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Total Mercury in Liver and Muscle Tissue of Two Coastal Sharks from the Northwest of Mexico

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Abstract Total mercury (THg) in liver and muscle of three costal sharks from Mexico were evaluated. The highest concentrations of THg in muscle tissue of juveniles were found in *Sphyrna lewini* (0.82 ± 0.33 mg kg^{-1} wet basis). *Rhizoprionodon longurio* adults had the highest concentrations (0.92 ± 1.03 mg kg^{-1}). THg concentrations in liver were low compared to those found in muscle tissue; higher levels were found in liver of juvenile *S. lewini* (0.250 ± 0.07 mg kg^{-1}). Results showed that 35 % of muscle tissue samples are above the precautionary limit (0.50 mg kg^{-1} of THg) and a 7 % exceeded the maximum limit for human consumption (1 mg kg^{-1}).

Keywords Total mercury · Toxicity · Elasmobranchs · Fisheries

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Mercury is a highly toxic element with capacity to bioaccumulate. Their presence in the environment is given by natural emissions, anthropogenic and the release into the atmosphere of Hg deposited on the surface (Moore 2000). The levels of mercury in the environment have increased significantly since the beginning of the industrial age. In addition, human activities such as mining and agriculture have resulted in serious contamination of surface water and sediment. On the other hand, atmospheric transport of mercury has led to increased concentration in aquatic systems and biota, even in areas free of anthropogenic influence (Ullrich et al. 2001). Most of the Hg released into the marine environment is inorganic, but it can be biotransformed by bacteria to a more toxic derivative, methylmercury (MeHg). In this stage, is rapidly accumulated in aquatic biota and attains its highest concentration in those fish occupying high levels in the food chain (Stortelli et al. 2002). Over 95 % of THg found in fish is in the form of MeHg (Branco et al. 2004). The extent of THg provides an approximation of MeHg and has been recommended as a standard for regulatory control. In this situation, consumption of fish and by-products is the main route of human exposure to Hg compounds (Marsico et al. 2007).

Apex predators, generally long-lived species such as swordfish, tuna and shark, have been reported to accumulate high concentrations of mercury (WHO 1995). It was observed that THg concentrations are positively correlated with size and age, and that accumulation occurs preferentially in certain tissues, mainly in muscle and liver (Ravera 2001; Gómez et al. 2004). In Mexico there are few studies of Hg contamination in sharks. These studies in the Gulf of California, have reported high concentrations in hammerhead sharks *Sphyrna lewini* (4.84 mg kg^{-1} dry basis, approximately 1.2 mg kg^{-1} in wet basis), *Alopias pelagicus* (4.95 mg kg^{-1} wet basis) *Carcharhinus limbatus* (1.12 mg kg^{-1}

on wet basis) and *Sphyrna zygaena* (1.93 mg kg^{-1} wet basis) (Ruelas-Inzunza and Paez-Osuna 2005; García-Hernández et al. 2007; Escobar-Sánchez et al. 2010). In Mexico, there is great diversity of species of elasmobranchs (sharks and rays) that sustain important fisheries (industrial and artisanal) in Sonora and Sinaloa (Márquez-Farías 2002; Bizzarro et al. 2009). The muscle of these fish is inexpensive, accessible to different sectors of the population and is highly consumed primarily by residents of coastal areas. The liver is a potential by-product which can be extracted oils used in animal feed formulation. The Ministry of Health in Mexico fixed the maximum levels of mercury in fish in 1 mg kg^{-1} on wet basis (NOM (Norma Oficial Mexicana). 1993). However, due to lack of monitoring on the coast of Sonora and Sinaloa, the concentrations of THg in most commercial shark species caught for consumption are unknown. Furthermore, in species that have been analyzed in previous studies, there has been no follow-up to the behavior of mercury levels. This study aims to determine the content of THg in muscle and liver of commercially important sharks off the coast of Sonora and Sinaloa, and estimate the amounts of muscle that can be consumed without exceeding the acceptable daily intake THg established by WHO.

Materials and Methods

The samples were obtained from artisanal fisheries landings of Bahia de Kino, Sonora, and Cospita, Sinaloa, Mexico from November 2009 to May 2010 (Fig. 1). Liver was removed and approximately 300 g of muscle tissue of the left dorsal area before the origin of first dorsal fin (García-Hernández et al. 2007). The tissues were washed with deionized water, wrapped in foil, placed in plastic bags and stored at −20°C until analysis. The analysis was conducted for a period less than 28 days to comply with the retention period of the method. Samples were homogenized using a blender with glass jar and stainless steel blades (EPA [Environmental Protection Agency] 2000, Method 823-B-00-007). For the digestion process, we took a subsample (5 g) of tissue homogenate by adding concentrated nitric acid and hydrogen peroxide. The digestion was carried out in a microwave oven model MARS 5 (CEM-Corp, EPA, Method 3052). The quantification process was performed by reduction of compounds of Hg using stannous chloride by cold vapor technique. We used a mercury analyzer equipment model Perkin-Elmer FIMS-100 (EPA [Environmental Protection Agency] 2000, Method 245.6). For quality control purposes, duplicate samples were used, targets and control sample used was the certified reference material DORM fish Protein-3 of the National Research Council Canada (NRCC), with a certified value for mercury of 0.382 ± 0.060 mg kg^{-1}. The percentage recovery of Hg (% R) using BR-3 ranged of 95 %–103 %. The method detection limit was 0.001 mg kg^{-1} of THg for tissue samples.

The data on concentrations of THg liver and muscle of three different species were tested for normality and further

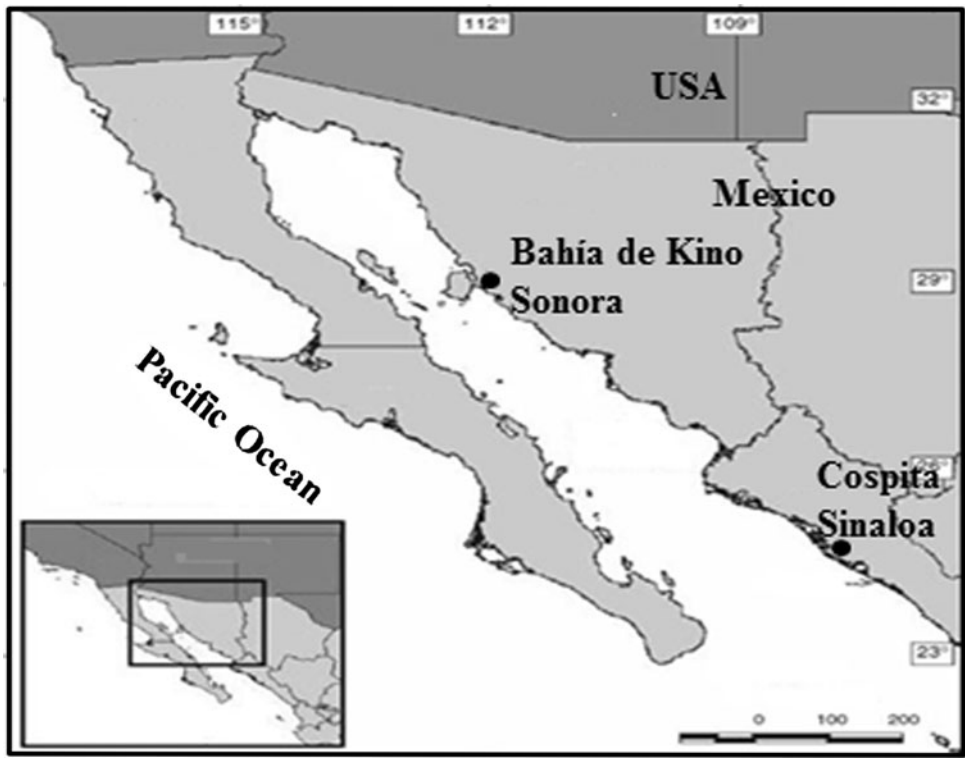

Fig. 1 Location of coastal areas in Sonora and Sinaloa where sharks were collected

statistical test was used accordingly. Differences between the concentrations of mercury by type of tissue (muscle, liver) and between species were tested with the Van Der Waerden test at a significant level of $\alpha = 0.05$. The effect of size on the concentration of mercury was evaluated by analysis of covariance (ANCOVA).

Results and Discussion

Samples analyzed include 12 specimens of *S. lewini*, 26 specimens of *Rhizoprionodon longurio* and 23 specimens of *Mustelus albipinnis*. In Table 1, size/weight ranges are tabulated by species maturity condition and sampling site. The highest concentrations of THg in muscle tissue were found in adults of *R. longurio* (3.36 mg kg^{-1} of THg on wet basis). Juveniles of the same species had markedly lower concentrations of THg (0.104 mg kg^{-1}) in muscle. The concentration of THg in all species of juveniles ranged 0.05–1.49 mg kg^{-1}). From this, juveniles, *S. lewini* (caught in Cospita, Sinaloa) averaged higher concentration (0.817 mg kg^{-1}) than *R. longurio* (0.179 mg kg^{-1}) and *M. albipinnis* (0.170 mg kg^{-1}). The highest concentration in overall juveniles was from *S. lewini* (1.49 THg ± 0.33 mg kg^{-1}). Differences in concentrations of THg between *R. longurio* and *M. albipinnis* collected in Bahia de Kino were not significant ($p < 0.5$) (Table 2).

Average concentrations of THg of *R. longurio* and *M. albipinnis* were 0.916 mg kg^{-1} and 0.336 mg kg^{-1}, respectively. Such differences were significant with a very high standard deviation of *R. longurio* (SD = 1.03) that resulted from the wide range of THg values (0.35–3.36 mg kg^{-1}). In all cases, adults showed higher concentration of THg than juveniles but in different order of magnitude, i.e., adults of *R. longurio* were 5.11 times higher than juveniles (ad/juv = 0.916/0.179), and adults of *M. albipinnis* were 1.97 times higher than juveniles (ad/juv = 0.336/0.170). Summary of the THg concentrations in muscle of different groups of species collected at the coast of Sonora and Sinaloa is showed in Table 2.

The differences in concentrations in liver THg between juveniles of the species were significant ranging from 0.006 to 0.38 mg kg^{-1}. In juveniles, *S. lewini* presented the highest concentrations with 0.25 mg kg^{-1} of THg, followed by *M. albipinnis* and *R. longurio*, with 0.083 mg kg^{-1} and 0.015 mg kg^{-1}, respectively. In adults, mean concentrations of THg in the liver for *R. longurio* (0.065 mg kg^{-1}) and *M. albipinnis* (0.128 mg kg^{-1}) showed significant differences ($p < 0.05$). Similar to the THg concentrations in muscle tissue, adults showed higher concentration of THg than juveniles. Adults of *R. longurio* were 4.33 times higher than juveniles (ad/juv = 0.065/0.015), and adults of *M. albipinnis* were 1.18 times higher than juveniles (ad/juv = 0.128/0.083) (Table 2).

Table 1 Data of specimens collected

Shark	Maturity condition	n	Length (cm)	Weight (kg)	Sampling site
S. lewini	Juveniles	12	65–83	1.1–2.5	COS
R. longurio	Juveniles	12	67–85	1.3–2.6	BK
R. longurio	Adults	14	107–122	5.5–9.3	BK
M. albipinnis	Juveniles	13	55–66	0.6–90	BK
M. albipinnis	Adults	10	78–86	1.4–2.4	BK

n = sample size,
COS = Cospita, Sinaloa;
BK = Bahía de Kino, Sonora

Table 2 Concentration of total mercury (THg) in muscle tissue and liver in three sharks from Sonora and Sinaloa

Shark	Maturity condition	Hg Concentration (mg kg^{-1} wet base)					
		Muscle tissue			Liver		
		Mean	Range	SD	Mean	Range	SD
S. lewini	Juveniles	0.817^{a}	0.05–1.49	0.33	0.250^{a}	0.170–0.380	0.07
R. longurio	Juveniles	0.179^{b}	0.104–0.45	0.09	0.015^{b}	0.006–0.108	0.01
M. albipinnis	Juveniles	0.170^{b}	0.12–0.28	0.04	0.083^{c}	0.049–0.226	0.02
S. lewini	Adults	NA	NA	NA	NA	NA	NA
R. longurio	Adults	0.916^{A}	0.35–3.36	1.03	0.065^{A}	0.001–0.22	0.05
M. albipinnis	Adults	0.336^{B}	0.19–0.69	0.13	0.128^{B}	0.048–0.283	0.07

Values are mean ± standard deviation of duplicates, The values in each row with different letters of juveniles (a–c) and adults (A, B) show a significantly different ($p < 0.05$)

SD Standard deviation, *NA* Not analyzed

Table 3 Estimated daily intake of THg, assuming a regular intake of 100 g day^{-1} of sharks collected from the coasts of Sonora and Sinaloa

Shark	Maturity condition	THg (mg kg^{-1} wb)	THg (μg.100 day^{-1})	Intake[a] (g)	Size (cm)
S. lewini	Juveniles	0.817	81.7	53	65–83
R. longurio	Juveniles	0.179	17.9	240	67–85
R. longurio	Adults	0.916	91.6	47	107–122
M. albipinnis	Juveniles	0.170	17.0	253	55–66
M. albipinnis	Adults	0.336	33.6	128	78–86

[a] Amount (g) equivalent to an intake of 43 μg day^{-1}

No significant correlation between size and Hg concentrations in muscle and liver in juveniles or adults of the three species was observed. Most of the values were very close to the limit of detection (Table 3). Based on THg concentrations found in this study, we estimate the amount of muscle that people can consume without exceeding the recommended daily intake of Hg by WHO of 43 mg daily (Table 3). The data showed that daily consumption of 100 g of muscle of juvenile *S. lewini* and dults of *R. longurio*, THg is the double intake recommended by WHO (43 μg day^{-1} for an adult of 70 kg). On the other hand, it would have to consume 200 g of juveniles of *R. longurio* and *M. albipinnis* to exceed that level.

The wide variation in concentrations of THg in muscle found in the three species evaluated in this study agrees with previous studies that have reported also a wide range of concentrations in muscle THg for apex predators such as billfishes and large sharks and in other demersal fishes (Adams et al. 2003; Marsico et al. 2007; García-Hernández et al. 2007; Escobar-Sánchez et al. 2010). The variation in concentrations of THg in muscle could be due to biological variability associated with the same species (age, size, physiology, diet), geological influences (rock, sediment), physical-chemical conditions (water temperature, pH, ORP) (Licata et al. 2005).

The THg levels found in juvenile *S. lewini* were higher than those found in its congener *S. zygaena* (0.44 mg kg^{-1}) off the coast of Santa Catarina southern Brazil (Marsico et al. 2007) and on the coast of Baja California Sur (0.73 mg kg^{-1}) (Escobar-Sánchez et al. 2010). On the other hand, the concentrations of THg observed in *S. lewini* match the values reported for the same species examined from the Gulf of California (García-Hernández et al. 2007). Although adults of *S. tiburo* reach smaller sized than *S. lewini* THg values also agrees with the levels reported for the bonethead shark *S. tiburo* off the coast of Florida (Evers et al. 2008).

In another similar study for *S. lewini*, Ruelas-Inzunza and Paez-Osuna (2005) reported higher levels of THg of individuals caught in Altata, Sinaloa than in those collected in Guaymas, Sonora in the present study. Such result suggests that higher levels of mercury pollution may exist in Sinaloa than in Sonora. This could be particularly true, given that the central part of Sinaloa is seasonally impacted by effluents from intensive farming of vegetables, grains and sugar cane.

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