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# Cadmium and Lead Concentrations in the Fish Tissues of a Coastal Lagoon System of the SE Gulf of California

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**Abstract** Mean Cd trend in the muscle of omnivorous (O), planktivorous (P), benthopelagic-carnivorous (BPC), and benthic carnivorous (BC) fish of one lagoon of NW Mexico was BPC > BC > P > O (0.89, 0.59, 0.55 and 0.24 $\mu g\ g^{-1}$). That of Pb was P > BC > O > BPC (1.07, 0.48, 0.17 and 0.04 $\mu g\ g^{-1}$). In the liver Cd was P > BPC > O > BC (5.09, 2.40, 2.07 and 1.95 $\mu g\ g^{-1}$). Pb was P > O > BPC > BC (0.63, 0.40, 0.13 and 0.07 $\mu g\ g^{-1}$). There were no differences in Cd and Pb contents due to feeding habits, and the correlations between metals and troph level were not significant ($p > 0.05$ in all cases).

**Keywords** Fish tissues · Metal contents · Lead · Cadmium

The coastal environment and the lagoons and estuaries of Sinaloa State (SE Gulf of California, NW Mexico) are important fishing grounds for traditional fisheries, and provide protection for invertebrate and fish communities. However, they receive the residues of the human activities taking place on their watershed, including nutrients, pesticides and heavy metals. Among metals, Cd and Pb reach coastal waters from agriculture, fuel combustion, mining, industrial and municipal discharges and harbour activities (Soto-Jiménez and Flegal 2009; Frías-Espericueta et al. 2010a, b). Through different mechanisms, these metals are taken up by aquatic organisms and transferred to upper levels of the respective food chains (Fisher and Hook 2002) and for this reason carnivorous species, especially top predators, may contain high levels of heavy metals because of their habitat or feeding habits. Therefore, their consumption by sensitive groups such as children and pregnant women should be limited (Soto-Jiménez et al. 2010).

For this, analysis of these pollutants in aquatic organisms is of interest not only for aquatic ecology and environmental science, but also as a public health issue. In spite of this, there have been few studies on the metal content of fish caught in the coastal lagoons of NW Mexico. In this study we determined the concentrations of Cd and Pb in the edible tissue (muscle) and liver of fishes with different trophic habits, living in different habitats of one of these coastal lagoons.

## Materials and Methods

The 41 species of fish used in this study were caught during a study on the bycatch of traditional artisanal shrimp fishery in NW Mexico (Amezcua et al. 2009). The samples were obtained at monthly intervals, from December 2008 to April 2009, in 29 stations distributed throughout the Santa Maria La Reforma lagoon system, which sustains an important artisanal fishing fleet in Sinaloa State. Fish were

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identified according to Amezcua-Linares (2009). Their habitats, feeding habits and trophic levels (troph, defined from their known food items) were obtained from Froese and Pauly (2012).

In the laboratory, the specimens were washed with distilled, deionised water, muscles and livers were separated, freeze-dried, ground and homogenized in a Teflon mortar, and 0.20 g subsamples were digested in 30 mL Teflon vessels with 5 mL of trace metal grade $HNO_3$:HCl mixture (3:1 v/v) heated overnight at 130°C on a Mod block unit, transferred to clean polypropylene vials and diluted to 25 mL with Milli-Q water (Soto-Jiménez et al. 2010). All materials and glassware were acid-washed as in Moody and Lindstrom (1977).

Depending on availability and size, pooled and/or individual samples of each tissue were used for determination of Pb and Cd concentrations (one determination/sample, without replicate readings) by atomic absorption spectrometry (GFAAS, Varian Spectra AA 220 with graphite furnace). Blanks and certified reference material (dogfish muscle DORM-2, National Research Council Canada) were used to verify the accuracy of the extraction method. Recoveries were 104.0 % for Cd and 98.4 % for Pb, and the limits of detection were 0.02 $\mu g\ g^{-1}$ for Cd and 0.06 $\mu g\ g^{-1}$ for Pb.

According to the information available on their habitat and feeding habits (Froese and Pauly 2012), the metal contents of each species were pooled into four groups: omnivorous (O), planktivorous (P), benthopelagic-carnivorous (BPC), and benthic carnivorous (BC) and, since the data were not normal and homoscedastic (Kolmogorov–Smirnov and Bartlett's tests), the respective mean values were compared with Kruskal–Wallis tests. Additionally, the correlations (Spearman or Pearson) were calculated between the metal concentration obtained for each species and its trophic level (mean troph values given in Froese and Pauly 2012). In all cases, the level of significance was $\alpha = 0.05$ (Zar 1999).

## Results and Discussion

The fish species and their respective trophic level (in parenthesis) were: 10 benthic-carnivorous (BC): *Achirus mazatlanus* (3.20), *Etropus crossotus* (3.27), *Trinectes fonsecensis* (3.39), *Dasyatis longa* (3.50), *Rhinobatos glaucostigma* (3.54), *Urotrygon nana* (3.61), *U. chilensis* (3.63), *Cyclopsetta querna* (3.97), *Syacium ovale* (4.02) and *Gymnothorax equatorialis* (4.20); 24 were benthopelagic, carnivorous (BPC): *Sphoeroides annulatus* (3.07), *S. lobatus* (3.20), *Cathorops fuerthii* (3.20), *Pseudopeneus grandisquamis* (3.33), *Diapterus peruvianus* (3.35), *D. aureolis* (3.68), *Menticirrhus nasus* (3.41), *Pomadasys axillaris* (3.43), *P. panamensis* (3.79), *P. nitidus* (3.43), *P. branickii* (3.44), *Orthopristis chalceus* (3.48), *Ophioscion scierus* (3.55), *Arius seemanni* (3.57), *Arius platypogon* (3.63), *Mulloidichthys dentatus* (3.69), *Prionotus ruscarus* (3.76), *Selene peruvianus* (4.25), *Cynoscion reticulatus* (3.89), *Synodus scituliceps* (4.20), *Cynoponticus coniceps* (4.03), *Peprilus snyderi* (4.11), *Scomberomorus sierra* (4.21) and *Paralabrax maculofasciatus* (4.20); four were planktivorous (P): *Anchovia macrolepidota* (2.69), *Anchoa* spp. (3.35), *A. walkeri* (3.41) and *Pliosteostoma lutipinnis* (3.31), and the remaining three were omnivorous (O) species: *Mugil cephalus* (2.13), *Eucinostomus currani* (3.21), *Chaetodipterus zonatus* (3.30).

The mean Cd concentrations of the muscle showed the following trend: BPC > BC > P > O (0.89 ± 2.23, 0.59 ± 0.48, 0.55 ± 0.21, and 0.24 ± 0.16 $\mu g\ g^{-1}$, respectively). In the case of Pb, the trend was P > BC > O > BPC (1.07 ± 0.14, 0.48 ± 1.24, 0.17 ± 0.14 and 0.04 ± 0.03 $\mu g\ g^{-1}$). In both cases there were no significant differences due to feeding habits ($p = 0.38$ and $p = 0.06$ for Cd and Pb, respectively) (Fig. 1a). The correlations calculated between the Cd and Pb content of the muscle of each species and its trophic level were not significant ($r = 0.25$, $p = 0.11$ and $r = -0.21$, $p = 0.20$, respectively).

In view of their extremely high Cd concentrations (11.05, 13.6 and 26.1 $\mu g\ g^{-1}$, respectively), the values determined in the livers of *P. snyderi*, *D. aureolis* and *D. peruvianus* (bentho-pelagic, carnivorous) were not considered in statistical processing. With these exceptions, the tendency of Cd in the fish liver was P > BPC > O > BC (5.09 ± 4.91, 2.40 ± 2.09, 2.07 ± 1.38 and 1.95 ± 1.48 $\mu g\ g^{-1}$) (Fig. 1b), and the correlation between Cd and troph level was not significant ($r = -0.12$, $p = 0.45$).

In the case of Pb, the tendency was P (0.63 ± 1.14 $\mu g\ g^{-1}$) > O (0.40 ± 0.54 $\mu g\ g^{-1}$) > BPC (0.13 ± 0.25 $\mu g\ g^{-1}$) > BC (0.07 ± 0.06 $\mu g\ g^{-1}$). Although there were no significant differences between the mean liver contents of Cd and Pb of the different groups ($p = 0.58$ and 0.57), there was a clear tendency to lower Pb concentrations in the liver of the fish of higher trophic levels, which was confirmed by the inverse relationship between Pb content and troph number, which was close to the significance level ($r = -0.30$, $p = 0.06$).

The tendency to higher Cd and Pb concentrations of the liver of planktivorous fish, in particular *Anchoa* spp. (11.81 and 2.34 $\mu g\ g^{-1}$, respectively), coincides with the Cd enrichment of the muscle and liver of planktivorous fish observed by Bustamante et al. (2003), who related this tendency to their Cd-rich zooplankton diet.

This may be the case of the omnivore *M. cephalus*, because its diet tends to include higher percentages of phytoplankton and other plant material than the remaining omnivorous species (troph level 2.13, compared to 3.2–3.3 for other species). Additionally, the adults of this species

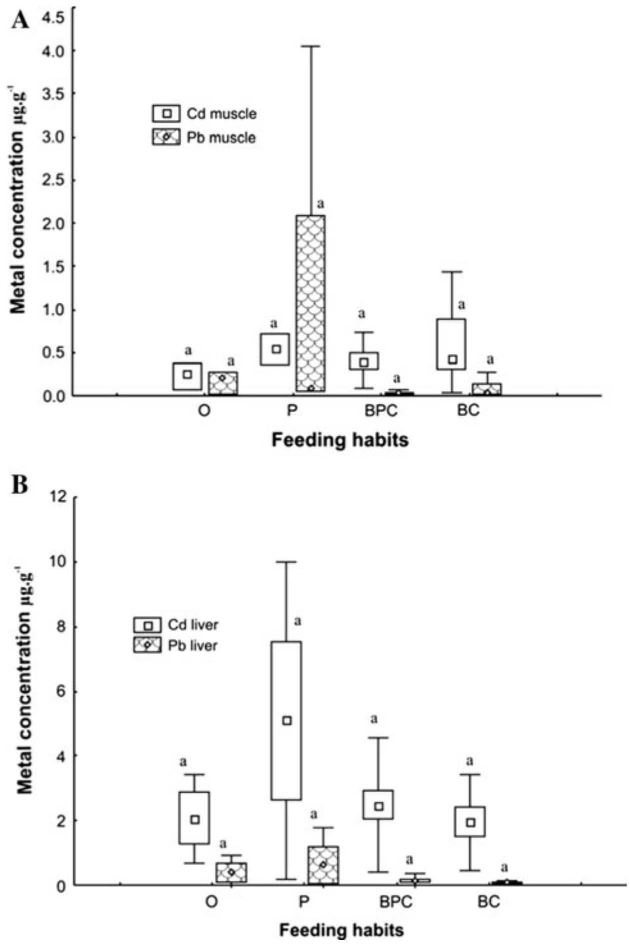


**Fig. 1** Comparison of Cd and Pb concentrations with feeding habit in edible muscle of fish. *O* omnivorous, *P* planktivorous, *BPC* benthopelagic-carnivorous, *BC* benthic carnivorous. The *equal letters* indicate lack of significant differences between the content of each metal in the tissue of fish with different feeding habit

tend to graze on soft sediments (Eggold and Motta 1992) where metal concentrations are 3–5 orders of magnitude higher than in the surrounding water (Bryan and Langston 1992), which may be an additional source of Cd and Pb.

There was no correlation between the Cd and Pb loads of muscle and liver ($p = 0.20$ and $p = 0.82$, respectively) probably because the strategy for dealing with excessive metal loads is through metallothionein induction in the liver, with minimum transfer of metal to the remaining fish tissues (Viarengo and Nott 1993).

The main source of Cd in Sinaloa coastal waters and lagoon systems are the fertilizers used in the agricultural fields in Sinaloa state (600,000 ha of intensive agriculture), and there are additional sources such as atmospheric deposition and the natural input to the coastal during upwelling events (Frías-Espericueta et al. 2010a). Through active uptake, this is concentrated by phytoplankton, accumulated through ingestion by the zooplankton and mobilized along the food web, although no biomagnification occurs in the case of Cd (Jara-Marini et al. 2009). Some, adsorbed to or otherwise associated to organic matter is deposited in the sediment, where it may be incorporated into the benthic food web and can reach the omnivorous, detritivorous and scavenger fish.

The presence of Pb in the coastal environment is mainly due to atmospheric transport and deposition from different sources, mainly from industrial activities such as smelters, battery manufacture and paint industries, as well as that accumulated in coastal sediments as residues of the traditional Pb-rich ores exploitation practiced since colony times, and of the leaded gasoline used in Mexico until 1997 (Soto-Jiménez et al. 2006).

Several of the species collected for this study are consumed locally, or are sold in the regional and national markets. For this reason, we evaluated the implications of their consumption for human health, considering only the Cd and Pb content of the edible muscle. According to our results, the Pb contents are lower than the values considered of risk for human health, whereas in the case of Cd the consumption of *M. cephalus* may be of concern particularly for fishermen and for the local people, since the daily ingestion of ~180 g of its muscle would be sufficient to reach the tolerable intake of Cd suggested by USFDA (1993) and WHO (1998) (Table 1). *Scomberomorus sierra* and *Anchoa walkeri* are also of potential concern, although the risk could be mitigated by the seasonality of their fishery.

Additionally, although fish liver is not marketed as food for human consumption, its metal content should be monitored because it may be used for fish oil extraction or used in the whole fish biomass in the manufacture of fish meal, which in turn are used for formulation of diets for livestock and aquacultural species (González-Félix et al. 2009).

**Table 1** Allowable limits of daily ingestion/person in edible muscle of fish species

| Species | Muscle ingestion (g day$^{-1}$) | |
|---|---|---|
| | (for Cd intake) | (for Pb intake) |
| *Anchoa* spp. | 755 | 35,377 |
| *Anchoa walkeri* | 379 | 922 |
| *Diapterus aureolis* | 784 | 61,074 |
| *Diapterus peruvianus* | 1,202 | 109,011 |
| *Mugil cephalus* | 178 | 15,368 |
| *Scomberomorus sierra* | 508 | 19,946 |

Provisional tolerable daily intake (PTDI) for Cd and Pb is 55 and 750 µg person$^{-1}$ day$^{-1}$, respectively, according to USFDA (1993) and WHO (1998)

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