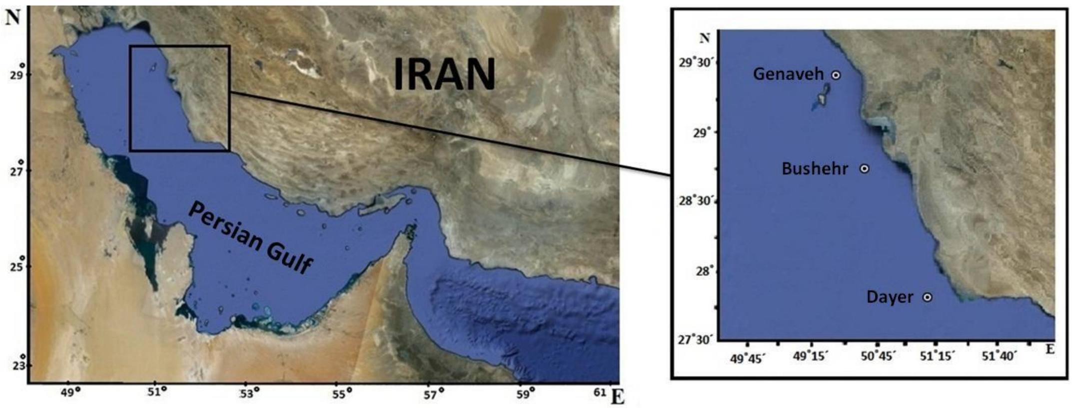

Figure 1. Location of stations in the Persian Gulf where samples of whitecheek shark, *Carcharhinus dussumieri,* were taken from.

Tissue samples were taken in the laboratory by necropsies of each specimen. Approximately 20 g of muscle, liver and fin were removed using a clean stainless-steel knife. Samples had no contact with human dermal layer or other surrounding surfaces during the dissection. After that, shark tissues were washed 3 times by tap water and rinsed with deionized water. To reduce the risk of contamination, each sample was immediately placed in a separate plastic zip-lock bag and frozen at -20 °C before analysis. Sex was also determined macroscopically and checked by examination of internal reproductive organs.

Analytical Methods

All samples were processed within two weeks of being captured according to the guidelines of the United States Environmental Protection Agency (USEPA 2000). Approximately 2 g of the sample tissue were freeze-dried at -50 °C and their moisture contents determined by weight loss. Then, the samples were ground, homogenized and sieved on a screen with a mesh size less than 175 µm.

The amount of THg in liver, muscle and fin was separately determined by an advanced mercury analyzer (LECO model AMA 254, USA), which does not require pretreatment or acid-digestion of the sample. In brief, aliquots ranging from 20 to 40 mg of freeze-dried samples were placed into the oven of the instrument. After drying, each sample was pyrolyzed at 800 °C under an oxygen atmosphere for 3 min and elemental mercury vapor was subsequently collected in a gold net (Au-amalgamator). The net was then heated for liberating and measuring mercury by atomic absorption spectrometry (AAS). Each sample was analyzed in triplicate for assurance of consistent results.

The accuracy of the procedure was examined by analyzing certified reference materials, including dogfish, *Squalus acanthias*, muscle (DORM-2) and liver (DOLT-3), and lobster hepatopancreas (TORT-2) obtained from the National Research Council of Canada (NRCC). The standard materials were analyzed according to the procedure described for the tissue samples of the whitecheek shark. A suitable conformity was found between certified and obtained values, as recovery ranged from 98.3% to 103.4%. All of THg results were stated as milligrams per kilogram of wet weight (mg/kg w.w.).

Statistical analysis

All data were analyzed using Statistical Package for the Social Sciences (SPSS) version 16. Differences in the amount of THg or fish size between sexes and sampling stations were examined by Kruskal-Wallis one-way analysis of variance on ranks (K-W ANOVA) followed by Mann-Whitney *U* test. Regression analysis was also conducted to evaluate the relationship between total lengths and mercury concentration in muscle, liver, and fins of the whitecheek shark.

Results

The number and total length of whitecheek sharks captured in different stations are shown in Table I. Out of a total of 149 specimens, most of the samples were collected from Dayer station (42.3%) followed by Genaveh (32.8%) and Bushehr (24.9%) stations. The total length of the sharks varied from 65 to 105 cm. The samples were composed of 61 (40.9%) males and 88 (59.1%) females. The length of females was significantly larger than males in all sampling stations (Kruskal–Wallis, H: 13.07, $df = 2$, $p<0.05$), except for Genaveh station where no significant differences were found between males and females.

Table I. Number (n) and total length (cm) of whitecheek sharks, *Carcharhinus dussumieri*, captured in three stations of the Persian Gulf.

Sampling Station	Total	Female (n)	Male (n)	Mean length	Female Length	Male Length
Genaveh	49	28	21	82.5±7.7	83.8±7.1	80.2±8.1
Bushehr	37	22	15	84.7±9.2	90.0±9.2	79.6±9.4*
Dayer	63	37	26	87.6±9.6	93.5±10.7	81.3±8.6*

* Shows significant difference at level of less than 0.05 between genders.

Mercury concentrations in different tissues of whitecheek shark are presented in Table II. Approximately 26% of all sharks had total mercury concentrations greater than 0.2 mg/kg w.w., 48% contained amounts higher than 0.4 mg/kg w.w., 22% had more than 0.6 mg/kg w.w., and only 4% had a concentration greater than 0.8 mg/kg w.w.

Although females were longer than males, no significant difference was observed in THg concentrations between sexes in any sampled tissues (Kruskal–Wallis, H: 19.28, $df = 1$, $p>0.05$). In all stations, muscle had the highest mercury levels, with an average concentration of 0.73±0.28 mg/kg w.w. in males and 0.77±0.27 mg/kg w.w. in females, followed by the liver (0.28±0.9 mg/kg w.w. in males and 0.29±0.9 mg/kg w.w. in females). Fins had the lowest concentration of mercury among the sampled tissues (0.13±0.05 mg/kg w.w. in males and 0.16±0.07 mg/kg w.w. in females).

Table II. Total mercury concentration (mg/kg wet weight) in tissues of whitecheek sharks, *Carcharhinus dussumieri*, from three stations of the Persian Gulf.

	Muscle				Liver				Fin			
	Female	Male	Max	Min	Female	Male	Max	Min	Female	Male	Max	Min
Genaveh	0.75±0.20^{ef}	0.72±0.27^{e}	1.20	0.18	0.26±0.10^{c}	0.25±0.09^{c}	0.41	0.02	0.15±0.09^{b}	0.15±0.06^{b}	0.24	0.01
Bushehr	0.76±029^{ef}	0.74±0.33^{e}	1.51	0.10	0.33±0.12^{d}	0.29±0.10^{cd}	0.58	0.08	0.15±0.07^{b}	0.16±0.05^{b}	0.29	0.07
Dayer	0.77±0.32^{ef}	0.71±0.26^{e}	1.35	0.34	0.30±0.10^{cd}	0.30±0.07^{cd}	0.47	0.06	0.18±0.04^{b}	0.10±0.05^{a}	0.30	0.07
Total	0.77±0.27^{ef}	0.73±0.28^{e}	1.51	0.10	0.29±0.10^{cd}	0.28±0.09^{c}	0.41	0.02	0.16±0.07^{b}	0.13±0.05^{ab}	0.30	0.01

Results are present as Mean±SE. Means that share the same superscript are not significantly different from one another (p>0.05).

There were significant positive relationships between total length and total mercury concentration in muscle, fins, and liver of whitecheek shark captured from three stations of the Persian Gulf (Fig. 2). Length had the strongest positive relationship with total mercury concentration in muscle (n=145, $p<0.01$), followed by fins (n=145, $p<0.01$) and liver (n=145, $p<0.05$).

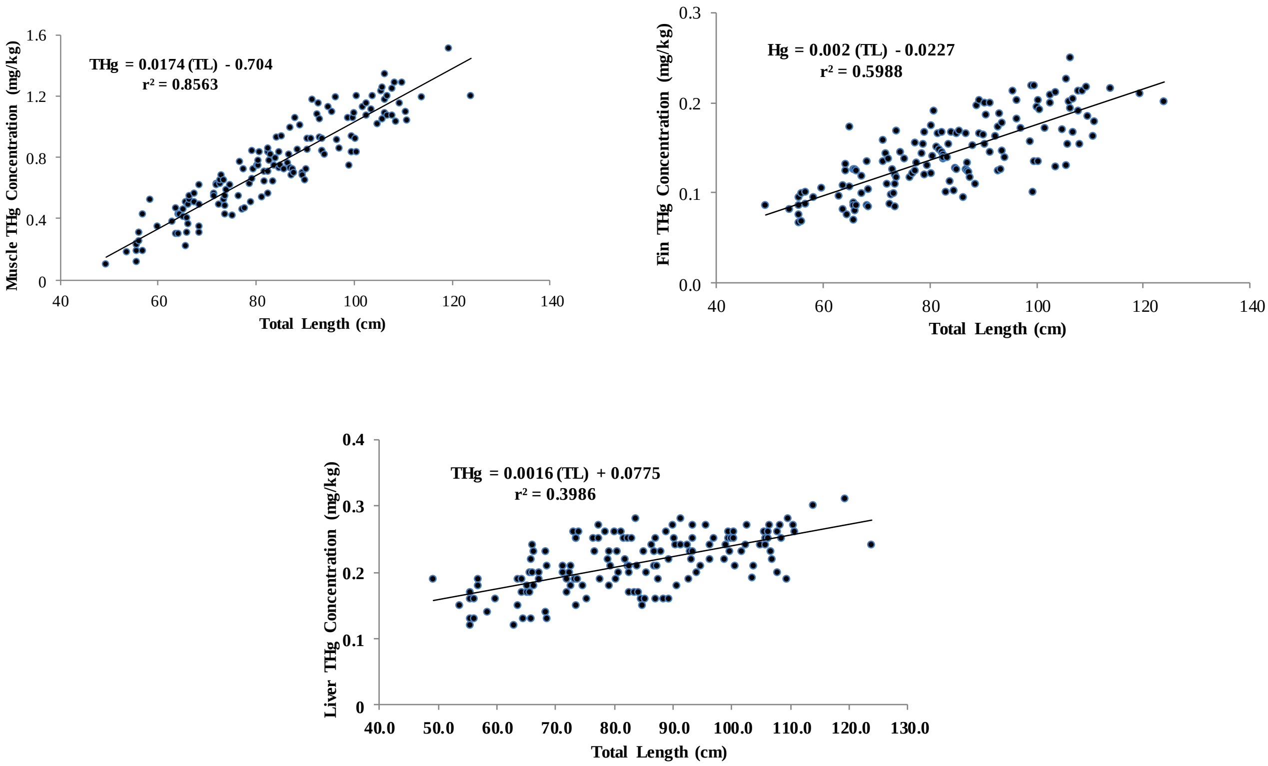

Figure 2. Relationship between total mercury concentration (THg) and total length (TL) of whitecheek shark, *Carcharhinus dussumieri*, captured in three stations of the Persian Gulf.

Discussion

This study provides information concerning total mercury levels in muscle, liver, and fins of the whitecheek shark, *C. dussumieri*, caught off the northern shore of the Persian Gulf. Based on the natural mercury amount in fish (0.15 to 0.2 mg/kg w.w., Johnels *et al*. 1967), total mercury in all surveyed tissues of the whitecheek shark is considered high. Overall concentrations were also high when the results are compared to the levels of mercury in other shark species captured off Brazil (Pinho *et al*. 2002, Ferreira *et al*. 2004), and in the western Pacific Ocean (Endo *et al*. 2008). However, mercury concentration in the muscle of *C. dussumieri* was similar to other species of the same genus like *C. leucas* and *C. limbatus* (Adams & McMichael 1999), but lower than in *C. signatus* (Pinho 1998, Ferreira *et al*. 2004).The present differences in mercury bioaccumulation could be related to the samples age, contamination sources, distinct feeding habits and other species-specific physiological parameters of *C. dussumieri* such as metabolic rate and lifetime for mercury process.

The current results are in agreement with previous research showed that the highest mercury level occurred in the muscle followed by liver and fins. Pethybridge *et al*. (2010) reported mercury content in various tissues of demersal sharks and chimaeras from the continental shelf and slope off southeast Australia. In ten shark species, the highest mercury level was recorded in the muscle, followed by the liver, kidney and skin. Endo *et al*. (2008) stated that the average mercury concentration in muscle of tiger shark, *Galeocerdo cuvier*, and silvertip shark, *Carcharhinus albimarginatus*, was higher than the concentration found in liver. Other shark species also have a higher concentration of total mercury in muscle as compared to the liver (*Prionace glauca*, Branco *et al*. 2007; *Scyliorhinus canicula*, Coelho *et al*. 2010). The pattern found supports the hypothesis that mercury is assimilated from the diet, easily distributed throughout the body and preferentially accumulated in the muscles (Lacerda *et al*. 2000, Wang 2002, Coelho *et al*. 2008). Lower concentrations of mercury in the liver could be likely related to the biochemical mechanisms, such as selenium-mercury liaisons, for converting the toxic mercury species to less harmful forms and their accumulation in other organs (Storelli & Marcotrigiano 2002, Branco *et al*. 2007).

Boening (2000) stated that dietary behavior has an important effect on mercury accumulation in marine predators. The whitecheek shark feeds primarily on teleost fishes, with crustaceans and cephalopods slightly less important (Compagno 1984). A higher mercury accumulation in muscle is generally associated to higher trophic level (Branco *et al*. 2007, Pethybridge *et al*. 2010), while environmental absorption has less impact on external organs like the skin and fins (Coelho *et al*. 2010, Pethybridge *et al*. 2010). Median concentration of mercury in liver could be explained by demethylation mechanism of mercury occurring in liver by selenium as antagonist and neutralizing agent (Storelli *et al*. 2002, Branco *et al*. 2007, Kaourd *et al*. 2012).

The current findings support the view that mercury level in the muscle has a linear relationship with size of the shark (Green & Knutzen 2003, Branco *et al*. 2007, Pethybridge *et al*. 2010). The continuous accumulation in muscle could be explained by a strong binding of mercury to thiol groups of proteins, whose content increases with size (Storelli *et al*. 2002, Sfezer *et al*. 2003). On the other hand, the mercury content in the liver was poorly correlated with individuals' length (Branco *et al*. 2007). The processes of detoxification in liver could cause the elimination of toxic forms of mercury in this organ (Storelli *et al*. 2002).

Although Bushehr station showed a slightly higher level of contamination, no significant difference was found in total mercury concentration of whitecheek sharks between stations. This result may be linked to the potentially migratory behavior of the whitecheek shark (IUCN Shark Specialist Group 2007) over short distances and identical absorption through the body, although more studies on distribution and the life cycle of the whitecheek shark are needed. There were no significant differences in total mercury concentration between sexes, although females exhibited slightly higher level of contamination than males.

The whitecheek shark is traditionally consumed by people living in the northern shore of the Persian Gulf and, therefore, its consumption could result in a major exposure to mercury. The average total mercury concentration found in the fillet (muscle) of whitecheek shark was 0.75±0.27 mg/kg w.w. The joint FAO/WHO Expert Committee on Food Additives recommended a provisional tolerable daily intake of 1.6 µg/kg of body weight for organic mercury equivalent to 300 µg of total mercury per person (WHO 2007). Thus, daily consumption of less than 0.1 kg of whitecheek shark muscle could result in a weekly intake of 525 µg mercury per kg of body weight which is near to two times the 300 µg per person as the maximum intake concentration established by the WHO (Ferreira *et al*. 2004, WHO 2007).

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