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Cadmium concentration in liver and muscle of silky shark (*Carcharhinus falciformis*) in the tip of Baja California south, México

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ABSTRACT

Cadmium concentrations were determined in the tissues of muscle and liver of *Carcharhinus falciformis* (silky shark) sampled in Todos Santos, Baja California South, Mexico. This is one of the main shark species for human consumption in Mexico. Results indicate that accumulation of Cd varied in both sexes, based on its metabolism, sex, maturity and other biological characteristics. High Cd values were observed in the liver of adults of male (529.61 μg g^{-1}) and female (457.43 μg g^{-1}), whereas, in muscular tissues it was low (0.37 μg g^{-1}) than the prescribed permissible limits for seafood (0.5 μg g^{-1}). Substantial correlations were observed between body length and Cd values in adults except young male due to faster growth rate and its metabolism. The study indicated the impact of environmental conditions in the accumulation of Cd and its risk to the food web structure in the marine environment and health hazard for humans.

In recent years, the impact of industrialization and agricultural activities has resulted in elevated levels of cadmium in the aquatic environment, posing serious threat to marine organisms, which adsorb toxic metals through their gills or other soft tissues or as a result of ingestion of food particulates rich in metals (Frías-Espericueta et al., 2014). In biological systems kinetic studies have shown that cadmium transport is performed by cations carriers such as Mn and Zn (Kim et al., 2015). In the case of marine organisms, sharks are vulnerable in accumulating metals (Mareovecchio et al., 1991; Vas, 1991; Storelli et al., 2011) due to their biological traits, such as longevity, slow growth rates and high trophic status (Lyle, 1984). Varying magnitude in the biological mechanisms of absorption, regulation, storage and excretion of metals, each species exhibit diversified degree of bioaccumulation rates (Catsiki and Strogyloudi, 1999). The main cadmium sources in aquatic ecosystems include mineral and phosphorite deposits, in which this element is a common impurity (Mann and Ritchie, 1995) and for its high soluble nature in aquatic environment, they are widely distributed in marine ecosystems. Moreover, the presence of hydrothermal vents and the large sub-duction zone in the study area adds significance as they contribute particulate and dissolved Cd continuously into the coastal waters (Nriagu and Pacyna, 1988; Segovia-Zavala et al., 2004).

The silky shark (*Carcharhinus falciformis*) is basically an oceanic pelagic shark, circumglobal in tropical waters and often found near the edge of continental shelves at depths of 200 m, with an average life span of 22 years and attains a length up to 330 cm TL (total length), and falls in the category of near threatened (NR) in the IUCN red list (Bonfil et al., 2009). Shark fishing have expanded globally for its high intensified growth in commercial market (Myers et al., 2007), due to its demand for the meat, which is used for human consumption, fins for the shark fin trade, skin processed for leather and liver for liver oil.

Despite the protein rich diet in fishes, numerous studies (Castro-González and Méndez-Armenta, 2008) indicate that seafood consumption is the foremost reason for the uptake and accumulation of metals and other contaminants in human body (Domingo et al., 2006; Adina et al., 2016). With several studies indicating the accumulation of metals in shark species (McMeans et al., 2007; Endo et al., 2008; Barrera-Garcia et al., 2012; Maz-Courrau et al., 2012; Gilbert et al., 2015), the present study is an attempt to understand the partioning of non-essential metal Cd among different tissues (muscle & liver) of shark.

The main aim of the study was to quantify the accumulation of Cd in muscle and liver tissues of *C. falciformis* (silky shark) from Todos Santos (23°25′ N; 110°14′ W) close to the southern tip of Baja California on the Mexican Pacific coast, which is well known for its artisanal fishing activity and the presence of one of the largest phosphorite deposits in Baja California Peninsula, Mexico (Fig. 1) (Riley, 1989).

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Fig. 1. Location of Todos Santos, Baja California South, Mexico.

Samples were acquired during August–December, 2014 about 4 to 57 Km away from the coast with depths ranging between 6 to 400 m using a line with hooks and bait. The total length of each shark was measured using a measuring tape; while the sex was determined by the presence of claspers in males. Approximately 20 g of muscle tissue from the head and liver was sampled, collected and frozen at −20 °C. The samples were rinsed and dried at 60 °C for further analysis. The dried samples were powdered and digested using 5 mL HNO_3 + 5 mL H_2O_2 + 0.5 mL HCl and subsequently analysed using an atomic absorption spectrometry (*Model*: *Perkin Elmer Model AAnalyst 100*) for the determination of Cd (Portman, 1976; EPA method 3010a, 1992). A certified reference material (CRM-TMF Lot 1,204,706) for trace metals in fish was analysed every five samples to ensure accuracy and precision. The entire analysis produced a recovery percentage of 96.6% for Cd. Correlation analysis using Statistica (version 8.0) was carried out to understand the accumulation trends based on the total body length.

C. falciformis presented high levels of Cd accumulation (Fig. 2c–d) in the hepatic tissues of male (274.08 μg g^{-1}) and female (295.03 μg g^{-1}) samples. This is mainly due to its high metabolic activity, and copious lipid contents (Last and Stevens, 2009), which are prone to the accumulation of lipophilic metallic species (Phinney and Bruland, 1994). The high average values of Cd in adult males (0.86 μg g^{-1} in muscle, 529.61 μg g^{-1} in liver) and females (0.21 μg g^{-1} in muscle, 457.43 μg g^{-1} in liver) are associated to the process of metallothenin (MT) synthesis (Frías-espericueta et al., 2014). In addition, MT is cysteine-rich proteins that play a key role in bioavilability and redistribution and compartmentalization of ligand metal-complexes (Klaassen et al., 2009). The high concentrations of Cd in the adult females are also a concern of the reproductive physiology which provides essential nutrients to the embryos (Vizcaino et al., 2014).

On an average, the order of Cd organ-tropism (Fig. 2a-d) in *C. falciformis* was observed to be: muscle (0.37 μg g^{-1}) > liver (284.55 μg g^{-1}). Lesser concentrations in muscles are attributed to the low levels of binding proteins (Storelli et al., 2011). The adult species exhibited high values (0.54 μg g^{-1} in muscle; 493.52 μg g^{-1} in liver) compared to juveniles (0.21 μg g^{-1} in muscle; 295.03 μg g^{-1} in liver) as the concentration of Cd increases with body length in muscle and maturity in the liver (Endo et al., 2008).

The Cd concentrations increased proportionally (Table 1) with the body length ($p < 0.05$), where females presented a significant correlation [($r^2 = 0.31$ (juvenile); $r^2 = 0.45$ (adults)] representing the role of liver as the end point of tissue distribution for non-essential metals, where it is accumulated (Mull et al., 2012). The high levels of Cd in adult fishes in the present study are due to their rich diet of cephalopods (Bustamante et al., 1998). Except the juvenile female species ($r^2 = 0.22$), there was no positive correlation which is mainly due to its low affinity for adsorbing metals and its dilution effect (Table 1). Results from cluster analysis in relation to length, muscle, liver and the Cd concentrations clearly define a pattern of accumulation in all species except the young male ones (Fig. 3a–d). The grouping and the negative linkage distance of muscle and liver suggest that it is inversely proportional and the faster growth rate where dilution influences the metal concentration (Braune et al., 1999; Newman and Doubet, 1989). Moreover, the metabolic rate of younger species is higher compared to the adult ones and the net result is the accumulation of Cd in either the parts of muscle or liver. In addition, the faster uptake by smaller species often indicates variation in the surface-volume ratio during the growth stage especially in this species (Liang et al., 1999; Merciai et al., 2014).

Comparing the Cd concentrations with other shark species from all over the world, the present study reported a very high concentration of Cd probably due to its high influence from phosphorite deposits present in the region, close proximity to the subduction zone and the effect

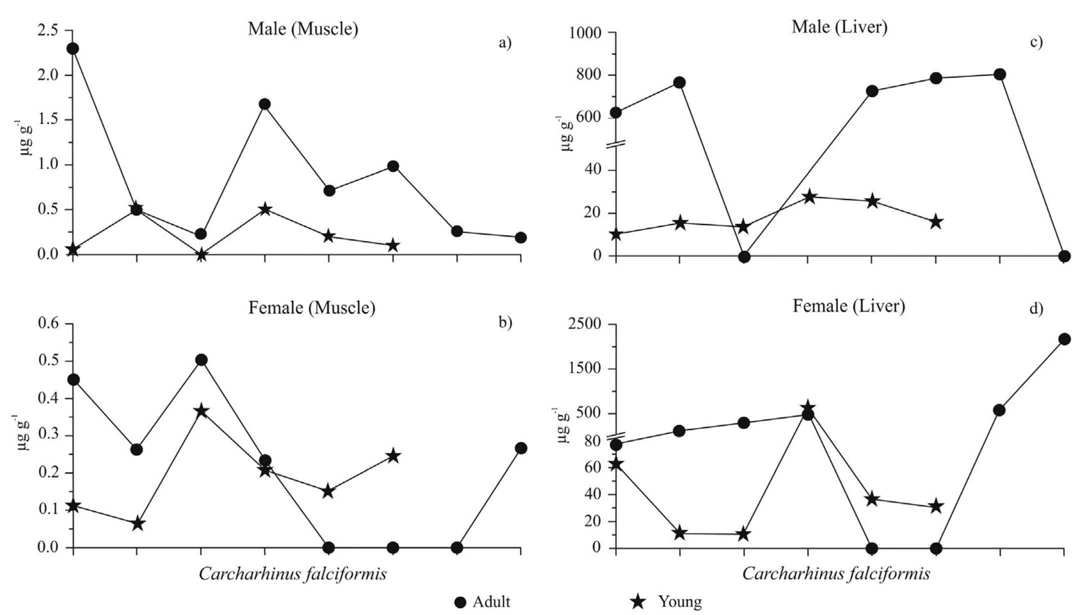

Fig. 2. Distribution of Cd in the tissues in the female and male species of *Carcharhinus falciformis* (a–d).