Bull Environ Contam Toxicol
DOI 10.1007/s00128-014-1311-9

Health Risk Assessment from Mercury Levels in Bycatch Fish Species from the Coasts of Guerrero, Mexico (Eastern Pacific)

P. Spanopoulos-Zarco · J. Ruelas-Inzunza · M. Meza-Montenegro · K. Osuna-Sánchez · F. Amezcua-Martínez

Received: 13 January 2014 / Accepted: 28 May 2014

Abstract With the aim of determining Hg distribution in muscle and liver of bycatch fish from Guerrero state in the Eastern Pacific Ocean and assess the potential risk to consumer, Hg was quantified in 14 species of bycatch fish. For the majority of fish the order of Hg levels was liver > muscle. The highest concentration corresponded to the liver of *Isopisthus remifer* (2.05 $\mu g\ g^{-1}$) and the lowest (0.02 $\mu g\ g^{-1}$) was detected in muscle of *Prionotus sp.* The highest hazard quotient (0.75) was found in the Mexican milkfish *Micropogonias ectenes*; considering all the individuals, mean hazard quotient was 0.336.

Keywords Mercury · Bycatch fish · Shrimp fishery · Guerrero coast · Risk assessment

Guerrero state has a territory of 63, 794 km^2, it accounts for 3.2 % of the total area of Mexico and the coast line is 500 km, approximately. Considering total Hg emissions per year, Guerrero state (10.73 tons of Hg) ranks 14th among the 32 states of Mexico (SEMARNAT 2008). In Mexican waters, including Guerrero coasts, the shrimp trawl fishery is the main source of bycatch; it includes fish, crustaceans, and mollusks that are discarded every year (Madrid-Vera et al. 2007). Among bycatch species, fish is the most abundant group (Rábago-Quiroz et al. 2008); during trawling operations, 10 kg of fish can be caught per one kg of shrimp (Alverson et al. 1994). Fishing operations are usually performed on soft bottoms of the continental shelf at a depth range of 10–240 m. Such areas are not far from the continent and influence of fluvial and atmospheric discharges might be noticeable in living resources. Heavy metal pollution is most evident in coastal areas as a result of industrial and municipal discharges; mining, agriculture, and dredging activity; and some natural processes. At sea, contaminants accumulate in organisms and sediments and they are subsequently transferred to humans through the food chain (Giordano et al. 1991). Among trace metals, mercury (Hg) is one of the most dangerous elements in the marine environment; it is supplied from natural and anthropogenic sources and can be extremely toxic to humans (ATSDR 1992). Pollution of the aquatic environment by Hg is of global concern; sometimes the sources of the element are not local and measured concentrations in fish may be of foreign origin. Besides, Hg can be converted to methylmercury; this chemical form of Hg accounts for most of the element in the muscle tissue of fish (Holsbeek et al. 1997). The consumption of food has been identified as the primary route of human exposure to trace metals. Risk to human health by Hg (specifically methyl Hg) can be assessed by non-cancer methods (US EPA 1989). The hazard quotient (HQ) allows an estimation of human health risk considering the rate of consumption and correspondent methyl Hg concentration in food stuffs, and a reference dose (RfD). The RfD is considered as the degree of metal exposure below which no adverse effects may occur (Marrugo-Negrete et al. 2008). In the case of methyl Hg, the RfD is 0.1 $\mu g\ kg^{-1}\ day^{-1}$ (US EPA 2000). When estimating HQ, values above one indicate potential effects

P. Spanopoulos-Zarco · M. Meza-Montenegro
Instituto Tecnológico de Sonora, 5 de Febrero 818 sur, Col. Centro, 85000 Ciudad Obregón, Sonora, Mexico

J. Ruelas-Inzunza (✉) · K. Osuna-Sánchez
Instituto Tecnológico de Mazatlán, Calle Corsario 1, No. 203, Col. Urías, 82070 Mazatlán, Sinaloa, Mexico
e-mail: ruelas@ola.icmyl.unam.mx

F. Amezcua-Martínez
Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, A. Joel Montes Camarena s/n, 82040 Mazatlán, Sinaloa, Mexico

on health of consumers. Rate of consumption of bycatch fish in Mexico has not been estimated; instead, we use a value of 9.01 kg person^{-1} year^{-1} (25 g person^{-1} day^{-1}) (Ruelas-Inzunza et al. 2010). Such figure is below the world average consumption of fish of 63 g person^{-1} day^{-1} (WWF 2000). In the above context, the purposes of this study are: (a) to quantify Hg in muscle and liver of bycatch fish; (b) to estimate the potential risk to consumer health according to the levels of Hg (considering that it is mostly in the form of methyl Hg) in the edible portion and the rate of consumption of bycatch fish.

Materials and Methods

Bycatch fish were obtained directly from the fishermen of the shrimp boats based in Mazatlán, Sinaloa. Fish samples were collected on November 25th 2011 from two sites in Guerrero state (Site A and Site B; Fig. 1) by using trawl nets on the continental shelf selecting those fish species representative of each site. In the laboratory, most fish were identified to species level, after total length and weight were recorded. Muscle tissue from the median dorsal portion area and liver were used for the analysis; samples were frozen at −20 °C. Glassware and plastic utensils were previously cleaned according to Moody and Lindstrom (1997). Samples were lyophilized for 72 h (−52 °C and 60 × 10^{-3} mbar) in a Labconco Freeze-dry-System-Free-Zone 6, they then were ground in an agate mortar with pestle (Fisher-Scientific). Powdered samples (0.25 g) were acid digested (5 mL of concentrated nitric acid-trace metal grade, Baker) using capped Teflon vials (Savillex^{TM}) on a hot plate (Barnstead Thermolyne) during 3 h (120 °C). Digested samples were stored in polyethylene containers for further analysis. For total mercury analysis we used a mercury analyzer Buck Scientific 410 by the cold vapor technique (UNEP 1993). To determine the accuracy and precision of the method we analyzed reference materials consistent of fish muscle tissue (DORM-3, NRC-Canada) and liver (DOLT-4, NRC-Canada). Detection limit was estimated in 0.012 µg g^{-1} dry weight. Recoveries for DORM-3 and DOLT-4 reference materials were 90 % and 102 % respectively. Blanks and reference materials were run with every batch of 20 samples. Results are reported in µg g^{-1} on a dry weight basis. Since legal limits of Hg are given on a fresh weight basis, conversion of Hg concentration from dry weight (Hg_{dw}) to fresh weight (Hg_{fw}) was made according to the equation: $Hg_{fw} = Hg_{dw} \times$ (100-% humidity)/100 (Magalhães et al. 2007); the percentages of humidity in liver and muscle tissue were 67 ± 5 % and 71 ± 6 %, respectively. To assess health risk from bycatch fish intake we used the equation (Newman and Unger 2002) HQ = E/RfD, where E is the level of exposure or metal intake and RfD is the reference dose for the metal of interest (methyl Hg = 0.1 µg/kg body weight/day). The level of exposure (E) is calculated as E = C × I/W, where C is the concentration of the metal of interest (µg g^{-1} wet weight), I is the ingestion rate per capita

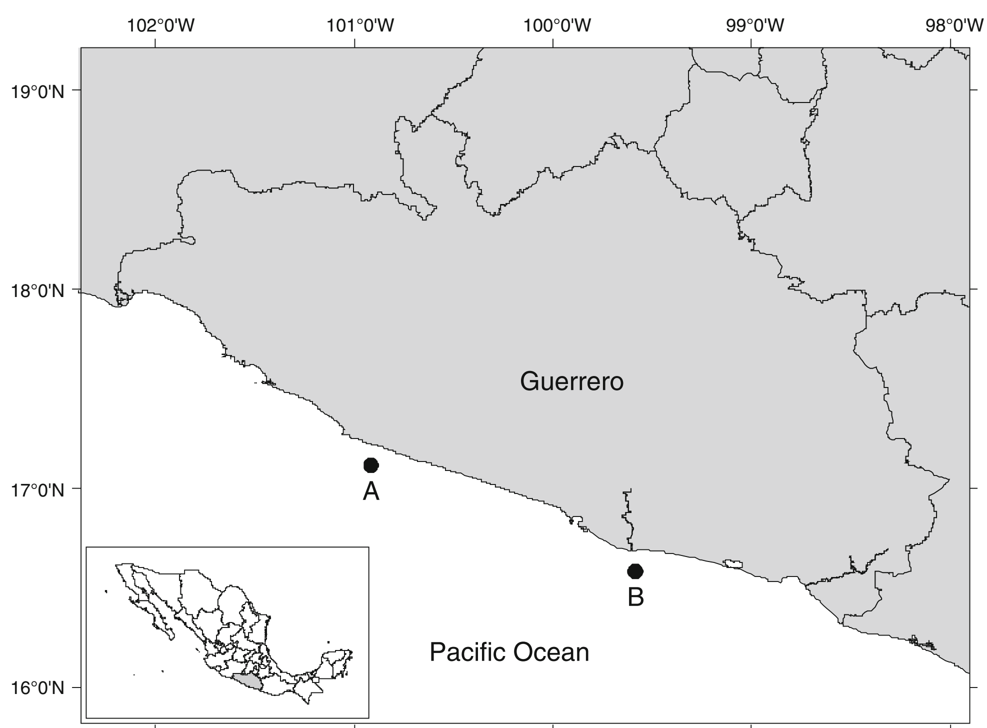

Fig. 1 Location of bycatch fish collection from two sites of Guerrero state (SW Mexico)

Table 1 Biometric characteristics of bycatch fish species from the state of Guerrero

Species	Common name	Food item	Area	N	Total length (cm)	Total weight (g)
Micropogonias ectenes	Mexican milkfish	Benthic crustaceans, mollusks, worms	A	25	17.36 ± 1.07	71.44 ± 21.69
Haemulopsis axillaris	Yellowstripe grunt	Benthic invertebrates	A	12	19.47 ± 1.52	109.17 ± 15.80
Trachinotus kennedyi	Blackblotch pompano	Benthic invertebrates	A	30	20.67 ± 1.47	103.63 ± 19.51
Cyclopsetta querna	Toothed flounder	Benthic invertebrates small fish	A	5	15.22 ± 1.61	40.40 ± 11.87
Umbrina xanti	Yellowtail croaker	Fish, crustaceans, bivalves	A	2	11.35 ± 2.62	17.00 ± 4.24
Prionotus sp	Raspy cow/Lumptail searobin	Shrimps, crabs, fish	A	1	13.20	20.00
Gymnothorax panamensis	Panamic moray	Fish, crustaceans	A	2	45.40 ± 10.47	171.00 ± 100.41
Isopisthus remifer	Silver weakfish	Fish, shrimps, cephalopods	A	2	22.50 ± 2.12	115.00 ± 43.84
Pomadasys panamensis	Panama grunt	Benthic invertebrates, crustaceans, fish	A	15	11.76 ± 0.59	22.77 ± 4.89
Larimus argenteus	Silver drum	Planktonic crustaceans	B	11	16.88 ± 1.46	53.64 ± 12.86
Micropogonias ectenes	Mexican milkfish	Benthic crustaceans, mollusks, worms	B	26	19.57 ± 0.81	98.85 ± 11.19
Haemulopsis axillaris	Yellowstripe grunt	Benthic invertebrates	B	16	19.25 ± 2.26	91.00 ± 23.16
Diapterus peruvianus	Peruvian mojarra	Benthic invertebrates, fish	B	62	16.78 ± 1.25	63.74 ± 16.31
Ancylopsetta dendritica	Three-spot flounder	Fish	B	10	16.56 ± 3.26	53.14 ± 30.98
Pseudupeneus grandisquamis	Bigscale goatfish	Worms, crustaceans mollusks, echinoderms	B	32	15.96 ± 1.11	56.79 ± 16.64
Hemicaranx leucurus	Yellowfin jack	Crustaceans	B	10	22.35 ± 1.16	126.48 ± 12.34

A Northern Guerrero, *B* Southern Guerrero

Table 2 Mean mercury concentrations (±standard deviation; in μg g^{-1}) in bycatch fish from Guerrero

Species	Area	Muscle		Liver	
		(Dry weight)	(Wet weight)	(Dry weight)	(Wet weight)
Micropogonias ectenes	A	0.72 ± 0.44[a]	0.21 ± 0.12[a]	0.42 ± 0.25[b]	0.14 ± 0.08[b]
Haemulopsis axillaris	A	0.61 ± 0.51	0.18 ± 0.15	0.69 ± 0.25	0.23 ± 0.08
Trachinotus kennedyi	A	0.11 ± 0.09	0.03 ± 0.02	0.05 ± 0.04	0.02 ± 0.01
Cyclopsetta querna	A	0.21 ± 0.25	0.06 ± 0.07	0.99 ± 1.26	0.33 ± 0.41
Umbrina xanti	A	0.40 ± 0.10	0.12 ± 0.03	NA	NA
Prionotus sp	A	0.02	0.006	0.40	0.13
Gymnotorax panamensis	A	0.19 ± 0.11	0.06 ± 0.03	0.21 ± 0.10	0.07 ± 0.03
Isopisthus remifer	A	0.48 ± 0.52	0.14 ± 0.15	2.05 ± 0.79	0.68 ± 0.26
Pomadasys panamensis	A	0.12 ± 0.09	0.03 ± 0.02	0.30 ± 0.25	0.10 ± 0.08
Larimus argenteus	B	0.21 ± 0.16	0.06 ± 0.04	0.09 ± 0.41	0.03 ± 0.13
Micropogonias ectenes	B	0.37 ± 0.15[a]	0.11 ± 0.04[a]	0.88 ± 0.35[b]	0.29 ± 0.11[b]
Haemulopsis axillaris	B	0.44 ± 0.08	0.13 ± 0.02	0.98 ± 0.64	0.32 ± 0.21
Diapterus peruvianus	B	0.53 ± 0.41	0.15 ± 0.011	0.69 ± 0.94	0.23 ± 0.31
Ancylopsetta dendritica	B	0.26 ± 0.15	0.08 ± 0.04	1.14 ± 1.39	0.38 ± 0.45
Pseudupeneus grandisquamis	B	0.38 ± 0.49	0.11 ± 0.14	0.20 ± 0.11	0.07 ± 0.03
Hemicaranx leucurus	B	0.13 ± 0.03	0.04 ± 0.01	0.15 ± 0.22	0.05 ± 0.07

A Northern Guerrero, *B* Southern Guerrero, *NA* not available; for a given column, same superscript letters denote significant differences ($p < 0.05$)

(25 g day^{-1}) and W is the average weight of an adult (70 kg). Therefore, a value of HQ below 1.0 means that the exposure level is less than the reference dose; it implies that daily exposure to this level is not likely to cause adverse effects during the life of the consumer. Differences of Hg levels between muscle and liver of fish from sites A and B were defined by t-Student and Mann–Whitney tests.

Table 3 Mean mercury concentrations (±standard deviation; in μg g^{-1} dry weight) in similar bycatch fish collected in the Eastern Pacific Ocean (Sinaloa state)

Species	Muscle	Liver	Reference
M. ectenes	0.656 ± 0.701	1.078 ± 0.791	Ruelas Inzunza et al. (2012)
H. axillaris	1.696 ± 1.022	0.69 ± 0.25	Ruelas Inzunza et al. (2012)
T. kennedyi	0.106 ± 0.09	0.528 ± 0.646	Ruelas Inzunza et al. (2012)
C. querna	0.394 ± 0.236	0.536 ± 0.532	Ruelas Inzunza et al. (2012)
U. xanti	0.579	2.9	Ruelas Inzunza et al. (2012)
Prionotus sp	0.530 ± 0.298	2.558 ± 0.000	Ruelas Inzunza et al. (2012)
I. remifer	1.776 ± 0.639	2.624 ± 1.933	Ruelas Inzunza et al. (2012)
L. argenteus	0.9 ± 0.752	4.622 ± 0.41	Ruelas Inzunza et al. (2012)
D. peruvianus	2.556 ± 1.171	3.186 ± 2.947	Ruelas Inzunza et al. (2012)
H. leucurus	0.582 ± 0.539	0.595 ± 0.424	Ruelas Inzunza et al. (2012)
H. axillaris[a]	1.01	NA	Ruelas Inzunza et al. (2011)
H. axillaris[b]	1.34	NA	Ruelas Inzunza et al. (2011)

[a] Topolobampo, Sinaloa, [b]Santa María, Sinaloa

Table 4 HQ in bycatch fish from Guerrero according to Hg concentrations (wet weight concentrations) in the edible portion and rate of consumption

Species	Area	HQ
Micropogonias ectenes	A	0.75
Haemulopsis axillaris	A	0.64
Trachinotus kennedyi	A	0.11
Cyclopsetta querna	A	0.21
Umbrina xanti	A	0.42
Prionotus sp	A	0.02
Gymnothorax panamensis	A	0.21
Isopisthus remifer	A	0.50
Pomadasys panamensis	A	0.11
Larimus argenteus	B	0.21
Micropogonias ectenes	B	0.39
Haemulopsis axillaris	B	0.46
Diapterus peruvianus	B	0.53
Ancylopsetta dendritica	B	0.29
Pseudupeneus grandisquamis	B	0.39
Hemicaranx leucurus	B	0.14

Results and Discussion

The biometric characteristics of bycatch fish species from the state of Guerrero are presented in Table 1. Fourteen fish species were analyzed from two different areas (A and B). *Micropogonias ectenes and Haemulopsis axillaris* were collected in both areas. From biometric information of collected bycatch fish, 80 % of the icthyofauna are juveniles, the rest are in adult stage (Allen and Robertson 1994). In terms of the number of collected individuals, the blackblotch pompano *Trachinotus kennedyi* (n = 30) and the Peruvian mojarra *Diapterus peruvianus* (n = 62) were the most representative species in areas A and B respectively. The sequence of Hg concentrations in the majority of fish in the present study was: liver > muscle (Table 2). Hg concentrations (μg g^{-1}, dry weight) were highly variable, the highest concentration was detected in the liver of *Isopisthus remifer* (2.05 μg g^{-1}) and the lowest (0.02 μg g^{-1}) was found in muscle of *Prionotus sp.* Levels of Hg in muscle of *M. ectenes* from area A were significantly ($p < 0.05$) higher than in individuals of the same species from area B; the opposite behavior was found in liver; i.e., individuals from area B had more Hg than fish from site A. Considering the analyzed tissues; in muscle, *M. ectenes* showed the highest level of Hg (0.72 μg g^{-1}) while in the liver, the highest concentration (2.05 μg g^{-1}) was detected in *I. remifer*. In Bahía Blanca (Argentina), De Marco et al. (2006) found similar values of Hg in muscle (0.305 μg g^{-1}) and liver (0.3 μg g^{-1}) of *Micropogonias furnieri*. In contrast, Carneiro et al. (2013) found higher Hg concentrations in liver (0.103 μg g^{-1}) than in muscle (0.073 μg g^{-1}) of *Micropogonias furnieri* collected from Sepetiba bay (Rio de Janeiro, Brazil).

Table 3 shows the results of Hg concentrations in muscle and liver of similar fish species collected in the Eastern Pacific Ocean (Sinaloa coasts).We included fish of the same species or genus since comparisons of metal concentrations should comprise individuals with similar physiology (Rainbow and Phillips 1991); i.e., it is more objective to do intraspecific comparisons. After comparing the same fish species and tissues from Sinaloa state (Table 3) and our results (Table 2) it can be seen that ten species were common in both areas (Sinaloa state and Guerrero state). In the case of muscle eight species from Sinaloa had higher Hg levels. In the case of liver, seven species from Sinaloa had higher Hg levels and only one species from Guerrero had higher Hg concentration. Though total Hg emissions (SEMARNAT 2008) to the environment in Sinaloa (9.84 tons of Hg) are lower than in Guerrero (10.73 tons of Hg), other factors may account for such differences; the characteristics of the environment where fish live (Johnson and Stevens 2000), the trophic position of studied species (Kress et al. 1998), and the age and size of the specimens are some of the most relevant.

Considering all the fish in this study the mean HQ values were 0.33 (from area A) and 0.34 (from area B), as can be observed values were similar. Hazard quotients from consumption of collected fish did not exceed the limit of 1.0 (Table 4), *M. ectenes* (from area A) presented the highest HQ (0.75); the lowest HQ (0.02) was for *Prionotus sp,* (from area A). It implies that daily exposure to levels and rate of fish consumption is not likely to cause adverse effects during the life of the consumers. It has been estimated that fishermen and people related to fishing activities consume more fish (from two to three times) than an average consumer (Ruelas Inzunza et al. 2011) so it is necessary to focus the attention on this sector of the population and generate information related to the rate of consumption of certain fish species and their Hg levels in the edible portion.

Acknowledgments To J. Patrón-Gómez for laboratory work and F. Vázquez-Melchor for fish sampling. Thanks are also due to DELFÍN Program. This project was funded by the Ministry of Public Education (Project REDES PROMEP/103.5/13/9366).

References

Agency for Toxic Substances and Disease Registry (ATSDR) (1992) Toxicological profile for lead. Agency for Toxic Substances and Disease Registry, Atlanta

Allen GR, Robertson DR (1994) Fishes of the tropical eastern Pacific. University of Hawaii Press, Honolulu

Alverson DL, Freeberg MH, Murawski SA, Pope JG (1994) A global assessment of fisheries bycatch and discards. FAO Fish Biol Tech Paper: 339

Carneiro CS, Mársico ET, Resende Ribeiro R, Oliveira de Jesus EF (2013) Total mercury bioaccumulation in tissues of carnivorous fish (*Micropogonias furnieri* and *Cynoscion acoupa*) and oysters (*Crassostrea brasiliana*) from Sepetiba Bay, Brazil. J Aquat Food Prod Tech 22:96–102

De Marco SG, Botté SE, Marcovecchio JE (2006) Mercury distribution in abiotic and biological compartments within several estuarine systems from Argentina: 1980–2005 period. Chemosphere 65(2):213–223

Giordano R, Arata P, Ciaralli L, Rinaldi S, Giani M, Cicero AM, Costantini S (1991) Heavy metals in mussels and fish from Italian coastal waters. Mar Pollut Bull 22:10–14

Holsbeek L, Das HK, Joiris CR (1997) Mercury speciation and accumulation in Bangladesh freshwater and anadromous fish. Sci Tot Environ 198:201–210

Johnson J, Stevens I (2000) A fine resolution model of the eastern North Atlantic between the Azores, the Canary Islands and Gibraltar Strait. Deep-Sea Res 1(47):875–899

Kress N, Hornung H, Herut B (1998) Concentrations of Hg, Cd, Cu, Zn, Fe and Mn in deep sea benthic fauna from the southeastern Mediterranean Sea: a comparison study between fauna collected at a pristine area and at two disposal sites. Mar Pollut Bull 36:911–921

Madrid-Vera J, Amezcua F, Morales-Bojórquez E (2007) An assessment approach to estimate biomass of fish communities from bycatch data in a tropical shrimp-trawl fishery. Fish Res 83:81–89

Magalhães MC, Costa V, Menezes GM, Pinho MR, Santos RS, Monteiro LR (2007) Intra- and inter-specific variability in total and methylmercury bioaccumulation by eight marine fish species from the Azores. Mar Pollut Bull 54:1654–1662

Marrugo-Negrete J, Olivero-Verbel J, Lans-Ceballos E, Norberto-Benítez L (2008) Total mercury and methylmercury concentrations in fish from the Mojana region of Colombia. Environ Geochem Health 30:21–30

Moody JR, Lindstrom RN (1997) Selection and cleaning of plastic containers for storage of trace element samples. Anal Chem 49:2264–2267

Newman MC, Unger MA (2002) Fundamentals of ecotoxicology. Lewis Publishers, Boca Raton

Rábago-Quiroz CH, López-Martínez J, Herrera-Valdivia E, Nevarez-Martínez MO, Rodríguez-Romero J (2008) Population dynamics and spatial distribution of flatfish species in shrimp trawl bycatch in the Gulf of California. Hydrobiology 18:193–202

Rainbow PS, Phillips DJH (1991) Cosmopolitan biomonitors of trace metals. Mar Pollut Bull 11:593–601

Ruelas Inzunza J, Páez-Osuna F, Ruiz-Fernández AC, Zamora-Arellano N (2011) Health risk associated to dietary intake of mercury in selected coastal areas of Mexico. Bull Environ Contam Toxicol 86:180–188

Ruelas Inzunza J, Sánchez-Osuna K, Amezcua-Martínez F, Spanopoulos-Zarco P, Manzano-Luna L (2012) Mercury levels in selected bycath fish species from industrial shrimp-trawl fishery in the SE Gulf California. Mar Pollut Bull 64:2857–2859

Ruelas-Inzunza J, Páez-Osuna F, García-Flores D (2010) Essential (Cu) and nonessential (Cd and Pb) metals in ichthyofauna from the coasts of Sinaloa state (SE Gulf of California. Environ Monit Assess 162:251–263

SEMARNAT (2008) Informe final—Inventario Nacional de Liberaciones de Mercurio—México 2004. 214 p

UNEP (1993) Guidelines for monitoring chemical contaminants in the sea using marine organisms. Reference methods for marine pollution studies, No 6

US EPA (1989) Risk assessment guidance for superfund. Human health evaluation manual (Part A). Interim final, vol 1. Environmental Protection Agency, Washington, EPA/540/1–89/002

Us EPA (2000) Handbook for non-cancer health effects evaluation. Environmental Protection Agency, Washington

WWF (2000) Living planet report. World Wide Fund, London