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Baseline

Mercury levels in selected bycatch fish species from industrial shrimp-trawl fishery in the SE Gulf of California

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ABSTRACT

Baseline Hg concentration in bycatch fish from the SE Gulf of California were determined in muscle and liver of 19 species. Levels of Hg in muscle were compared with legal limits of this element in national and international legislation. Considering all fish species, mean concentrations in liver (2.458 ± 1.997 μg g^{-1}) were significantly higher ($p < 0.05$) than in muscle (0.993 ± 0.670 μg g^{-1}). The sequence of averaged Hg concentrations in most ichthyofauna was liver > muscle. Highest level of Hg in muscle (2.556 μg g^{-1}) and liver (7.515 μg g^{-1}) corresponded to *Diapterus peruvianus* and *Ophioscion strabo*, respectively. Considering muscle samples, none of the species had levels of Hg above the limit (1.0 μg g^{-1} wet weight) in the Mexican legislation; with respect to the Japanese (0.4 μg g^{-1} wet weight) and British (0.3 μg g^{-1} wet weight) legislations, 26.3% and 31.6% of the species respectively, were above the corresponding limits.

In Mexican waters, specifically in the Gulf of California, the shrimp trawl fishery is the main source of bycatch, a total of 114,000 t of fish, crustaceans and mollusks (equivalent to a total biomass of 90 ± 45 × 10^3 t) are discarded every year (Madrid-Vera et al., 2007). Among bycatch species, fish is the most abundant group (Rábago-Quiroz et al., 2008); the families mainly represented (as number of species) as bycatch (López-Martínez et al., 2001) are Sciaenidae (34), Paralichtydae (18), Haemulidae (16) and Carangidae (16). The number of fish species (>200) in the Gulf of California is relatively high in comparison with ichthyofauna from other areas in the Mexican Pacific (Amezcua-Linares, 1990); the overlapping of geographical distribution of fish from contiguous zoogeographic provinces results in an elevated biodiversity in this part of the Eastern Pacific Ocean (Mora and Robertson, 2005). Considering the elevated biomass of fish species captured as bycatch, diverse alternatives to use these fish have been proposed; for example in Venezuela, diverse bycatch fish were used to prepare hamburgers, breaded fillet, pasta and salami (Cabello et al., 2005), Madrid-Vera et al. (2007) suggest that in Mexico most of the fish caught as bycatch could be filleted and thus give it an increased value.

Most of the captured fish inhabit coastal zones and it is known that elevated discharges of industrial and urban wastes near to the shores are important sources of trace metals. These contaminants are considered as relevant from the ecological and toxicological point of view. Mercury (Hg) is one of the most dangerous elements in the marine environment; it is supplied to the environment from natural (mineral deposits, volcanoes, forest fires and oceanic emissions) and anthropogenic (cement kilns, roasting of sulfide ores for acid production and smelting for gold, copper, iron, lead and zinc production) sources (Hylander and Meili, 2003). The issue of Hg occurrence in fish is of major environmental concern, in fact, accumulation of Hg in biota is the most important features of Hg cycle in the marine environment (Fitzgerald et al., 2007). To our knowledge, no information related to Hg levels in bycatch fish from the Gulf of California has been published; considering the above statement, the main objectives of the present study were: (a) to determine baseline Hg concentration in muscle and liver of bycatch fish, and (b) to compare Hg levels in the edible portion of fish with legal limits of this element in national and international legislation.

Fish were obtained during March 2011 from the shrimp trawl fishery that operates at the continental shelf in the SE Gulf of California at a depth range of 30–46 m (Fig. 1). Fish species were selected considering their importance as a food source for humans. In the laboratory, most fish were identified to species level; after total length and weight were recorded, specimens were dissected. Muscle tissue from the median dorsal area and liver were used for the analysis; samples were frozen at −20 °C. Glassware and plastic utensils were previously washed according to Moody and

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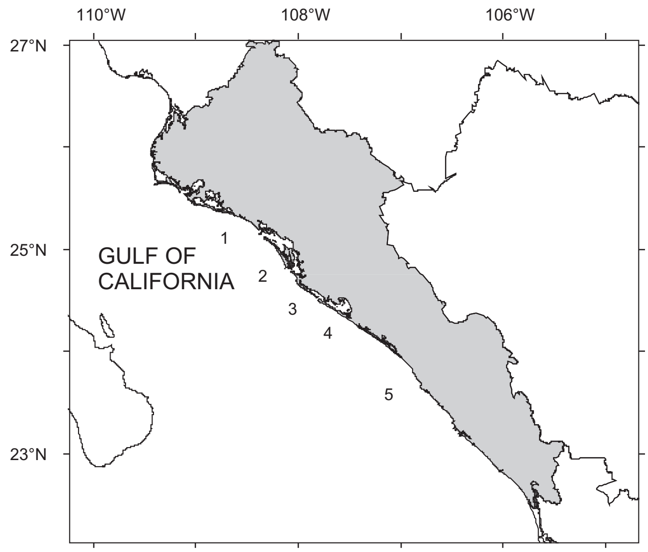

Fig. 1. Sites of shrimp trawling where bycatch fish were collected.

Lindstrom (1977). Samples were freeze-dried for 72 h (−52 °C and 60×10^{-3} mbar) in a Labconco Freeze-dry System-FreeZone 6, then ground in an agate mortar with pestle (Fischer-Scientific). Powdered samples (0.25 g) were acid digested (5 ml of concentrated nitric acid-trace metal grade, Baker) using capped teflon vials (Savillex™) on a hot plate (Barnstead Thermolyne) during 3 h (120 °C). Digested samples were stored in polyethylene containers for further analysis. Analyses of Hg were made by cold vapor atomic absorption spectrophotometry (CV-AAS) in a mercury analyzer (Buck Scientific-model 410) (UNEP, 1993). Validation of the analytical process was assessed by analyzing certified reference materials (DORM-3, fish protein; DOLT-4, dogfish liver). Blanks and reference materials were run with every batch of 20 samples. Results are reported in $\mu g\, g^{-1}$ on a dry weight basis, detection limit was estimated in 0.012 $\mu g\, g^{-1}$ dry weight. Recoveries for DORM-3 and DOLT-4 reference materials were 90% and 102%, respectively. Since legal limits of Hg are given on a fresh weight basis, conversion of Hg concentrations from dry weight (Hg_{dw}) to fresh weight (Hg_{fw}) was made according to the equation: $Hg_{fw} = Hg_{dw} * (100 - \%$ humidity)/100 (Magalhães et al., 2007). Differences of Hg levels with the feeding habit of fish and comparison of Hg concentrations between muscle and liver of all fish species were made by a Stu-

Table 2
Concentrations of Hg ($\mu g\, g^{-1}$ dry weight) in selected tissues of studied ichthyofauna from the state of Sinaloa (SE Gulf of California).

Species	Muscle	Liver
Larimus argenteus	0.900 ± 0.752	4.622 ± 4.585
Haemulopsis axillaris	1.696 ± 1.022	4.358 ± 2.668
Micropogonias ectenes	0.656 ± 0.701	1.078 ± 0.791
Selar crumenophthalmus	0.555 ± 0.496	4.820 ± 2.899
Trachinotus kennedyi	0.106 ± 0.080	0.528 ± 0.646
Diapterus peruvianus	2.556 ± 1.171	3.186 ± 2.947
Cyclopsetta quema	0.394 ± 0.236	0.536 ± 0.532
Epinephelus acanthistius	0.238 ± 0.0078	0.263 ± 0.136
Umbrina xanti	0.579	2.900
Ophioscion strabo	1.653 ± 1.176	7.515 ± 7.042
Diplectrum pacificum	0.446 ± 0.357	0.560 ± 0.495
Hemicaranx leucurus	0.582 ± 0.539	0.595 ± 0.424
Synodus scituliceps	0.845 ± 0.535	1.512 ± 0.467
Diplectrum macropoma	1.214 ± 0.944	2.598 ± 0.000
Sphyraena ensis	0.701	4.66
Scorpaena sp.	1.725	0.669
Prionotus sp.	0.530 ± 0.298	2.558 ± 0.000
Polydactylus approximans	1.720 ± 0.663	1.171 ± 0.450
Isopisthus remifer	1.776 ± 0.639	2.624 ± 1.933

Table 3
Significant ($p < 0.05$) correlations of Hg concentrations in muscle and liver with weight and total length of bycatch fish.

Species	Correlation	*r*	Type
Cyclopsetta querna	Hg muscle-weight	0.6904	+
	Hg muscle-length	0.6286	+
Diplectrum pacificum	Hg muscle-weight	0.9641	+
	Hg muscle-length	0.9382	+
	Hg liver-weight	0.9743	+
	Hg liver-length	0.9259	+
Hemicaranx leucurus	Hg muscle-weight	0.8967	+
	Hg liver-weight	0.9895	+
Polydactylus approximans	Hg muscle-weight	0.9750	+
Isopisthus remifer	Hg muscle-weight	0.5828	+
Larimus argenteus	Hg muscle-weight	0.3937	–
	Hg muscle-length	0.3898	–
	Hg liver-length	0.3507	–
Haemullopsis axillaris	Hg muscle-weight	0.2880	+
	Hg muscle-length	0.2880	+
Synodus scitulipes	Hg muscle-length	0.9789	+
Diapterus peruvianus	Hg liver-weight	0.9895	+

r-correlation coefficient.

Table 1
Biological information of analyzed ichthyofauna from the SE Gulf of California.

Species	Common name	*N*	Total weight (g)	Total length (cm)	Feeding habit
Larimus argenteus	Silver drum	67	134 ± 51 (76–366)	23 ± 3 (19–31)	Omnivore, benthic feeder
Haemulopsis axillaris	Yellowstripe grunt	109	234 ± 92 (102–270)	27 ± 3 (24–30)	Carnivore, benthic feeder
Micropogonias ectenes	Slender croaker	31	163 ± 61 (108–466)	27 ± 2 (21–33)	Carnivore, benthic feeder
Selar crumenophthalmus	Bigeye scad	3	130 ± 17 (118–150)	23.5 ± 1 (22.5–25)	Omnivore, benthopelagic feeder
Trachinotus kennedyi	Blackblotch pompano	34	152 ± 38 (78–268)	22 ± 2 (18–27)	Carnivore, benthic feeder
Diapterus peruvianus	Peruvian mojarra	123	149 ± 34 (74–240)	21 ± 2 (16–25)	Carnivore, benthic feeder
Cyclopsetta querna	Toothed flounder	10	293 ± 112 (148–446)	29 ± 4 (20.3–33)	Omnivore, benthic feeder
Epinephelus acanthistius	Rooster hind	3	156 ± 21 (134–175)	22 ± 1 (20.6–22.5)	Omnivore, benthopelagic feeder
Umbrina xanti	Polla drum	1	284	28.5	Carnivore, benthic feeder
Ophioscion strabo	Squint-eyed croaker	2	393 ± 140 (294–492)	35 ± 5 (31–38)	Carnivore, benthic feeder
Diplectrum pacificum	Inshore sand perch	5	117 ± 25 (98–148)	21 ± 1 (19.3–22.4)	Carnivore, benthic feeder
Hemicaranx leucurus	Yellowfin jack	3	137 ± 11 (126–148)	25 ± 1 (24–25.5)	Omnivore, benthopelagic feeder
Synodus scituliceps	Shorthead lizardfish	4	380 ± 157 (148–484)	36 ± 6 (28–40)	Carnivore, benthopelagic feeder
Diplectrum macropoma	Mexican sand perch	2	206 ± 74 (154–258)	24 ± 2 (22.5–25.2)	Carnivore, benthic feeder
Sphyraena ensis	Mexican barracuda	1	130	31	Carnivore, pelagic feeder
Scorpaena sp.	Rockfish	1	336	26	Carnivore, benthic feeder
Prionotus sp.	Searobin	2	323 ± 61 (234–350)	30 ± 5 (26–30)	Omnivore, benthic feeder
Polydactylus approximans	Blue bobo	4	149 ± 21 (128–174)	26 ± 2 (23–27)	Omnivore, benthic feeder
Isopisthus remifer	Silver weakfish	12	98 ± 14 (74–128)	57 ± 81 (20.5–24.5)	Omnivore, benthopelagic feeder

Table 4
Percentage and species of bycatch that exceeded the maximum permissible limits (μg g^{-1} wet weight) of Hg for human consumption.

Legislation	Limit	(%)	Fish species
Mexico	1.0	0	–
Japan	0.4	26.3	*Haemulopsis axillaris*, *Diapterus peruvianus*, *Scorpaena* sp., *Polydactylus approximans*, *Isopisthus remifer*
United Kingdom	0.3	31.6	*Haemulopsis axillaris*, *Diapterus peruvianus*, *Scorpaena* sp., *Polydactylus approximans*, *Isopisthus remifer*, *Ophioscion strabo*

dent's *t* test using GraphPad Prism 4.0 (Graph Pad Software, San Diego, CA).

Biometric information of selected ichthyofauna is presented in Table 1. For this study, nineteen fish species were analyzed. On the basis of the number of specimens, fish species were mainly represented by the Peruvian mojarra *Diapterus peruvianus* (123 individuals), the yellowstripe grunt *Haemulopsis axillaris* (109 individuals), and the silver drum *Larimus argenteus* (67 individuals). In relation to the feeding habits, most of the fish species corresponded to carnivorous (11) followed by omnivorous (8). The feeding guild was benthic or benthopelagic, so all the revised individuals feed, at least partially, from the bottom.

Concentrations of Hg (μg g^{-1} dry weight) in studied ichthyofauna are shown in Table 2. For both tissues, mean Hg concentrations ranged by one order of magnitude. Considering all fish species, mean concentrations in liver (2.458 ± 1.997 μg g^{-1}) were significantly higher ($p < 0.05$) than in muscle (0.993 ± 0.670 μg g^{-1}). With the exception of *Scorpaena* sp. and *Polydactilus approximans*, the sequence of averaged Hg concentrations in analyzed ichthyofauna was liver > muscle. Highest level of Hg in muscle (2.556 μg g^{-1}) corresponded to the Peruvian mojarra *D. peruvianus*; in the case of liver, the highest concentration of Hg (7.515 μg g^{-1}) occurred in squint-eyed croaker *Ophioscion strabo*. In another study (Ruelas-Inzunza et al., 2008) with some of the fish species used in the current investigation from the SE Gulf of California, it was reported that Hg concentrations in muscle of *H. axillaris* (1.18 μg g^{-1}) and *Selar crumenophthalmus* (0.65 μg g^{-1}) were comparable to values reported here for the same species, while Hg concentration in *D. peruvianus* (0.58 μg g^{-1}) was lower than that reported in the current investigation with the same species. Regarding Hg concentration in similar fish from other regions, average level in muscle (0.19 μg g^{-1}) of *S. crumenophthalmus* from SE Asia was comparable to value reported in the current study for the same species; in the case of liver, Hg concentration (0.15 μg g^{-1}) in specimens from SE Asia was lower than value reported here (Agusa et al., 2007). In another report from SE Asia, Agusa et al. (2007) measured Hg concentration in muscle (0.34 μg g^{-1}) and liver (0.63 μg g^{-1}) of *Sphyraena obtusata*; values in muscle were comparable to the level reported here for *Sphyraena ensis* but one order of magnitude lower than Hg concentration in liver. With respect to Hg concentrations in fish species according to the feeding habit, it was found that muscle and liver of carnivores were not significantly ($p > 0.05$) different to corresponding tissues in omnivores. Significant ($p < 0.05$) correlations of Hg levels in muscle and liver with total length and weight of fish are presented in Table 3. In eight of the studied species correlations were positive; i.e. levels of Hg in muscle and liver of fish increased as the organism was longer or heavier.

In relation to legal limits of Hg in fish and fishery products for human consumption established by national and international agencies, percentages of fish species (edible portion) that exceeded such limits are presented in Table 4. It is noticeable that none of the species had levels of Hg in muscle that were equal or above the concentration (1.0 μg g^{-1} wet weight) considered in the Mexican legislation; nevertheless, as legal limits decrease, the number of species over such limits increases. With respect to the legal limit set in the Japanese legislation, 26.3% of the species had Hg levels in the edible portion above 0.4 μg g^{-1}; if Hg levels in muscle tissue are compared with limits (0.3 μg g^{-1} wet weight) set in the United Kingdom, 31.6% of the muscle samples of bycatch fish species were above that concentration. From a compilation of legal limits of trace metals for diverse fishery products (Nauen, 1983), it is evident that levels set for Hg are variable and they should be taken with caution since some species can have values below some legislation but above another; this is the case of the current study. Additionally, it is worth mentioning that the ratio of methylHg (MeHg) to total Hg in muscle tissue of fish can be as high as 100% (Agah et al., 2007); this issue is of great concern since organic Hg (mainly as MeHg) is more toxic to humans than inorganic forms because of its capacity to pass through biological membranes, high stability and potential of bioaccumulation (Clarkson and Magos, 2006).

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