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Review

Review of the biomonitoring of persistent, bioaccumulative, and toxic substances in aquatic ecosystems of Mexico: 2001-2016

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ABSTRACT. Mexico is responsible for the protection and management of a large number and variety of aquatic bodies of national and international importance. Environmental pollution by so-called persistent and bioaccumulative toxic substances (PBTS) poses significant risks for all of the world's aquatic ecosystems, especially in countries with emerging economies, where environmental regulations are often poorly implemented. In Mexico, the development of industrial projects and the deficient application of environmental regulations, together with the rapid increase in population and the inefficient disposal of urban waste, have generated a severe problem of water pollution in the country. National environmental protection programs have not included the monitoring of PBTS, even though researchers have been monitoring the main aquatic ecosystems of the country for nearly three decades, generating valuable information that could help improve the protection and exploitation of these ecosystems. The present work reviewed a large portion of the available literature (~150 articles) on aquatic biomonitoring of the main PBTS (Hg, Cd, Pb, POCs, and PCBs) in Mexico. This work aims to collect, synthesize, and facilitate the management and interpretation of the reported data to improve the country's aquatic ecosystems' protection and management.

Keywords: PBTS; pollution; heavy metals; pesticides; biomonitoring; management; Mexico

INTRODUCTION

The chemical pollution of aquatic ecosystems, especially that caused by persistent and bioaccumulative toxic substances (PBTS), is one of the most critical problems facing modern society, both because of the important contribution to the overall degradation of aquatic ecosystems and the loss of biodiversity, but also because of the immediate risk posed for public health and food safety (Reyes *et al.*, 2016). Creates a growing and multidimensional problem because aquatic ecosystems are the final destination of most PBTS derived from industrial, agricultural, and domestic activities, and this problem is expected to get more complicated by population and urban growth, as well as the accelerated growth of industrial activity around the world, especially in countries with emerging economies. Due to these countries' need for economic-industrial development, their governments often make important concessions to industrial sectors, sometimes

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at the expense of the integrity of their aquatic ecosystems and natural resources in general. Some of these countries also have great ecological wealth, belonging to the group of countries considered megadiverse (11 countries that, together, harbor about 70% of Earth's biodiversity), including China, India, Brazil, Mexico, and Indonesia. Mexico, a leading member of this group, has many aquatic ecosystems of both national and international importance, being the second country with the highest number of wetlands included in the RAMSAR agreement (RAMSAR, 2019). It is also the eleventh most populous country on the planet, and even though its industrial development has lagged behind that of other emerging economies, several of the country's industrial sectors have been developed intensively, as is the case of the mining industry, the oil industry, the textile industry, and the agricultural industry.

Due to the complicated balance between economic development and ecological protection, several international conventions and treaties, laws, regulations, national policies, and monitoring programs (including the National Monitoring Network of National Waters Quality restructured in 1995; CONAGUA, 2017) have been implemented to promote the protection and conservation of the country's aquatic ecosystems. However, the complex contamination scenarios involving much of the country's aquatic ecosystems (CONAGUA, 2017) require other competent authorities (McCulligh, 2014). It has become clear that pollutant monitoring programs of aquatic ecosystems are essential to ensure compliance with national and international commitments (*e.g.*, Minamata Treaty or Stockholm Convention, ratified by Mexico in 2003 and 2015, respectively) regarding the protection and responsible exploitation of these natural assets.

In Mexico, there is enough information about the short-term effects of aquatic pollutants on wild organisms, but there is very little information on their effects on human health, particularly of those effects that are associated with impacted ecosystems (Álvarez-Moya & Reinoso-Silva, 2015; Gómez-Meda *et al.*, 2017). However, researchers have spent nearly three decades monitoring the concentration of the most important PBTS in various environmental matrices (water, sediment, air, and biota) of the country's aquatic ecosystems, generating valuable information that can serve as the basis for decision-making in environmental and public health matters, and help improve the protection and responsible management of aquatic ecosystems. This work aims to review the available studies on the biomonitoring of PBTS (mainly heavy metals, organochlorine pesticides, and polyaromatic hydrocarbons) in the various aquatic ecosystems of Mexico between 2001 and 2016, presenting both the different concentrations of the main PBTS (Hg, Cd, Pb, POC) presented as well as the organisms most commonly used in their monitoring.

Selection of bibliographic material

The selection of scientific publications was made through a search in different academic databases and search engines (Elsevier-Scopus, SCIELO, CONRICyT, and Google Scholar) of monitoring studies of PBTS in aquatic ecosystems in Mexico. The search was delimited using several combinations of keywords such as: "Mexico", "aquatic ecosystems", "lagoon", "estuary", "bay", "lake", "river", "wetland", "swamp", "pollution", "pollutant", "COPs", "heavy metals", "PCBs", "biota", "aquatic organisms", "fish", "bivalves", "clams", "crustaceans", "aquatic birds", among others, both in Spanish and in English. The search was carried out for the period from 2001 to 2016. For the selection of publications, only the articles and chapters of scientific books that met the following requirements were considered: 1) studies conducted in aquatic ecosystems of the Mexican territory, 2) studies on the concentration of heavy metals (Hg, Cd, and Pb), organochlorine pesticides, polychlorinated biphenyls, and polyaromatic hydrocarbons, and 3) studies conducted in biota tissue (muscle, liver, blood, eggs).

Selected studies

Based on these criteria, 150 publications were selected. The number of studies selected in the present study is consistent with Páez-Osuna *et al.* (2017), who found 382 publications on general pollution for the Gulf of California area in the last 45 years. For practicality, we divided the country's aquatic ecosystems into four regions (Fig. 1): Gulf of California, Gulf of Mexican Caribbean, Mexican Pacific, and inland ecosystems (rivers and lakes-reservoirs). The average concentration obtained by each study in the calendar year of sampling was considered the annual average concentration to simplify the visualization and interpretation of the concentrations of PBTS in the present work. In the cases in which the authors did not indicate a single annual average for the calendar year in which the sampling was carried out, as, in the case of seasonal sampling (rain and dry season, or spring, summer, autumn, and winter), the data corresponding to that calendar year were selected and averaged using the following expression:

$$\text{Annual average} = \sum_1^i \frac{x_1 n_1 + x_2 n_2 + \dots + x_i n_i}{n_{1+} n_{2+\dots+} n_i} \qquad (1)$$

where x_1, x_2, ... x_i are average concentrations within the corresponding calendar year, and n_1, n_2, ..., n_i are the sample sizes of the respective average. In the case in

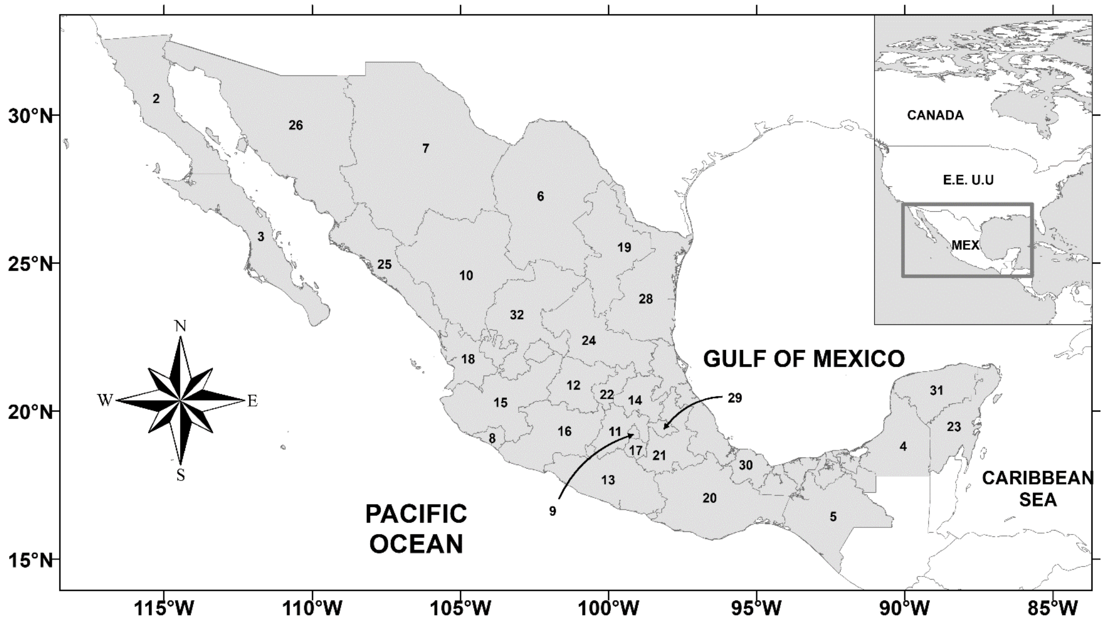

Figure 1. Mexican territory and political division. 1 Aguascalientes, 2 Baja California, 3 Baja California Sur, 4 Campeche, 5 Chiapas, 6 Chihuahua, 7 Coahuila, 8 Colima, 9 México Distrito Federal, 10 Durango, 11 Estado de México, 12 Guanajuato, 13 Guerrero, 14 Hidalgo, 15 Jalisco, 16 Michoacán, 17 Morelos, 18 Nayarit, 19 Nuevo León, 20 Oaxaca, 21 Puebla, 22 Querétaro, 23 Quintana Roo, 24 San Luis Potosí, 25 Sinaloa, 26 Sonora, 27 Tabasco, 28 Tamaulipas, 29 Tlaxcala, 30 Veracruz, 31 Yucatán, 32 Zacatecas.

which authors reported average concentrations for each sampling site within their study area, Equation 1 was used but taking x_1, x_2, ... , x_i as the averages of each sampling site and. n_1, n_2, ..., n_i as the sample sizes of the respective averages. Concerning persistent organic pesticides (POPs), which are found in the form $X = x_1 + x_2, ..., x_n$ where X is the group of POPs and x are the metabolites, derivatives, or related compounds of X, the total annual concentration was obtained using the following expression:

$$X = \sum_1^i \frac{\frac{x_1n_1+x_2n_2+\ldots+x_in_i}{n_1+n_2+\cdots+n_i}}{k} \quad (2)$$

where x_1, x_2, ..., x_i are the averages of each of the derivatives, n_1, n_2, ..., n_i are the sample sizes of the respective averages, and k is the number of derivatives of each group. When the authors presented more than one total annual concentration, Equation 1 was applied, substituting x for X, and n for k, applying the same temporal and spatial distribution criteria.

Persistent pollutants in aquatic organisms

Contamination of aquatic ecosystems with PBTS is one of the most critical environmental problems caused by direct human action (Saaristo *et al*., 2018) due to the great negative impact on wildlife. The adverse effects of pollution with PBTS can occur both in the short term (acute effects) and in the long term (chronic effects), including transgenerational effects. The effects of several of these pollutants (heavy metals and POPs mainly) at the sub-organism and organism level have been extensively studied for several decades and have been thoroughly described. PBTS are currently found in virtually all aquatic ecosystems in the world and, in most cases, below the probable effect concentrations established by environmental protection agencies, even below detec-tion limits. Thus, aquatic organisms are continuously exposed to a wide variety of concentrations and mixtures of these substances throughout their life cycle, and the real effects of this exposure cannot be appreciated in the short term or at basic levels of biological organization (Schwarzenbach *et al*., 2006). Nevertheless, the effects of chronic long-term exposure to low concentration levels are equally harmful; they are just less obvious (Saaristo *et al*., 2018). These effects may occur at the genetic, epigenetic, or behavioral level, affecting present or future gene-rations, compromising long-term survival and repro-duction, and decimating and damaging existing populations.

Since a large part of the world's population depends on the consumption of fishery products (marine and freshwater, animal and vegetable) as an essential part of their daily diet and due to this fact, the ability of PBTS to bioaccumulate and biomagnify in the trophic networks of aquatic ecosystems pose a serious public health problem, mainly in developing countries (FAO, 2018). The consumption of fishery products is considered the primary source of exposure to PBTS in humans (Dórea, 2008). Although the effects of poisoning with food contaminated with PBTSs have been well established, while the long-term effects of the consumption of fishery products contaminated with low concentrations of PBTS are still being studied. These effects may include neurological, cardiovascular, endocrine, or immunological alterations, but further studies are required (Dórea, 2008). The biomonitoring of PBTS in aquatic ecosystems is thus a vital tool for protecting wildlife and public health, providing valuable information on these substances' bioavailability and the spatial and temporal variation of these substances' bioavailable fraction pollutants. For an organism to have potential as a biomonitor, it must possess a series of desirable attributes (both ecological and logistical) to facilitate its application. A wide variety of organisms are currently used as biomonitors of aquatic pollution, including fish, bivalves, crustaceans, macroalgae, birds, or mammals.

Heavy metals in biota

The presence, bioaccumulation, and biomagnification of heavy metals in aquatic ecosystems have been widely studied in recent decades because the presence and bioaccumulation of some of these metals in trophic networks can pose a serious risk to human health (Mendoza-Carranza *et al*., 2016). The potential for bioaccumulation and biomagnification of heavy metals is high, and such a process can be complex and difficult to understand. It is not yet clear how some metals biomagnify the trophic networks of aquatic ecosystems, while the biomagnification of Hg and Se is an easy process to elucidate; other cases, such as Cd and Pb, are still under discussion (Schneider *et al*., 2018). Bioaccumulation and bioconcentration processes are influenced by the exposure routes and by intraspecific and interspecific differences; thus, it is recommended that biomonitoring studies use several different species to make a better estimation of the behavior of pollutants in ecosystems (Jara-Marini *et al*., 2013). In general, monitoring the concentration of metals in aquatic organisms can make evident the pollution status of an ecosystem and help understand the potential risk to consumers (Wang *et al*., 2013).

Different organisms were used for monitoring the concentration of Hg, Cd, and Pb in different aquatic ecosystems in Mexico (Tables 1-2). Based on the information obtained in the present review, coastal ecosystems have been the most studied in this regard, mainly the coastal ecosystems of the Gulf of California. The organisms used as biomonitors include various groups, such as macroalgae, bivalve mollusks, fish, sharks, rays, birds, and turtles. Bivalves and fish were the most frequently used, maybe because bivalves are frequently used as biomonitors throughout the world (Páez-Osuna & Osuna-Martínez, 2011). They have various desirable qualities for aquatic biomonitoring, such as resistance to handling (which means they can be used for both *in situ* and *ex situ* studies), simple eating habits, they are efficient accumulators, sedentary, abundant, and cosmopolitan. However, even though they are found virtually on all Mexican coastal sites, their use as biomonitors has been limited to the Gulf of California area, mainly the States of Sonora and Sinaloa coasts. Furthermore, in some areas of the central Mexican Pacific (Jalisco-Colima-Michoacán), the northern part of the Gulf of Mexico (Tamaulipas), and the Mexican Caribbean, the number of studies using bivalves within the reviewed period are significantly scarce. Regarding the bivalve species used, the genus *Crassostrea* was the most common, probably due to its commercial importance, given that these species are extensively cultivated in coastal lagoons of the Gulf of California, which would have simplified many logistical issues during the sampling campaigns.

The use of teleost fish as biomonitors of aquatic pollution is also of great importance. These fish are found in virtually all aquatic ecosystems throughout the world, and many species can be considered integrators of ecological conditions, especially those closest to the highest levels of the food chain. Since they perform the function of transferring energy from the low to the high levels of the trophic networks of aquatic ecosystems (Van der Oost *et al*., 2003), they are a good mirror of the health of the ecosystem (Sedeño-Díaz & López-López, 2012). Fish are the organisms most frequently consumed by humans, especially those in high trophic levels and by bioaccumulating heavy metals (such as Cd, Pb Hg), they passed them on to consumers and can cause both acute (poisoning) and chronic diseases, most of which are not yet fully understood. Unlike bivalves, fish as biomonitors of aquatic pollution is more widespread throughout the Mexican territory, including coastal and inland ecosystems. The present review shows that pollution monitoring studies have used different species of fish belonging to different trophic levels and with different eating habits, including planktivorous fish (sardines), detritivorous fish (lizas), omnivorous fish (catfish), carnivorous-piscivorous fish (mojarras, snooks, snappers), carnivorous-benthic fish and major pelagic fish. The most used species were the lizas (Mugilidae), probably due to their commercial importance in Mexico (Frías-Espiricueta *et al*., 2011).

Table 1. Average concentration of Hg (in µg g^{-1} dw) in different tissues of organisms from various aquatic ecosystems of Mexico. EU: Estero Urías; AEP: Altata-Ensenada del Pabellón; BGY: Bahía Guaymas; GCFR: Golfo de California; GSNR: Granjas-Sonora; GSNL: Granjas Sinaloa; GNYR: Granjas Nayarit; BBP: Bahía de Bacochibampo; BCT: Bahía de Cueta; BBCN: Bocana; GYEMP: Guaymas-Empalme LTM: Laguna de Términos; LTB: Laguna El Tobari; LCL: El Colorado; ERY: Estero El Rey; SMOT: Santa María-Ohurias-Topolobampo; SMR: Santa María- LA Reforma; LCHP: Lago de Chapala; BKK: Bahía de Kuu Kaak; BGMS: Bahía Las Guácimas; LAV: Laguna Alvarado; CSNR: Costa de Sonora; BTBP: Bahía de Topolobampo; BAP: Laguna Agiabampo; BCHC: Bachoco; CSC: Ciénega Santa Clara; LBN: Laguna Barra de Navidad; SBRB: Santa Bárbara; RPL: Río Palizada; RCHP: Río Chumpán; BTPB: Bahía de Topolobampo; BCMCH: Boca Camichín; BCHM: Bahía Chetumal; PLL: Presa Luis León; CSDR: Cañón del sumidero; MTCL: Mercado de Tecuala; RCL: Río Colorado; RCDLR: Río Candelaria; BCY: Bahía La Choya; ESBL: Estero de San Blas; LCTC: Lago de Catemaco; BLB: Bahía de Lobos; RMYR: El Mayor; RUSMT: Río Usumacinta; TCPN: Teacapán; PVM: Presa Viejo Mandín; CCP: Cucapa; MTTN: Minatitlán; RSTG: Río Santiago; TLCP: Tlacotalpan; URTCP: Urías-Teacapán; PVCZ: Puerto de Veracruz; CSPT: Cospita; CBCF: Baja California; PBLCH: Punta Belcher; IMGD: Isla Magdalena; PPG: El Portugués; BCHY: El Choyudo; PRY: Playa del Rey; DTLL: Dautillos; PCHL: Puerto Chale; RCHPT: Río Champotón; LPNCLT: Los Petenes-Celestún; RHND: Río Hondo; CGRR: Costa de Guerrero; CSNL: Costa de Sinaloa; PDBC: Península de Baja California; PEPA: Playa la Escobilla-Puerto Escondido-Puerto Ángel. SON: Sonora; SIN: Sinaloa; NAY: Nayarit; JAL: Jalisco; COL: Colima; MIC: Michoacán; GRO: Guerrero; OAX: Oaxaca; CHP: Chiapas; CAM: Campeche; ROO: Quintana Roo; YUC: Yucatán; TAB: Tabasco; VER: Veracruz; TAM: Tamaulipas; BCS: Baja California Sur; BCN: Baja California Norte; AGU: Aguascalientes; MEX: México; CMX: Ciudad de México. N/E: not specified; ND: not detect; -: not analized; D: dry weight; W: wet weight; M: muscle; ST: soft tissue; T: whole body; S: blood; B: biopsy; H: eggs.

Species	Place	Hg	Reference
Primary producers			
Fitoplankton	UR (SIN)	0.02^{D} (2006)	Jara-Marini *et al.* (2012)
Gracilaria sp.	UR (SIN)	0.02^{D} (2006)	Jara-Marini *et al.* (2012)
Gracilaria subsecuentata	BGY (SON)	0.09 (1998)	Green-Ruiz *et al.* (2005)
Chaetomorpha linum	UR (SIN)	0.04^{D} (2006)	Jara-Marini *et al.* (2012)
Caulerpa serticularioides	UR (SIN)	0.02^{D} (2006)	Jara-Marini *et al.* (2012)
Ulva Lactuca	BGY (SON)	0.05^{D} (1998)	Green-Ruiz *et al.* (2005)
Mollusks			
Crassostrea corteziensis	BBP (SON)	0.04^{W} (2004) ST	García-Rico *et al.* (2010)
		0.03^{W} (2005) ST	García-Rico *et al.* (2010)
	UR (SIN)	0.05^{D} (2006) ST	Jara-Marini *et al.* (2012)
		0.17^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	BCT (SIN)	0.37^{D} (N/E) ST	Osuna-Martínez *et al.* (2010)
		0.57^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	LTB (SON)	0.43^{D} (2009) ST	Jara-Marini *et al.* (2013)
	LCL (SIN)	0.54^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	SMOT (SIN)	0.18^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	INM (SIN)	0.39^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	SMR (SIN)	0.30^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	AEP (SIN)	0.52^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	ERY (SIN)	0.29^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	UR (SIN)	0.05^{D} (2006) ST	Jara-Marini *et al.* (2008)
Crassostrea gigas	BGY (SON)	0.23 (1998) ST	Green-Ruiz *et al.* (2005)
	LTB (SON)	0.39^{D} (2009)	Jara-Marini *et al.* (2013)
	LCL (SIN)	0.93^{D} (N/E) ST	Osuna-Martínez *et al.* (2010)
	BCT (SIN)	0.46^{D} (N/E) ST	Osuna-Martínez *et al.* (2010)
	SMR (SIN)	0.24^{D} (N/E) ST	Osuna-Martínez *et al.* (2010)
	AEP (SIN)	0.23^{D} (N/E) ST	Osuna-Martínez *et al.* (2010)
	CSNR (SON)	0.03^{W} (1997) ST	Garcia-Rico & Ramos-Ruiz (2001)
Crassostrea virginica	LTM (CAM)	0.0001 (2011) ST	Benítez *et al.* (2012)
	RPL (CAM)	0.5 (N/E) ST	Aguilar *et al.* (2012)
	RCHP (CAM)	0.7 (N/E) ST	Aguilar *et al.* (2012)
	RCDLR (CAM)	1.1 (N/E) ST	Aguilar *et al.* (2012)
Crassostrea sp.	BCHC (SON)	0.17^{D} (2010-2011) ST	Delgado-Álvarez *et al.* (2015b)
	SBRB (SON)	0.25^{D} (2010-2011) ST	Delgado-Álvarez *et al.* (2015b)
	LTB (SON)	0.14^{D} (2010-2011) ST	Delgado-Álvarez *et al.* (2015b)
	BAP (SON)	0.17^{D} (2010-2011) ST	Delgado-Álvarez *et al.* (2015b)

continuation

Species	Place	Hg	Reference
	SMR (SIN)	0.19^{D} (2010-2011) ST	Delgado-Álvarez *et al.* (2015b)
	BCMCH (NAY)	0.19^{D} (2010-2011) ST	Delgado-Álvarez *et al.* (2015b)
	CGC (N/A)	0.17^{D} (2010-2011) ST	Delgado-Álvarez *et al.* (2015b)
Megapitaria squalida	BKK (SON)	0.001 (2003) ST	García-Hernández *et al.* (2005)
Mytella strigata	UR (SIN)	0.06^{D} (2006) ST	Jara-Marini *et al.* (2012)
	UR (SIN)	0.06^{D} (2006) ST	Jara-Marini *et al.* (2008)
Chione fluctifraga	LTB (SON)	0.28^{D} (2009) ST	Jara-Marini *et al.* (2013)
Chione gnidia	LTB (SON)	0.47^{D} (2009) ST	Jara-Marini *et al.* (2013)
Chione californiensis	BKK (SON)	0.001^{W} (2003) ST	García-Hernández *et al.* (2005)
Chione subrugosa	BGY (SON)	0.06 (1998) ST	Green-Ruiz *et al.* (2005)
Chione sp.	DRC (SON)	0.04^{D} (1998-2000) ST	García-Hernández *et al.* (2001)
Anadara tuberculosa	LTB (SON)	0.20^{D} (2009) ST	Jara-Marini *et al.* (2013)
Corbicula sp.	RCL (SON)	0.04^{D} (1998-2000) ST	García-Hernández *et al.* (2001)
Corbicula fluminea	RCZ (VER)	0.09^{D} 2005) ST	Ruelas-Inzunza *et al.* (2009a)
Polymesoda caroliniana	RCZ (VER)	0.155^{D} (2005) ST	Ruelas-Inzunza *et al.* (2009a)
Polymesoda caroliniana	RCZ (VER)	0.115^{D} (2006) ST	Ruelas-Inzunza *et al.* (2009a)
Pinna rugosa	BKK (SON)	0.022^{W} (2003) ST	García-Hernández *et al.* (2005)
Hexaplex erythrostomus	BKK (SON)	0.05^{W} (2003) ST	García-Hernández *et al.* (2005)
Mytilopsis sallei	BCHM (ROO)	1.09 (2002) ST	Díaz-López *et al.* (2006)
Crustaceans			
Penaeus vannamei	AEP (SIN)	0.20^{D} (1998-1999) M	Ruelas-Inzunza *et al.* (2004)
	UR (SIN)	0.03^{D} (2006) T	Jara-Marini *et al.* (2012)
	AEP (SIN)	0.06^{W} (1998-1999) M	Ruelas- Inzunza *et al.* (2011a)
	GSNR (SON)	0.19 (2010) M	Delgado-Álvarez *et al.* (2015a)
	GSNL (SIN)	0.31 (2010) M	Delgado-Álvarez *et al.* (2015a)
	GNYR (NAY)	0.45 (2010) M	Delgado-Álvarez *et al.* (2015a)
Litopenaeus stylirostris	AEP (SIN)	0.30^{D} (1998-1999) M	Ruelas-Inzunza *et al.* (2004)
	AEP (SIN)	0.09^{W} (1998-1999) M	Ruelas-Inzunza *et al.* (2011a)
Litopenaeus setiferus	LTM (CAM)	ND (2011) M	Benítez *et al.* (2012)
Penaeus aztecus	LAV (VER)	0.008 (2003) M	Guentzel *et al.* (2007)
	LAV (VER)	0.03^{W} (2005) M	Guentzel *et al.* (2007)
Farfantepenaeus brevirostris	AEP (SIN)	0.06^{W} (1998-1999) M	Ruelas-Inzunza *et al.* (2011a)
	AEP (SIN)	0.21^{D} (1998-1999) M	Ruelas-Inzunza *et al.* (2004)
Farfantepenaeus californiensis	AEP (SIN)	0.04^{W} (1998-1999) M	Ruelas-Inzunza *et al.* (2011a)
	AEP (SIN)	0.13^{D} (1998-1999) M	Ruelas-Inzunza *et al.* (2004)
Xiphopenaeus kroyeri	AEP (SIN)	0.04^{W} (1998-1999) M	Ruelas-Inzunza *et al.* (2011a)
	AEP (SIN)	0.13^{D} (1998-1999) M	Ruelas-Inzunza *et al.* (2004)
Palaemonetes	BBCN (SON)	0.40^{D} (1998-2000) T	García-Hernández *et al.* (2001)
Paludosus	CSC (SON)	0.60^{D} (1998-2000) T	García-Hernández *et al.* (2001)
Callinectes arcuatus	UR (SIN)	0.13^{D} (2006) T	Jara-Marini *et al.* (2012)
Callinectes rathbunae	LAV (VER)	0.02^{W} (2012) M	Guentzel *et al.* (2007)
Callinectes bellicosus	BCY (SON)	0.20^{W} (2012) M	García-Hernández *et al.* (2015)
	BST (SON)	0.26^{W} (2012) M	García-Hernández *et al.* (2015)
	BKK (SON)	0.15^{W} (2012) M	García-Hernández *et al.* (2015)
	GYEMP (SON)	0.08^{W} (2012) M	García-Hernández *et al.* (2015)
	BGMS (SON)	0.09^{W} (2012) M	García-Hernández *et al.* (2015)
	BLB (SON)	0.05^{W} (2012) M	García-Hernández *et al.* (2015)
	LTB (SON)	0.10^{W} (2012) M	García-Hernández *et al.* (2015)
	BYV (SON)	0.12^{W} (2012) M	García-Hernández *et al.* (2015)
	BAP (SON)	0.19^{W} (2012) M	García-Hernández *et al.* (2015)
	INM (SIN)	0.20^{W} (2012) M	García-Hernández *et al.* (2015)
	BOH (SIN)	0.14^{W} (2012) M	García-Hernández *et al.* (2015)
	SMR (SIN)	0.09^{W} (2012) M	García-Hernández *et al.* (2015)
	AEP (SIN)	0.13^{W} (2012) M	García-Hernández et al. (2015)
Procambarus clarkii	RMYR (SON)	0.05^{D} (1998-200) T	García-Hernández *et al.* (2001)
Fish			
Opisthonema libertate	BGY (SON)	0.20^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2005)
	BGY (SON)	0.06^{W} (1998) M	Ruelas-Inzunza *et al.* (2011a)
Paralichthys woolmani	BTBP (SON)	0.68^{W} (2004) M	Ruelas-Inzunza *et al.* (2008)
	BTBP (SON)	0.21^{W} (2004) M	Ruelas-Inzunza *et al.* (2011a)

continuation

Species	Place	Hg	Reference
Cyclopsetta querna	CGRR (GRO)	0.21^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
	CSNL (SIN)	0.39^{D} (2011) M	Ruelas-Inzunza *et al.* (2012)
Ancylopsetta dendritica	CGRR (GRO)	0.26^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
Achirus mazatlanus	LBN (JAL)	0.29^{D} (2014) M	Aguilar-Betancourt *et al.* (2016)
Bagre marina	LAV (VER)	0.29^{W} (2005) M	Guentzel *et al.* (2007)
Cathorops fuerthii	BGY (SON)	0.45^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2005)
Cathorops fuerthii	BGY (SON)	0.14^{W} (1998) M	Ruelas-Inzunza *et al.* (2011a)
Galeichthys peruvianus	AEP (SIN)	1.58^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2005)
Arius platypogon	BTBP (SON)	0.29^{W} (2004) M	Ruelas-Inzunza *et al.* (2011a)
Sciades guatemalensis	LBN (JAL)	1.43^{D} (2014) M	Aguilar-Betancourt *et al.* (2016)
Arius felis	LAV (VER)	0.27^{W} (2000-2003) M	Elliott *et al.* (2015)
Arius sp.	ESBL (NAY)	0.20^{W} (2000-2003) M	Elliott *et al.* (2015)
Ictalurus furcatus	PLL (CHH)	0.08^{W} (2001-2012) M	Luna-Porres *et al.* (2014)
Pterygoplichthys pardalis	RUSMT (TAB)	0.45^{D} (N/E) M	Maldonado-Enríquez *et al.* (2015)
Eugerris plumeri	LAV (VER)	0.35^{W} (2002) M	Guentzel *et al.* (2007)
	LAV (VER)	0.30^{W} (2005) M	Guentzel *et al.* (2007)
Eugerris axillaris	UR (SIN)	0.70^{D} (2012) M	Frías-Espericueta *et al.* (2016)
	UR (SIN)	0.48^{D} (2013) M	Frías-Espericueta *et al.* (2016)
Gerres cinereus	UR (SIN)	0.15^{D} (2006) M	Jara-Marini *et al.* (2012)
	TCPN (SIN)	0.29^{W} (2005) M	Ruelas-Inzunza *et al.* (2011a)
	ERCZ (VER)	0.09^{W} (2005) M	Ruelas-Inzunza *et al.* (2011a)
	ERCZ (VER)	0.19^{D} (2005) M	Ruelas-Inzunza *et al.* (2009a)
Diapterus peruvianus	BTBP (SON)	0.16^{W} (2004) M	Ruelas-Inzunza *et al.* (2011a)
	CGRR (GRO)	0.53^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
	CSNL (SIN)	2.55^{D} (2011) M	Ruelas-Inzunza *et al.* (2012)
Diapterus brevirostris	LBN (JAL)	0.36^{D} (2014) M	Aguilar-Betancourt *et al.* (2016)
Cyprinus carpio	LCHP (JAL)	0.39^{W} (2010) M	Stong *et al.* (2013)
	LCHP (JAL)	0.35^{W} (2011) M	Torres *et al.* (2014)
	LCHP (JAL)	0.10^{W} (2012) M	Torres *et al.* (2014)
	PVM (MEX)	ND^{W} (2013) M	Morachis-Valdez *et al.* (2015)
	PLL (CHH)	0.008^{W} (2011-2012) M	Luna-Porres *et al.* (2014)
Criprynus sp.	LCHP (JAL)	0.83^{W} (2007) M	Trasande *et al.* (2010)
Chirostoma sp.	LCHP (JAL)	0.11^{W} (2007) M	Trasande *et al.* (2010)
	LCHP (JAL)	0.15^{W} (2011) M	Torres *et al.* (2014)
	LCHP (JAL)	0.07^{W} (2012) M	Torres *et al.* (2014)
Gambusia affinis	RCL (SON)	0.63^{D} (1998-2000) T	García-Hernández *et al.* (2001)
	RHD (SON)	0.32^{D} (1998-2000) T	García-Hernández *et al.* (2001)
	RMYR (SON)	0.89^{D} (1998-2000) T	García-Hernández *et al.* (2001)
Poecilia latipinna	CSC (SON)	0.12^{D} (1998-2000) T	García-Hernández *et al.* (2001)
Mugil cephalus	CCP (SON)	0.04^{D} (1998-2000) T	García-Hernández *et al.* (2001)
	BGY (SON)	0.02^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2005)
	AEP (SIN)	0.13^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2005)
	UR (SIN)	0.06^{D} (2006) T	Jara-Marini *et al.* (2012)
	BGY (SON)	ND^{D} (1998) M	Ruelas-Inzunza *et al.* (2011a)
	BTBP (SON)	0.01^{W} (2004) M	Ruelas-Inzunza *et al.* (2011a)
	AEP (SIN)	0.04^{W} (1998-1999) M	Ruelas-Inzunza *et al.* (2011a)
	AEP (SIN)	0.03^{W} (2004) M	Ruelas-Inzunza *et al.* (2011a)
Mugil curema	UR (SIN)	0.02^{W} (2003) M	Ruelas-Inzunza *et al.* (2011a)
	SMR (SIN)	0.03^{W} (2003) M	Ruelas-Inzunza *et al.* (2011a)
	LAV (VER)	0.57^{W} (2003) M	Guentzel *et al.* (2007)
	LCTC (VER)	0.02^{W} (2000-2003) M	Elliott *et al.* (2015)
	MTTN (VER)	0.14^{W} (2000-2003) M	Elliott *et al.* (2015)
	LAV (VER)	0.03^{W} (2000-2003) M	Elliott *et al.* (2015)
	LBN (JAL)	0.03^{D} (2014) M	Aguilar-Betancourt *et al.* (2016)
	LCTC (VER)	0.02^{W} (2000-2003) M	Elliott *et al.* (2015)
Mugil sp.	RSTG (NAY)	0.04^{W} (2000-2003) M	Elliott *et al.* (2015)
	LBN (JAL)	0.02^{W} (2000-2003) M	Elliott *et al.* (2015)
	UR (SIN)	0.18^{D} (2012) M	Frías-Espericueta *et al.* (2016)
	UR (SIN)	0.15^{D} (2013) M	Frías-Espericueta *et al.* (2016)
Cichlasoma sp.	LBN (JAL)	0.05^{W} (2000-2003) M	Elliott *et al.* (2015)

continuation

Species	Place	Hg	Reference
Oreochromis sp.	LCHP (JAL)	0.04^{W} (2007) M	Trasande *et al.* (2010)
	LCHP (JAL)	0.03^{W} (2011) M	Torres *et al.* (2014)
	LCHP (JAL)	0.03^{W} (2012) M	Torres *et al.* (2014)
	CSDR (CHP)	0.05^{W} (2000-2003) M	Elliott *et al.* (2015)
Oreochromis sp.	RCZ (VER)	0.05^{D} (2005) M	Ruelas-Inzunza *et al.* (2009a)
Oreochromis niloticus	LCTC (VER)	0.01^{W} (2000-2003) M	Elliott *et al.* (2015)
	LAV (VER)	0.02^{W} (2000-2003) M	Elliott *et al.* (2015)
Lepomis macrochirus	RHD (SON)	0.65^{W} (2010) M	García-Hernández *et al.* (2013)
	CSC (SON)	0.69^{D} (1998-2000) T	García-Hernández *et al.* (2013)
Lepomis cyanellus	PLL (CHH)	0.07^{W} (2011-2012) M	Luna-Porres *et al.* (2014)
Archosargus probatocephalus	LAV (VER)	0.09^{W} (2002) M	Guentzel *et al.* (2007)
Gobiomorus polylepis	RCZ (VER)	0.86^{D} (2006) M	Ruelas-Inzunza *et al.* (2009a)
Centropomus parallelus	LAV (VER)	0.15^{W} (2002) M	Guentzel *et al.* (2007)
	LAV (VER)	0.18^{W} (2000-2003) M	Elliott *et al.* (2015)
	MTTN (VER)	0.29^{W} (2000-2003) M	Elliott *et al.* (2015)
	TLCP (VER)	0.13^{W} (2000-2003) M	Elliott *et al.* (2015)
Centropomus viridis	ERCZ (VER)	0.26^{W} (2005) M	Ruelas-Inzunza *et al.* (2011a)
	ERCZ (VER)	0.68^{D} (2005) M	Ruelas-Inzunza *et al.* (2009a)
	ERCZ (VER)	0.48^{D} (2006) M	Ruelas-Inzunza *et al.* (2009a)
Centropomus nigrescens	BTBP (SON)	0.56^{D} (2004) M	Ruelas-Inzunza *et al.* (2008)
	BTBP (SON)	0.17^{W} (2004) M	Ruelas-Inzunza *et al.* (2011a)
Centropomus armatus	BTBP (SON)	1.51^{D} (2004) M	Ruelas-Inzunza *et al.* (2008)
	BTBP (SON)	0.44^{W} (2004) M	Ruelas-Inzunza *et al.* (2011a)
Centropomus medius	SMR (SIN)	0.82^{D} (2003) M	Ruelas-Inzunza *et al.* (2008)
Centropomus ensiferus	LAV (VER)	0.18^{W} (2005) M	Guentzel *et al.* (2007)
Centropomus sp.	MTCL (NAY)	0.30^{W} (2000-2003) M	Elliott *et al.* (2015)
Cynoscion xanthulus	AEP (SIN)	0.1^{D} (1998-1999) M	García-Hernández *et al.* (2005)
Micropogonias ectenes	CGRR (GRO)	0.54^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
	CSNL (SIN)	0.65^{D} (2011) M	Ruelas-Inzunza *et al.* (2012)
Haemulopsis axillaris	CGRR (GRO)	0.51^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
	CSNL (SIN)	1.69^{D} (2011) M	Ruelas-Inzunza *et al.* (2012)
Umbrina xanti	CGRR (GRO)	0.40^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
	CSNL (SIN)	0.58^{D} (2011) M	Ruelas-Inzunza *et al.* (2012)
Pomadasys panamensis	CGRR (GRO)	0.12^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
Pseudupeneus grandisquamis	CGRR (GRO)	0.38^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
Hemicaranx leucurus	CGRR (GRO)	0.13^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
	CSNL (SIN)	0.58^{D} (2011) M	Ruelas-Inzunza *et al.* (2011)
Lutjanus colorado	AEP (SIN)	0.89^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2005)
	URTCP (SIN)	0.53^{D} (2003-2004) M	Ruelas-Inzunza *et al.* (2008)
	UR (SIN)	0.10^{W} (2003) M	Ruelas-Inzunza *et al.* (2011a)
	AEP (SIN)	0.26^{W} (1998-1999) M	Ruelas-Inzunza *et al.* (2011a)
	UR (SIN)	0.18^{W} (2003) M	Ruelas-Inzunza *et al.* (2011b)
Lutjanus argentiventris	UR (SIN)	0.19^{D} (2006) T	Jara-Marini *et al.* (2012)
Caranx caninus	BTBP (SON)	3.32^{D} (2004) M	Ruelas-Inzunza *et al.* (2008)
	BTBP (SON)	1.0^{W} (2004) M	Ruelas-Inzunza *et al.* (2011a)
	BTBP (SON)	0.2^{W} (2004) M	Ruelas-Inzunza *et al.* (2011b)
Polydactylus approximans	CSNL (SIN)	1.72^{D} (2011) M	Ruelas-Inzunza *et al.* (2012)
Scorpaena sp.	CSNL (SIN)	1.72^{D} (2011) M	Ruelas-Inzunza *et al.* (2012)
Oligoplites saurus	BTBP (SON)	1.74^{D} (2004) M	Ruelas-Inzunza *et al.* (2008)
Isopisthus remifer	CSNL (SIN)	1.77^{D} (2011) M	Ruelas-Inzunza *et al.* (2012)
Trachinotus kennedyi	CGRR (GRO)	0.11^{D} (2011) M	Spanopoulos-Zarco *et al.* (2014)
	CSNL (SIN)	0.10^{D} (2011) M	Ruelas-Inzunza *et al.* (2012)
Seriola lalandei	BGY (SON)	0.76^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2005)
	GCFR (N/A)	0.07^{W} (2003-2004) M	García-Hernández *et al.* (2007)
	BGY (SON)	0.23^{W} (1998) M	Ruelas-Inzunza *et al.* (2011a)
Thunnus albacares	GCFR (N/A)	0.03^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Coryphaena hippurus	GCFR (N/A)	0.05^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Makaira mazara	GCFR (N/A)	0.36^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Istiophorus platypterus	GCFR (N/A)	0.40^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Acanthocybium solandri	GCFR (N/A)	0.15^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Tetrapturus audax	GCFR (N/A)	0.14^{W} (2003-2004) M	García-Hernández *et al.* (2007)

continuation

Species	Place	Hg	Reference
Sharks and rays			
Carcharhinus limbatus	PVCZ (VER)	3.33^{W} (1994-1995) M	Núñez-Noriega (2005)
	GCFR (N/A)	0.51^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Carcharhinus leucas	AEP (SIN)	0.20^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2005)
	AEP (SIN)	0.62^{W} (2003) M	Ruelas-Inzunza *et al.* (2011b)
Carcharhinus falciformis	GCFR (N/A)	0.30^{W} (2003-2004) M	García-Hernández *et al.* (2007)
	PDBC (BCS)	3.40^{D} (2001-2005) M	Maz-Courrau *et al.* (2012)
Sphyrna lewini	AEP (SIN)	0.49^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2005)
	GCFR (N/A)	1.08^{W} (2003-2004) M	García-Hernández *et al.* (2007)
	CSPT (SIN)	0.81^{W} (2009-2010) M	Hurtado-Banda *et al.* (2012)
	TCPN (SIN)	0.63^{W} (2011-2012) M	Bergés-Tiznado *et al.* (2015)
Sphyrna zygaena	GCFR (N/A)	8.25^{W} (2003-2004) M	García-Hernández *et al.* (2007)
	PDBC (BCS)	0.98^{D} (2001-2005) M	Maz-Courrau *et al.* (2012)
Prionace glauca	CBCF (BSC)	1.39^{W} (2005-2006)	Escobar-Sánchez *et al.* (2011)
	PDBC (BCS)	1.96^{D} (2001-2005) M	Maz-Courrau *et al.* (2012)
	PBLCH (BCS)	1.03^{W} (2011) M	Barrera-García *et al.* (2012)
Isurus oxyrinchus	PDBC (BCS)	1.05^{D} (2001-2005) M	Maz-Courrau *et al.* (2012)
	IMGD (BCS)	0.39w (2008) M	Vélez-Alavez *et al.* (2013)
Squatina californica	PPG (BCS)	0.24^{W} (2012-2013) M	Escobar-Sánchez *et al.* (2016)
Rhizoprionodon terraenove	PVCZ (VER)	0.76^{W} (1994-1995) M	Núñez-Noriega (2005)
Rhizoprionodon longurio	GCFR (N/A)	1.3^{W} (2003-2004) M	García-Hernández *et al.* (2007)
	BKN (SON)	0.91^{W} (2009-2010) M	Hurtado-Banda *et al.* (2012)
Nasolamia velox	GCFR (N/A)	1.02^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Triakis semifasciata	GCFR (N/A)	0.08^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Dasyatis dipterura	BCHY (SON)	0.946^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
	PRY (NAY)	2.84^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
Dasyatis longus	GCFR (N/A)	0.71^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Dasyatis brevis	GCFR (N/A)	0.45^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Dasyatis longa	PRY (NAY)	4.465^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
Rhinobatos productus	GCFR (N/A)	0.31^{W} (2003-2004) M	García-Hernández *et al.* (2007)
	PPG (BCS)	0.89^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
Rhinoptera steindachnerii	GCFR (N/A)	0.43^{W} (2003-2004) M	García-Hernández *et al.* (2007)
	DTLL (SIN)	0.37^{W} (2012) M	Escobar-Sánchez *et al.* (2014)
Narcine entemedor	PPG (BCS)	0.101^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
	PCHL (BCS)	1.053^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
	GCFR (N/A)	0.12^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Zapteryx exasperata	GCFR (N/A)	0.11^{W} (2003-2004) M	García-Hernández *et al.* (2007)
	PCHL (BCS)	0.898^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
Gymnura marmorata	GCFR (N/A)	0.14^{W} (2003-2004) M	García-Hernández *et al.* (2007)
	DTLL (SIN)	0.706^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
Myliobatis californica	GCFR (N/A)	0.05^{W} (2003-2004) M	García-Hernández *et al.* (2007)
Mustelus albipinnis	BKN (SON)	0.33^{W} (2009-2010) M	Hurtado-Banda *et al.* (2012)
Urolophus halleri	PPG (BCS)	1.37^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
	PRY (NAY)	2.33^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
Urolophus spp.	PRY (NAY)	3.713^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
Mobula thurstoni	DTLL (SIN)	0.09^{W} (2012) M	Escobar-Sánchez *et al.* (2014)
	SBRB (SON)	0.20^{W} (2012) M	Escobar-Sánchez *et al.* (2014)
Mobula munkiana	SBRB (SON)	0.19^{W} (2012) M	Escobar-Sánchez *et al.* (2014)
Mobula japanica	SBRB (SON)	0.14^{W} (2012) M	Escobar-Sánchez *et al.* (2014)
	DTLL (SIN)	0.01^{W} (2012) M	Escobar-Sánchez *et al.* (2014)
Urotrygon chilensis	PCHL (BCS)	0.52^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
Raja velezi	PPG (BCS)	1.127^{D} (2012) M	Ruelas-Inzunza *et al.* (2013)
Turtles			
Chelonia mydas	PDBC (BCS)	0.021 (N/E) M	Kampalath *et al.* (2006)
	LTM (CAM)	0.37 (2009) H	Benítez *et al.* (2012)
Caretta caretta	PDBC (BCS)	0.026 (N/E) M	Kampalath *et al.* (2006)
Lepidochelys olivacea	PDBC (BCS)	0.05 (N/E) M	Kampalath *et al.* (2006)
	PEPA (OAX)	0.0006 (2005-2006) S	Páez-Osuna *et al.* (2011)
	PEPA (OAX)	0.001 (2005-2006) H	Páez-Osuna *et al.* (2011)
Eretmochelys imbrincata	LTM (CAM)	0.37 (2009) H	Benítez *et al.* (2012)

continuation

Species	Place	Hg	Reference
Birds			
Phalacrocorax	CSNL (SIN)	1.49^{D} (2002) M	Ruelas-Inzunza *et al.* (2009b)
Brasilianus	UR (SIN)	1.01^{D} (2006) M	Jara-Marini *et al.* (2012)
Pelecanus occidentalis	CSNL (SIN)	2.85^{D} (2002) M	Ruelas-Inzunza *et al.* (2009b)
Anas clypeata	CSNL (SIN)	0.47^{D} (2002) M	Ruelas-Inzunza *et al.* (2009b)
Anas discors	CSNL (SIN)	0.77^{D} (2002) M	Ruelas-Inzunza *et al.* (2009b)
Aythya affinis	CSNL (SIN)	1.06^{D} (2002) M	Ruelas-Inzunza *et al.* (2009b)
Sula leucogaster	SMR (SIN)	1.12 (2010-2012) S	Lerma *et al.* (2016)
Crocodiles			
Crocodylus moreletti	RCHPT (CAM)	3.1 (2012) B	Trillanes *et al.* (2014)
	LPNCLT (ROO)	4.3 (2012) B	Trillanes *et al.* (2014)
	RHND (ROO)	20 (2012-2013) S	Buenfil-Rojas *et al.* (2015)
	RHND (ROO)	0.33 (2012-2013) B	Buenfil-Rojas *et al.* (2015)
Mammals			
Tursiops truncatus	LTM (CAMP)	ND (2011) B	Benítez *et al.* (2012)
Stenella longirostris	GCFR (N/A)	1.2 (1993) M	Ruelas-Inzunza *et al.* (2003)
Trichechus manatus	LTM (CAMP)	ND (2011) B	Benítez *et al.* (2012)
Eschrichtius robustus	GCFR (N/A)	0.14 (1999) M	Ruelas-Inzunza *et al.* (2003)
Baleanoptera musculus	GCFR (N/A)	0.06 (2012) B	Ruelas-Inzunza *et al.* (2014)

This genus of fish is one of the most used around the world in aquatic monitoring studies (Waltham *et al.*, 2013), since they are directly associated with sediments, allowing to evaluate the transfer of pollutants from this environmental matrix to the first levels of the trophic chain. Other commercially important fish that have been used in Mexico are snooks, mojarras, and snappers. Other organisms belonging to different trophic levels have also been used for biomonitoring purposes, including crustaceans, sharks, rays, macroalgae (which also have a high commercial value), sea turtles, birds, crocodiles, and mammals.

Mercury in biota

Table 1 shows the average concentrations of Hg found in various tissues of aquatic organisms in Mexico. The average values of Hg in macrophytes were 0.02-0.09 µg g^{-1} dw (dry weight) for *Gracilaria* sp., and 0.05 µg g^{-1} dw for *Ulva lactuca*, both cases in the Gulf area of California. No references for the presence of Hg in macrophytes were found in other areas of the country. Similar concentrations have been reported in other areas around the world. Qiu & Wang (2016) reported concentrations of 0.04 µg g^{-1} dw in *U. fasciata* in Daya Bay in southern China. Pereira *et al.* (2008) reported average Hg values of 0.04-0.34 µg g^{-1} dw in *Gracilaria* sp. in Ria de Aveiro, Portugal. Akcali & Kucuksezgin (2011) reported a much higher average Hg (53-72 µg g^{-1} dw) in *Ulva* sp. found in Turkey's Aegean coast.

Regarding mollusks, its use has increased in the Gulf of California area. We found 15 studies focused on important ecosystems on the Gulf of California's coastal area during 1997-2011 (sampling year) that used the genus *Crassostrea* species. These studies reported average values of Hg of 0.05-0.9 µg g^{-1} dw, EL Colorado Lagoon being the site with the highest concentrations (0.54 µg g^{-1} dw in 2008 and 0.93 µg g^{-1} dw in an undetermined date), and the Urías Lagoon with the lowest concentrations (0.05 µg g^{-1} dw in 2006 and 0.17 µg g^{-1} dw in 2008). It is known that there are difficulties when comparing the levels of metals in mollusks of different species or different geographical areas since the concentrations can vary depending on the metabolism, age, gonadal stage, habitat (freshwater, marine; lagoons, estuaries, mangroves), sampling season, among others. Thus, the comparison of pollution levels between different mollusk species must be made with reservations (Ruelas-Inzunza *et al.*, 2014).

There is little information on the content of Hg in *Crassostrea* in other areas of the country. Benítez *et al.* (2012) reported concentrations <0.001 µg g^{-1} dw in *Crassostrea virginica* collected in the Terminos Lagoon, in Campeche. Aguilar *et al*. (2012) reported concentrations of 0.5, 0.7, and 1.1 µg g^{-1} dw in *C. virginica* collected in the Palizada, Candelaria, and Chumpán rivers, in the state of Campeche, respectively. No other studies with *Crassostrea* were found in other areas of the country during the review period. However, Hicks *et al.* (1976), in Villanueva & Botello (1992), reported concentrations of 0.05 µg g^{-1} dw in *C. virginica* collected in the Terminos Lagoon. *Chione* bivalves were also used to assess the concentration of Hg in coastal areas of the Gulf of California, Kuu Kaak Bay, in the state of Sonora, was where the lowest concen-

Table 2. Average concentration of Cd and Pb (µg g^{-1} dw, D or ww, W) in different tissues of organisms from various aquatic ecosystems of Mexico. EU: Estero Urías; AEP: Altata-Ensenada del Pabellón; BTS: Bahía Todos Santos; BGY: Bahía Guaymas; EBNT: Estero Banderitas; CSNR: Costa de Sonora; CSNL: Costa de Sinaloa; GNYR: Granjas Nayarit; BBP: Bahía de Bacochibampo; INM: Laguna San Ignacio-Navachiste-Macapule; BCT: Bahía de Cueta; PAGC: Parte alta del Golfo de California; PCHG: Pichiligue; BBCN: Bocana; BLRT: Bahía de Loreto; GYEMP: Guaymas-Empalme LTM: Laguna de Términos; LTB: Laguna El Tobari; LSLQ: San Luquitas; SMR: Santa María- La Reforma; LCL: El Colorado; ERY: Estero El Rey; LCHP: Lago de Chapala; GSC: Golfo de Santa Clara; LHCM: Laguna Huizache-Caimanero; LGM: Laguna Guasimo; LSI: Laguna de San Ignacio; BKK: Bahía de Kuu Kaak; LOL: Laguna Ojo de Liebre; BGMS: Bahía Las Guácimas; LAV: Laguna Alvarado; LYLH: Laguna Yalahau; BBP: Bacochibampo; BTBP: Bahía de Topolobampo; BAP: Laguna Agiabampo; BOH: Bahía de Ohuria; PPCD: Pescadero; BCHC: Bachoco; CSC: Ciénega Santa Clara; BMGD: Bahía Magdalena; LLRL: Los Laureles; CLSNR: Canal Sonora; PLM: Puerto López Mateos; DRC: Delta del Río Colorado; LBN: Laguna Barra de Navidad; SBRB: Santa Bárbara; RPL: Río Palizada; RCHP: Río Chumpán; BTPB: Bahía de Topolobampo; BYV: Laguna de Yavaros; BCMCH: Boca Camichín; BCHM: Bahía Chetumal; BPZ: Bahía La Paz; PLL: Presa Luis León; LSPT: Laguna de San Pedrito; CSDR: Cañón del sumidero; MTCL: Mercado de Tecuala; RCL: Río Colorado; PSLT: Presa el Salto; RCDLR: Río Candelaria; BCY: Bahía La Choya; BGSB: Guasabe; ESBL: Estero de San Blas; LCTC: Lago de Catemaco; ICND: Islas Coronado; BLB: Bahía de Lobos; RMYR: El Mayor; RUSMT: Río Usumacinta; TCPN: Teacapán; PVM: Presa Viejo Mandín; CCP: Cucapa; LSTN: Laguna Ostión; MTTN: Minatitlán; RSTG: Río Santiago; LMCN: Lago Mecoacán; TLCP: Tlacotalpan; URTCP: Urías-Teacapán; PVCZ: Puerto de Veracruz; LTJ: Laguna Tasajera; CSPT: Cospita; CBCF: Baja California; LTMH: Laguna de Tamiahua; PSCLL: Playa La Escobilla; PBLCH: Punta Belcher; NVT: Nuevo Vallarta; PBND: Punta Banda; LSRL: Laguna de Santa Rosalía; LVCH: Verde Camacho; LMXT: Laguna de Mexcaltitlán; PMZ: Puerto de Mazatlán; DTLL: Dautillos; CDOC: El Doctor; RNJ: Río Naranjos; PCHL: Puerto Chale; CARL: Curso Alto de Río Lerma; RCHPT: Río Champotón; CCMP: Costa de Campeche; LPNCLT: Los Petenes-Celestún; RSPSP: Río San Pedro y San Pablo RSPT: Río San Pedrito; RHND: Río Hondo; PAA: Presa Antonio Alzate; CFN: Infiernillo; RLM: Río Lerma; RPJ: Río Pantoja; LSA: Laguna de San Andrés; LTPL: Laguna Tres Palos; LMDG: Laguna Mandinga. SON: Sonora; SIN: Sinaloa; NAY: Nayarit; JAL: Jalisco; COL: Colima; MIC: Michoacán; GRO: Guerrero; OAX: Oaxaca; CHP: Chiapas; CAM: Campeche; ROO: Quintana Roo; YUC: Yucatán; TAB: Tabasco; VER: Veracruz; TAM: Tamaulipas; BCS: Baja California Sur; BCN: Baja California Norte; AGU: Aguascalientes; MEX: México; CMX: Ciudad de México. N/E: not specified; ND: not detect; -: not analized; D: dry weight; W: wet weight; M: muscle; ST: soft tissue; T: whole body; S: blood; B: biopsy; H: eggs.

Species	Place	Cd	Pb	References
Primary producers				
Plankton	PAA (MEX)	-	8^{W} (1998-1999)	Rodríguez *et al*. (2001)
Phytoplankton	AEP (SIN)	0.27^{D}(1998-1999)	23^{D} (1998-1999)	Ruelas-Inzunza & Páez-Osuna (2006)
Ulva lactuca	INM (SIN)	1.9^{D} (2002)	174.8^{D} (2002)	Orduña-Rojas & Longoria-Espinoza (2006)
	BGY (SON)	0.54^{D}(1998-1999)	0.35^{D} (1998-1999)	Ruelas-Inzunza & Páez-Osuna (2006)
	LCHT (SIN)	-	3^{D} (2002-2003)	Soto-Jiménez *et al.* (2008)
	UR (SIN)	-	3^{D} (2002-2003)	Soto-Jiménez *et al.* (2008)
Gracilaria textorii	BMGD (BCS)	3.65^{D}(2004-2005)	0.83^{D} (2004-2005)	Talavera-Sáenz *et al.* (2007)
	EBNT (BCS)	3.16^{D}(2004-2005)	0.9^{D} (2004-2005)	Riosmena-Rodríguez *et al.* (2010)
Gracilaria subsecundata	AEP (SIN)	0.18^{D} (1998-1999)	0.19^{D} (1998-1999)	Ruelas-Inzunza & Páez-Osuna (2006)
Gracilaria vermiculophylla	BMGD (BCS)	1.40^{D} (2004-2005)	0.84^{D} (2004-2005)	Talavera-Sáenz *et al.* (2007)
	EBNT (BCS)	1.36^{D} (2004-2005)	0.8^{D} (2004-2005)	Riosmena-Rodríguez *et al.* (2010)
	UR (SIN)	-	3.9^{D} (2002-2003)	Soto-Jiménez *et al.* (2008)
	LCHT (SIN)	-	5^{D} (2002-2003)	Soto-Jiménez *et al.* (2008)
Gracilaria sp.	AEP (SIN)	0.23^{D} (1998-1999)	4.9^{D} (1998-1999)	Ruelas-Inzunza & Páez-Osuna (2006)
	AEP (SIN)	0.23^{D} (1999-2000)	4.9^{D} (1999-2000)	Ruelas-Inzunza & Páez-Osuna 2008
Zostera marina	LSI (BCS)	6.2^{D} (2000)	8.8^{D} (2000)	Macías-Zamora *et al*. (2008)
	LOL (BCS)	1.6^{D} (2000)	14.9^{D} (2000)	Macías-Zamora *et al*. (2008)
	BMGD (BCS)	1.09^{D} (2004-2005)	1.23^{D} (2004-2005)	Talavera-Sáenz *et al.* (2007)
Ruppia maritima	EBNT (BCS)	4.5^{D} (2004-2005)	2.15^{D} (2004-2005)	Riosmena-Rodríguez *et al.* (2010)
	BMGD (BCS)	4.52^{D} (2004-2005)	2.12^{D} (2004-2005)	Talavera-Sáenz *et al.* (2007)
Caulerpa sertularioides	UR (SIN)	0.14^{D} (2006)	2.45^{D} (2006)	Jara-Marini *et al.* (2008)
Echhornia crassipes	RLM (MEX)	-	4.32^{D} (2006)	Tejeda *et al.* (2010)
Hydrocoyle ranunculoides	CARL (MEX)	-	5.27^{D} (2010)	Zarazúa *et al*. (2013)
Thalassia testudinum	LYLH (YUC)	0.72^{D} (2005-2006)	-	Avelar *et al.* (2013)
Polysiphonia	AEP (SIN)	0.87^{D} (1998-1999)	3.1D (1998-1999)	Ruelas-Inzunza & Páez-Osuna (2006)

continuation

Species	Place	Cd	Pb	References
Bivalves				
Crassostrea corteziensis	UR (SIN)	0.27^{D} (2006) ST	1.14^{D} (2006) ST	Jara-Marini *et al.* (2008)
	UR (SIN)	2.6^{D} (2003-2004) ST	11.5^{D} (2003-2004) ST	Frías-Espericueta *et al.* (2005)
	AEP (SIN)	6.4^{D} (2004-2005) ST	8.36^{D} (2004-2006)	Frías-Espericueta *et al.* (2008)
	UR (SIN)	-	4.9^{D} (2002-2003) M	Soto-Jiménez *et al.* (2008)
	AEP (SIN)	6.47^{D} (2008) ST	2.11^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	BBP (SON)	3.2^{W} (2004-2005) ST	0.5^{W} (2004-2005) ST	García-Rico *et al.* (2010)
	LTB (SON)	0.42^{D} (2009) ST	3.18^{D} (2009) ST	Jara-Marini *et al.* (2013)
	LCL (SIN)	7.65^{D} (2008) ST	0.74^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	INM (SIN)	-	3.72^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	SMR (SIN)	9.02^{D} (2008) ST	1.64^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	BCT (SIN)	-	7.11^{D} (1996) S	Páez-Osuna *et al.* (2002)
	BCT (SIN)	4.27^{D} (2008) ST	0.96^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	AEP (SIN)	7.2^{D} (1999-2000) ST	3.4^{D} (1999-2000) ST	Ruelas-Inzunza & Páez-Osuna 2008
	UR (SIN)	1.45^{D} (2008) ST	1.36^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	SMOT (SIN)	5.56^{D} (2008) ST	0.3^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	BYV (SON)	-	2.50^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	BAP (SON)	-	6.82^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	BOH (SIN)	-	2.50^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	SMR (SIN)	-	5.32^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	AEP (SIN)	-	7.62^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	PMZ (SIN)	-	7.42^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	LHCM (SIN)	-	5.22^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	TPAB (NAY)	-	3.63^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	LMXT (NAY)	-	5.10^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	LSCL (NAY)	-	2.33^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	NVT (JAL)	-	4.72^{D} (1996) ST	Páez-Osuna *et al.* (2002)
	LBN (JAL)	-	4.83D (1996) ST	Páez-Osuna *et al.* (2002)
	INM (SIN)	6.4^{D} (2006-2007) ST	4.8^{D} (2006-2007) ST	Frías-Espericueta et *al.* (2009)
	SMR (SIN)	5.8^{D} (2006-2007) ST	5.3^{D} (2006-2007) ST	Frías-Espericueta *et al.* (2009)
	AEP (SIN)	5.01^{D} (2006-2007)	5.7^{D} (2006-2007) ST	Frías-Espericueta *et al.* (2009)
	BCT (SIN)	6.9^{D} (2006-2007) ST	8.1^{D} (2006-2007) ST	Frías-Espericueta *et al.* (2009)
	UR (SIN)	1.5^{D} (2006-2007) ST	6.5^{D} (2006-2007) ST	Frías-Espericueta *et al.* (2009)
	LHCM (SIN)	5.9^{D} (2006-2007) ST	4.2^{D} (2006-2007) ST	Frías-Espericueta *et al.* (2009)
	INM (SIN)	8.39^{D} (2008) ST	0.65^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	ERY (SIN)	0.64^{D} (2008) ST	1.51^{D} (2008) ST	Páez-Osuna & Osuna-Martínez (2015)
	TPBA (SIN)	3.6^{D} (2006-2007) ST	9.4^{D} (2006-2007) ST	Frías-Espericueta *et al.* (2009)
	BCT (SIN)	5^{D} (N/E) ST	0.46^{D} (N/E) ST	Osuna-Martínez *et al.* (2011)
Crassostrea gigas	LCL (SIN)	5.1^{D} (N/E) ST	1.85^{D} (N/E) ST	Osuna-Martínez *et al.* (2011)
	CSNR (SON)	0.76^{W} (1997) ST	0.5^{W}(1997) ST	García-Rico & Ramos-Ruiz (2001)
	LTB (SON)	0.38^{D} (2009) ST	2.35^{D} (2009) ST	Jara-Marini *et al.* (2013)
	AEP (SIN)	12.1^{D} (N/E) ST	1.42^{D} (N/E) ST	Osuna-Martínez *et al.* (2011)
	BCT (SIN)	8.6^{D} (N/E) ST	1.11^{D} (N/E) ST	Osuna-Martínez *et al.* (2011)
	SMR (SIN)	11.55^{D} (N/E) ST	0.92^{D} (N/E) ST	Osuna-Martínez et al. (2011)
	CSNR (SON)	5.5^{D} (N/E) ST	1.3^{D} (N/E) ST	Vázquez -Boucard *et al.* (2014)
	CSNL (SIN)	3.4^{D} (N/E) ST	2.2^{D} (N/E) ST	Vázquez -Boucard *et al.* (2014)
Crassostrea virginica	LSA (TAM)	2.27^{D} (2000) ST	0.802^{D} (2000) ST	Vázquez-Sauceda *et al.* (2005)
	LTM (CAM)	2.55^{D} (2002) ST	-	Gold-Bouchot *et al.* (2007)
	LMDG (VER)	2.2^{D} (2003-2004) ST	5.84^{D} (2003-2004) ST	Guzmán-García *et al.* (2009)
	LTMH (VER)	11.8^{D} (2004) ST	0.5^{D} (2004) ST	Lango-Reynoso *et al.* (2010)
	LSA (TAM)	2.27^{D} (2000) ST	0.802^{D} (2000) ST	Vázquez-Sauceda *et al.* (2011)
	LTM (CAM)	0.0295^{W} (N/E) ST	0.1445^{W} (N/E) ST	Aguilar-Ucán *et al.* (2014)
	LMCN (TAB)	42.23^{D} (2007) ST	189.78^{D} (2007) ST	Castañeda-Chávez *et al.* (2014)
	RPJ (TAB)	2.33^{D} (2011) ST	0.8^{D} (2011) ST	Castañeda-Chávez *et al.* (2014)
	RPL (CAM)	3^{D} (N/E) ST	-	Aguilar *et al.* (2012)
	RCHP (CAM)	3.2^{D} N/E) ST	-	Aguilar *et al.* (2012)
Crassostrea iridescens	PMZ (SIN)	2.3^{D} (1995-1996) ST	2.3^{D} (1995-1996) ST	Soto-Jiménez *et al.* (2001)
Megapitaria squalida	BKK (SON)	0.4^{W} (2003) ST	0.001^{W} (2003) ST	García-Hernández *et al.* (2005)
	BPZ (BCS)	5.57^{D} (2003) ST	2.5^{D} (2003) ST	Méndez *et al.* (2006)

continuation

Species	Place	Cd	Pb	References
	AEP (SIN)	3.2^{D} (2004-2005) ST	7.7^{D} (2004-2005) ST	Frías-Espericueta *et al.* (2008)
	BPZ (BCS)	7^{D} (N/E) ST	4.02^{D} (N/E) ST	Cantu-Medellin *et al.* (2009)
	BLRT (BCS)	4.66^{D} (2004) ST	0.03^{D} (2004) ST	Cadena-Cárdenas *et al.* (2009)
	BPZ (BCS)	0.93^{W} (N/E) ST	-	Escobedo-Fregoso *et al.* (2010)
Mytilus edulis	LSLQ (BCS)	2.42^{D} (2004) ST	0.27^{D} (2004) ST	Cadena-Cárdenas *et al.* (2009)
	LSRL (BCS)	4.05^{D} (2004) ST	5.8^{D} (2004) ST	Cadena-Cárdenas *et al.* (2009)
Mytella strigata	AEP (SIN)	6.3^{D} (2004-2005) ST	5.22^{D} (2004-2005) ST	Frías-Espericueta *et al.* (2008)
	UR (SIN)	0.22^{D} (2006) ST	1.72^{D} (2006) ST	Jara-Marini *et al.* (2008)
	UR (SIN)	-	3.1^{D} (2002-2003) M	Soto-Jiménez *et al.* (2008)
	INM (SIN)	1.91^{D} (1996) ST	13.18^{D} (1996) ST	Osuna-López *et al.* (2009)
	AEP (SIN)	1.75^{D} (1996) ST	17.42^{D} (1996) ST	Osuna-López *et al.* (2009)
	UR (SIN)	0.73^{D} (1996) ST	11.11^{D} (1996) ST	Osuna-López *et al.* (2009)
	BCT (BCT)	0.82^{D} (1996) ST	9.39^{D} (1996) ST	Osuna-López *et al.* (2009)
	LMXT (NAY)	0.75^{D} (1996) ST	11.21D (1996) ST	Osuna-López *et al.* (2009)
	LSCL (NAY)	0.72^{D} (1996) ST	8.58^{D} (1996) ST	Osuna-López *et al.* (2009)
Mytilus californianus	ICND (BCN)	9.86^{D} (1989-1990) M	-	Segovia-Zavala *et al.* (2004)
	PBND (BCN)	17^{D} (1989-1990) ST	-	Segovia-Zavala *et al.* (2004)
Chione californiensis	BKK (SON)	0.4^{W} (2003) ST	0.001^{W} (2003) ST	García - Hernández *et al.* (2005)
	GSC (SON)	0.42^{D} (2006) ST	9.2^{D} (2006) ST	Cadena-Cárdenas *et al.* (2009)
Chione fluctifraga	LTB (SON)	0.54D (2009) ST	2.17^{D} (2009) ST	Jara-Marini *et al.* (2013)
Chione gnidia	LTB (SON)	0.52^{D} (2009) ST	3.27^{D} (2009) ST	Jara-Marini *et al.* (2013)
	BGY (SON)	2.29^{D} (N/E) ST	0.85^{D} (N/E) ST	Méndez *et al.* (2002)
Chione sp.	PAGC (SON)	0.8^{D} (1998-2000) ST	1.6^{D} (1998-2000) ST	García - Hernández *et al.* (2001)
Pinna rugosa	BKK (SON)	2.44^{W} (2003) ST	0.001^{W} (2003) ST	García - Hernández *et al.* (2005)
Anadara multicostata	BKK (SON)	8.16^{W}(2003) ST	0.001^{W} (2003) ST	García - Hernández *et al.* (2005)
Corbicula sp.	CLSNR (SON)	0.4^{D} (1998-2000) ST	ND (1998-2000) ST	García - Hernández *et al.* (2001)
	RCL (SON)	0.4^{D} (1998-2000) ST	2^{D} (1998-2000) ST	García - Hernández *et al.* (2001)
Hexaplex erythrostomus	BKK (SON)	5.15^{W} (2003) ST	0.48^{W} (2003) ST	García-Hernández *et al.* (2005)
Corbicula fluminea	ECZ (VER)	-	0.1^{D} (2005) ST	Ruelas-Inzunza *et al.* (2007)
Mytilopsis sallei	BCHM (ROO)	0.86^{D} (2002) ST	1.24^{D} (2002) ST	Díaz López *et al.* (2006)
Argopecten ventricosus	PCHG (BCS)	1.7^{D} (1998-2000) ST	3.34^{D} (1998-2000) ST	Sobrino-Figueroa *et al.* (2007)
Fistulobalanus dentivarians	LTB (SON)	0.72^{D} (2009) ST	2.97^{D} (2009) ST	Jara-Marini *et al.* (2013)
Lampsilis tampicoensis	LTJ (TAB)	0.18^{W} (2008) ST	4.96^{W} (2008) ST	Pérez-Cruz *et al.* (2013)
	RSPT (TAB)	0.25^{W} (2008) ST	N/D (2008) STT	Pérez-Cruz *et al.* (2013)
Potamilus alata	LGM (TAB)	0.33^{W} (2008) ST	N/D (2008) ST	Pérez-Cruz *et al.* (2013)
Polymesoda caroliniana	ECZ (VER)	-	1.15^{D} (2005) ST	Ruelas-Inzunza *et al.* (2007)
	ECZ (VER)	-	0.6^{D} (2006) ST	Ruelas-Inzunza *et al.* (2007)
Polymesoda arctata	RSPSP (TAB)	0.5^{W} (2008) ST	2.06^{W} (2008) ST	Pérez-Cruz *et al.* (2013)
Lampsilis tampicoensis	RNJ (TAB)	0.16^{W} (2008) ST	2.58^{W} (2008) ST	Pérez-Cruz *et al.* (2013)
	RPJ (TAB)	0.44W (2008) ST	0.76^{W} (2008) ST	Pérez-Cruz *et al.* (2013)
Crustaceans				
Penaeus vannamei	AEP (SIN)	3.48^{D} (1998-1999) M	0.74^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2004a)
	AEP (SIN)	3.1^{D} (1999-2000) M	0.5^{D} (1999-2000) M	Ruelas-Inzunza & Páez (2008)
	AEP (SIN)	0.36^{D} (2006) M	4.89^{D} (2006) M	Frías-Espericueta *et al.* (2009)
	LVCH (SIN)	0.66^{D} (2003) M	2.3^{D} (2003) M	Frías-Espericueta *et al.* (2005)
	LLRL (NAY)	0.59^{D} (2003) M	1.4^{D} (2003) M	Frías-Espericueta *et al.* (2005)
	PPCD (NAY)	0.65^{D} (2003) M	2^{D} (2003) M	Frías-Espericueta *et al.* (2005)
	LMXT (NAY)	0.62^{D} (2003) M	1.5^{D} (2003) M	Frías-Espericueta *et al.* (2005)
	LHCM (SIN)	0.7^{D} (2003) M	2.4^{D} (2003) M	Frías-Espericueta *et al.* (2005)
	LHCM (SIN)	0.39^{D} (2006) M	4.21^{D} (2006) M	Frías-Espericueta *et al.* (2009)
	SMR (SIN)	0.44^{D} (2006) M	5.18^{D} (2006) M	Frías-Espericueta *et al.* (2009)
	AEP (SIN)	0.4^{D} (2006) M	5.52^{D} (2006) M	Frías-Espericueta *et al.* (2009)
	INM (SIN)	0.40^{D} (2006) M	5.62^{D} (2006) M	Frías-Espericueta *et al.* (2009)
	TPAB (SIN)	0.7^{D} (1998-1999) M	6.93^{D} (1998-1999) M	Frías-Espericueta *et al.* (2009)
	AEP (SIN)	0.45^{D} (1998-1999) M	0.40^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2004a)
	AEP (SIN)	0.89^{D} (2003) M	4.5^{D} (2003) M	Frías-Espericueta *et al.* (2005)
	AEP (SIN)	0.5^{D} (1999-2000) M	0.9^{D} (1999-2000) M	Ruelas-Inzunza & Páez (2008)
Penaeus setiferus	CCMP (CAM)	3.64^{D} (1997) M	4.22^{D} (1997) M	Vázquez *et al.* (2001)
	LAV (VER)	0.05^{D} (200) M	0.5^{D} (200) M	Lango-Reynoso *et al.* (2013)
Litopenaeus setiferus	LTM (CAM)	ND (N/E)	ND (N/E)	Aguilar-Ucán *et al.* (2014)

continuation

Species	Place	Cd	Pb	References
Farfantepenaeus californiensis	AEP (SIN)	4.94^{D} (1998-1999) M	0.54^{D} (1998-1999) M	Ruelas-Inzunza & Páez-Ozuna (2004a)
Farfantepenaeus aztecus	LTMH (VER)	0.032^{D} (2004) M	0.12^{D} (2004) M	Palomarez-García *et al.* (2009)
	LTMH (VER)	0.04^{D} (200) M	0.05^{D} (200) M	Lango-Reynoso *et al.* (2013)
Paleomonetes paludosus	BBCN (SON)	0.4^{D} (1998-2000) T	ND (1998-2000) T	García - Hernández *et al.* (2001)
Callinectes similis	LSPT (TAB)	0.12^{D} (2009) M	-	Mendoza-Carranza *et al.* (2016)
Callinectes arcuatus	UR (SIN)	-	23^{D} (2002-2003) M	Soto-Jiménez *et al.* (2008)
Callinectes sapidus	LTM (CAM)	0.05^{W} (N/E)	0.34^{W} (N/E)	Aguilar-Ucán *et al.* (2014)
Macrobrachium acanthurus	LSPT (TAB)	0.72^{D} (2009) M	-	Mendoza-Carranza *et al.* (2016)
Panulirus gracilis	PMZ (SIN)	0.4^{D} (1995-1996) M	1.55^{D} (1995-1996) M	Morales-Hernández *et al.* (2004)
Procambarus clarkii	CSC (SON)	0.2^{D} (1998-2000) T	1.8^{D} (1998-2000) T	Gracia-Hernández *et al.* (2001)
Fish				
Pterygoplichthys pardalis	RUSMT (TAB)	0.31D (N/E) ^{M}	-	Maldonado-Enríquez *et al.* (2015)
Cyprinus carpio	CSC (SON)	ND (1998-2000) T	1.1^{D} (1998-2000) T	García-Hernández *et al.* (2001)
Achirus mazatlanus	LBN (JAL)	0.08^{D} (2014) M	0.7^{D} (2014) M	Aguilar-Betancourt *et al.* (2016)
Sciades guatemalensis	LBN (JAL)	0.08^{D} (2014) M	0.7^{D} (2014) M	Aguilar-Betancourt *et al.* (2016)
Syacium gunteri	CCMP (CAM)	0.001^{D} (1997) M	1.66^{D} (1997) M	Vázquez *et al.* (2001)
Ariopsis guatemalensis	LTPL (GRO)	2.25^{D} (2011) M	5.27^{D} (2011) M	Rodríguez-Amador *et al.* (2014)
	LTPL (GRO)	1.28^{D} (2012) M	6.58^{D} (2012) M	Rodríguez-Amador *et al.* (2014)
Ariopsis assimilis	BCHM (ROO)	ND (1999) M	0.90D (1999) M	García-Ríos & Gold-Bouchot (2002)
	BCHM (ROO)	ND (2000) M	ND (2000) M	García-Ríos & Gold-Bouchot (2002)
Ictalurus punctatus	ECZ (VER)	-	0.001^{D} (2006) M	Ruelas-Inzunza *et al.* (2007)
Gerres cinereus	LSTN (VER)	-	0.2^{D} (2005) M	Ruelas-Inzunza *et al.* (2007)
	ECZ (VER)	-	1.88^{D} (2005) M	Ruelas-Inzunza *et al.* (2007)
Dormitators latifrons	LTPL (GRO)	9.6^{D} (2011) M	-	Rodríguez *et al.* (2012)
Oreochromis aureus	PSLT (SIN)	0.28^{D} (2004-2005) M	2.12^{D} (2004-2005) M	Frías-Espericueta *et al.* (2010)
Oreochromis sp.	ECZ (VER)	-	2.24^{D} (2005) M	Ruelas-Inzunza *et al.* (2007)
Diapterus sp.	PMZ (SIN)	0.32^{D} (2004-2005) M	2.8^{D} (2004-2005) M	Frías-Espericueta *et al.* (2010)
Gambusia affinis	RLC (SON)	ND (1998-2000) T	1.4^{D} (1998-2000) T	García-Hernández *et al.* (2001)
	CSC (SON)	ND (1998-2000) T	ND (1998-2000) T	García-Hernández *et al.* (2001)
	CDOC (SON)	0.2^{D} (1998-2000) T	0.3^{D} (1998-2000) T	García-Hernández *et al.* (2001)
	RHD (SON)	ND (1998-2000) T	0.90^{D} (1998-2000) T	García-Hernández *et al.* (2001)
Poecilia lapitina	CSC (SON)	0.1^{D} (1998-2000) T	1.3^{D} (1998-2000) T	García-Hernández *et al.* (2001)
Mugil cephalus	CCP (SON)	ND (1998-2000) T	1.9^{D} (1998-2000) T	García-Hernández *et al.* (2001)
	AEP (SIN)	0.3^{D} (1999-2000) M	1^{D} (1999-2000) M	Ruelas-Inzunza & Páez (2008)
	UR (SIN)	-	3.3^{D} (2002-2003) M	Soto-Jiménez *et al.* (2008)
	PMZ (SIN)	0.31^{D} (2004-2005) M	2.62^{D} (2004-2005) M	Frías-Espericueta *et al.* (2010)
	INM (SIN)	0.23^{D} (2006) M	1.95^{D} (2006) M	Frías-Espericueta *et al.* (2011)
	SMLR (SIN)	0.13^{D} (20069 M	1.66^{D} (2006) M	Frías-Espericueta *et al.* (2011)
	AEP (SIN)	0.14^{D} (2006) M	2.1^{D} (2006) M	Frías-Espericueta *et al.* (2011)
	BCT (SIN)	0.17^{D} (2006) M	1.53^{D} (2006) M	Frías-Espericueta *et al.* (2011)
	UR (SIN)	0.16^{D} (2006) M	1.24^{D} (2006) M	Frías-Espericueta *et al.* (2011)
	LHCM (SIN)	0.16^{D} (2006) M	1.38^{D} (2006) M	Frías-Espericueta *et al.* (2011)
	TPAB (SIN)	1.7^{D} (2006) M	1.58^{D} (2006) M	Frías-Espericueta *et al.* (2011)
Mugil curema	LBN (JAL)	0.08^{D} (2014) M	0.7^{D} (2014) M	Aguilar-Betancourt *et al.* (2016)
	ECZ (VER)	-	2.1^{D} (2006) M	Ruelas-Inzunza *et al.* (2007)
Centropomus viridis	LSTN (VER)	-	1.8^{D} (2005) M	Ruelas-Inzunza *et al.* (2007)
	ECZ (VER)	-	2.5^{D} (2005) M	Ruelas-Inzunza *et al.* (2007)
	ECZ (VER)	-	0.001^{D} (2006) M	Ruelas-Inzunza *et al.* (2007)
Lutjanus analis	CCMP (CAM)	0.001^{D} (1997) M	4.68^{D} (1997) M	Vázquez *et al.* (2001)
Lutjanus colorado	AEP (SIN)	0.2^{D} (1999-2000) M	1.3^{D} (1999-2000) M	Ruelas-Inzunza & Páez (2008)
Cynoscion xanthulus	AEP (SIN)	0.9^{D} (1999-2000) M	2.6^{D} (1999-2000) M	Ruelas-Inzunza & Páez (2008)
Thrichurus nitens	ECZ (VER)	-	3.7^{D} (2005) M	Ruelas-Inzunza *et al.* (2007)
Scomberomorus sierra	PMZ (SIN)	0.27^{D} (2004-2005) M	2.33^{D} (2004-2005) M	Frías-Espericueta *et al.* (2010)
Paraneetroplus synspilus	LSPT (TAB)	0.14^{D} (2009) M	-	Mendoza-Carranza *et al.* (2016)
Paraneetroplus bifasciatus	LSPT (TAB)	0.41^{D} (2009) M	-	Mendoza-Carranza *et al.* (2016)
Amphilophus robertsoni	LSPT (TAB)	0.26^{D} (2009) M	0.28^{D} (2009) M	Mendoza-Carranza *et al.* (2016)
Rocio octofasciata	LSPT (TAB)	0.55^{D} (2009) M	-	Mendoza-Carranza *et al.* (2016)
Cichlasoma salvini	LSPT (TAB)	0.28^{D} (2009) M	0.68^{D} (2009) M	Mendoza-Carranza *et al.* (2016)
Sharks and rays				
Carcharhinus limbatus	PVCZ (VER)	0.35^{W} (1994-1995) M	2.51^{W} (1994-1995) M	Núñez-Noriega (2005)
Carcharhinus falciformis	BTS (SON)	0.37^{W} (2014) M	-	Terrazas-López *et al.* (2016)

continuation

Species	Place	Cd	Pb	References
Prionace glauca	PBLCH (BCS)	0.2^{W} (2011) M	0.07^{W} (2011) M	Barrera-García *et al.* (2012)
Isurus oxyrinchus	IMGD (BCS)	0.0001^{D} (2008) M	0.16^{D} (2008) M	Vélez-Alvares *et al.* (2013)
Rhizoprionodon terraenovae	PVCZ (VER)	0.34^{W} (1994-1995) M	3.31^{W} (1994-1995) M	Núñez-Noriega (2005)
Turtle**s**				
Chelonia mydas	PDBC (BCS)	0.06^{W} (2005-2007) S	-	Labrada-Martagón *et al.* (2011)
	CBCF (BCS)	0.01^{D} (N/E) M	0.01^{D} (N/E) M	Gardner *et al.* (2006)
	BMGD (BCS)	0.03^{W} (2005-2007) S	-	Labrada-Martagón *et al.* (2011)
	CFN (SON)	0.99^{D} (2008) S	-	Ley-Quiñonez *et al.* (2013)
Caretta caretta	CBCF (BS)	0.10^{D} (N/E) M	0.01^{D} (N/E) M	Gardner *et al.* (2006)
	PLM (BCS)	1.8^{W} (N/E) S	-	Ley-Quiñonez *et al.* (2011)
Lepidochelys olivacea	BCT (SON)	2.6^{D} (2005) M	8.9^{D} (2005) M	Frías-Espericueta *et al.* (2006)
	CBCF (BCS)	0.48^{D} (N/E) M	ND (N/E) M	Gardner *et al.* (2006)
	PSCLL (OAX)	0.24^{D} (2005-2006) H	-	Páez-Osuna *et al.* (2010a)
	PSCLL (OAX)	0.45^{D} (2005-2006) S	-	Páez-Osuna *et al.* (2010a)
	PSCLL (OAX)	-	1.08^{D} (2005-2006) E	Páez-Osuna *et al.* (2010b)
	PSCLL (OAX)	-	0.95^{D} (2005-2006) S	Páez-Osuna *et al.* (2010b)
	PSCLL (OAX)	1.16^{W} (2012) S	0.02^{W} (2012) S	Cortez-Gómez *et al.* (2014)
	BGSB (SIN)	1.33^{W} (2011) S	ND	Zavala-Norzagaray *et al.* (2014)
Eretmochelys imbrincata	CBCF (BCS)	1.02^{D} (N/E) M	0.38^{D} (N/E) M	Gardner *et al.* (2006)
Birds				
Phalacrocorax brasilianus	AEP (SIN)	1.2^{D} (1999-2000) M	1.7^{D} (1999-2000) M	Ruelas-Inzunza & Páez (2008)
Pelecanus occidentalis	AEP (SIN)	0.7^{D} (2000) M	4.2^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
	CBCF (BCS)	0.20^{W} (2012-2013) H	-	Ceyca *et al.* (2016)
	AEP (SIN)	0.7^{D} (1999-2000) M	4.2^{D} (1999-2000) M	Ruelas-Inzunza & Páez (2008)
Phalacrocorax olivaceus	AEP (SIN)	1.2^{D} (2000) M	1.7^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
Fulica americana	AEP (SIN)	1.4^{D} (2000) M	4.1^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
Recurvirostra americana	AEP (SIN)	1.2^{D} (2000) M	4.8^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
Dendrocygna autumnalis	AEP (SIN)	1.3^{D} (2000) M	1.8^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
Anas cyanoptera	AEP (SIN)	1.3^{D} (2000) M	1.4^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
Sula nebouxii	CBCF (BCS)	0.26^{W} (2012-2013) H	-	Ceyca *et al.* (2016)
Sula leucogaster	CBCF (BCS)	0.32^{W} (2012-2013) H	-	Ceyca *et al.* (2016)
Phalacrocorax auritus	CBCF (BCS)	0.33^{W} (2012-2013) H	-	Ceyca *et al.* (2016)
Aythia affinis	AEP (SIN)	1.2^{D} (2000) M	-	Ruelas-Inzunza & Páez-Osuna (2004b)
Dendrocygna bicolor	AEP (SIN)	0.2^{D} (2000) M	2.8^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
Plagadis chihi	AEP (SIN)	1.3^{D} (2000) M	2.5^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
Charadrius vociferus	AEP (SIN)	1.6^{D} (2000) M	5.7^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
Casmerodius albus	AEP (SIN)	1.4^{D} (2000) M	0.9^{D} (2000) M	Ruelas-Inzunza & Páez-Osuna (2004b)
Zenaida macroura	DRC (SON)	0.44^{D} (N/E) H	0.20^{D} (N/E) H	García - Hernández *et al.* (2006)
Athene cunicularia	DRC (SON)	0.13^{D} (N/E) H	0.06^{D} (N/E) H	García - Hernández *et al.* (2007)
Cistothorus palustris	DRC (SON)	0.78^{D} (N/E) H	0.07^{D} (N/E) H	García - Hernández *et al.* (2008)
Sula leucogaster	SMR (SIN)	0.05^{D} (2010-2012) S	0.3^{D} (2010-2012) S	Lerma *et al.* (2016)
Crocodiles				
Crocodylus moreletti	RCHPT (CAM)	63.8^{D} (2011) B	-	Trillanes *et al.* (2014)
	LPNCLT (CAM)	64.8^{D} (2012) B	-	Trillanes *et al.* (2014)
	RHND (ROO)	16.04^{W} (2012) B	-	Buenfil-Rojas *et al.* (2015)
	RHND (ROO)	7.85^{W} (2012) S	-	Buenfil-Rojas *et al.* (2015)

tration was found (<0.001 µg g^{-1} dw; 2003), while the highest concentration was found in El Tobari lagoon (0.47 µg g^{-1} dw; 2009). Studies conducted on *Mytilopsis sallei* in Chetumal Bay, in Quintana Roo, reported values of 1.09 µg g^{-1} dw (2002), the highest reported values in Mexico during the review period. The only studies on Hg's concentration in bivalves of inland ecosystems were made with the genus *Corbicula*. One study was conducted in the Colorado River, in Sonora, and another in the Coatzacoalcos River, in Veracruz. The values reported were <0.04 and 0.09 µg g^{-1} dw, respectively. Hg's concentration values reported in Mexico's bivalves are similar to those reported by other authors in other parts of the world. For example, Astudillo *et al.* (2005), in Ruelas-Inzunza *et al.* (2013a), reported Hg values of 0.04 µg g^{-1} dw in *Crassostrea* sp. collected in the Gulf of Paria, Venezuela. Vaisman *et al.* (2005), in Ruelas-Inzunza *et al.* (2014), reported values of 0.04, 0.05, 0.08, and 0.15 µg g^{-1} dw in *Crassostrea rhizophorae* collected in the

Pacoti estuary, the Coco estuary, and Ceara estuary in Brazil, respectively. Zorita *et al.* (2007), in Ruelas-Inzunza *et al.* (2013a) reported values of 0.23 µg g^{-1} dw in *Mytilus galloprovincialis* collected in the northeast of the Mediterranean Sea. Concerning inland ecosystems, Neufeld (2010), and Faria *et al.* (2010), in Ruelas-Inzunza *et al.* (2014), reported Hg values of 1.89 and 2.3 µg g^{-1} dw in *Corbicula fluminea* collected in the Norte river in the USA and the Ebro river in Spain, respectively.

The content of Hg in crustaceans was evaluated mainly in marine organisms. Concerning inland ecosystems, the only cases found were those of *Procambarus clarkii* and *Palaemonetes paludosus*, collected in the state of Sonora, in the Colorado River, the Bocana Lagoon, and the Santa Clara swamp, with values of 0.40, 0.05, and 0.69 µg g^{-1} dw in the whole organism, respectively. These values are similar to others reported worldwide; for example, Li *et al.* (2015) reported Hg concentrations in *Macrobrachium nipponense* of 0.03, 0.04, and 0.03 µg g^{-1} dw in three reservoirs located in the central part of China. These values, however, are lower than concentrations found in other freshwater crustaceans collected in contaminated areas. For example, Higueras *et al.* (2006) reported values of Hg > 9.06 µg g^{-1} dw in the muscle of *P. clarkii* collected in an area impacted by mining activities in central Spain (Almaden), and Suárez-Serrano *et al.* (2010) reported Hg concentrations of 1.5 µg g^{-1} dw in *P. clarkii* collected in an area impacted by industrial waste in the Ebro river, Spain. Concerning marine crustaceans, Delgado-Álvarez *et al.* (2015a) monitored Hg's concentration in muscle tissue of *Penaeus vannamei* grown in aquaculture farms in the states of Sonora, Sinaloa, and Nayarit. They found concentration levels of 0.19, 0.31, and 0.45 µg g^{-1} dw respectively, similar to those found in *P. vannamei* by Ruelas-Inzunza *et al.* (2004) (0.2 µg g^{-1} dw) and Ruelas-Inzunza *et al.* (2011a) (0.42 µg g^{-1} dw) in the Altata-Ensenada del Pabellón Lagoon complex in the state of Sinaloa. Similar concentrations have been reported in other species of penaeids in this lagoon complex (Table 1), which suggests that these organisms have similar responses to Hg exposure. García-Hernández *et al.* (2015) conducted a monitoring study of Hg's concentration in crustaceans from thirteen coastal ecosystems in Sonora. Sinaloa's states focused on the *Callinectes bellicosus* crab, in which they found concentrations ranging from 0.07 up to 1.8 µg g^{-1} dw in muscle tissue. The highest concentrations were found in crabs from Santo Tomas Bay, with 1.82 µg g^{-1} dw. The mercury concentration in these ecosystems' sediments, determined in the same study, was <0.001 µg g^{-1}, while the concentration in water (total fraction) was 5.2 µg L^{-1}. The authors indicate the importance of the water matrix in the content of Hg in *C. bellicosus*; however, the highest concentrations of Hg in the water were found in the Guaymas-Empalme Bay, with 6.3 µg g^{-1}, while the Hg concentrations in *C. bellicosus* were the lowest, with 0.56 µg g^{-1} dw. On the other hand, the highest Hg concentration in sediment was found in Las Guásimas Bay, with 1.23 µg g^{-1} dw, while the concentration in *C. bellicosus* was 0.63 µg g^{-1} dw showing the complex interaction between organisms and environmental pollutants.

Teleost fish are the most heterogeneous group of organisms used as biomonitors of aquatic pollution in Mexico. Marine and freshwater fish from different ecosystems (rivers, lakes, lagoons, estuaries, bays) and different eating habits (planktivorous, detritivorous, omnivorous, and carnivorous) have been used for this purpose. The present review shows that Hg concentration in fish may vary depending on the type of ecosystem, geographical location (anthropogenic or geological influence), eating habits (trophic level), and species. In the case of rivers, the highest concentration of Hg was found in muscle tissue of *Lepomis macrochirus*, in the Hardy river, with 3.2 µg g^{-1} dw, followed by *Gobomorius polylepis* in the Coatzacoalcos river, with 0.86 µg g^{-1} dw, then *Pterygoplichthys pardalis* in the Usumacinta River, with 0.45 µg g^{-1} dw, and *Mugil* sp., in the Santiago River, with 0.20 µg g^{-1} dw. Concerning lakes and other reservoirs, the highest concentrations of Hg were found in Lake Chapala in muscle tissue of *Cyprinus* sp., with 4.15 µg g^{-1} dw in 2007, 1.95 µg g^{-1} dw in 2010, 1.75 µg g^{-1} dw in 2011, and 0.5 µg g^{-1} dw in 2012. In other sites, such as the Luis León Dam, the concentration was 0.04 µg g^{-1} dw in 2011-2012, and not detected (ND) in the Viejo Mandin Dam in 2013.

Coastal ecosystems have a greater diversity of fish communities, harboring different trophic levels through which energy (and pollutants) is transferred within the same community. It is possible to observe an increase in the Hg levels in muscle from the lower trophic levels to higher levels. In the Urias Lagoon, for example, the concentration of Hg in muscle tissue increased from 0.1-0.18 µg g^{-1} dw in *Mugil* sp. to 0.7 µg g^{-1} dw in *Eugerris axillaris* and 0.9 µg g^{-1} dw in *Lutjanus colorado*; the latter two have a predator-prey relationship with *Mugil* sp., at least in their earlier stages (Jara-Marini *et al*., 2012). The same trend can be observed in other places, such as Altata-Ensenada del Pabellón, where Hg's concentration went from 0.13-0.20 µg g^{-1} dw in muscle tissue of *M. cephalus* to 0.89 µg g^{-1} dw in the muscle of *L. colorado*. In Santa Maria-La Reforma, the Hg concentration went from 0.13 µg g^{-1} dw in muscle tissue of *M. curema* to 0.82 µg g^{-1} dw in

C. medius's muscle. In Topolobampo, the concentration Hg in muscle tissue of *M. cephalus* was 0.03 µg g^{-1} dw, increasing to 3.32 µg g^{-1} dw in the muscle of *C. caninus*. Other cases in which the level of mercury increased from lower to higher trophic levels were found in Guaymas (Sonora), Barra de Navidad Lagoon (Jalisco), and the estuary of the Coatzacoalcos River (Veracruz) (Table 1). There were also cases where the trend mentioned above was not clearly seen. In the Alvarado lagoon, for example, in Veracruz's state, the concentration of Hg in muscle tissue of *M. curema* was 2.85 µg g^{-1} dw (2003), while the concentration of Hg in *C. parallelus* was 0.75-0.9 µg g^{-1} dw (2000-2003). In general, top predators such as the great amberjack (*Seriola lalandi*), the striped marlin (*Tetrapturus audax*), the wahoo (*Acanthocybium solandri*), the blue marlin (*Makaira mazara*), and the Indo-Pacific sailfish (*Istiophorus platypterus*) had higher concentrations of mercury.

In coastal ecosystems, elasmobranchs are considered top predators, making them susceptible to pollutants' biomagnification such as mercury (Ruelas-Inzunza *et al*., 2013b). Most of the studies analyzed in this review focused on rays and sharks were conducted in the Gulf of California region. Among sharks, *Sphyrna zygaena* showed the highest average Hg concentration, with 33 µg g^{-1} dw in muscle for 2003-2004; however, other studies reported concentrations of 0.98 µg g^{-1} dw of Hg in muscle tissue of the same species in 2001-2005 (Table 1). Other species such as *S. lewini*, *Prionace glauca*, *C. leucas*, *C. falciformis*, and *Rhizoprionodon longurio* showed average concentrations of 0.49-4.32, 1.96-5.56, 0.2-2.48, 1.2-3.4, and 3.6-5.2 µg g^{-1} dw of Hg in muscle tissue, respectively. Regarding the other regions of Mexico, only one study was found for the Gulf of Mexico region; Núñez-Noriega (2005) analyzed the concentrations of Hg in muscle tissue of *C. limbatus* sampled in the port of Veracruz, finding average concentrations of 13.32 µg g^{-1} dw, higher than those found in *C. limbatus* from the Gulf of California (2.04 µg g^{-1} dw in muscle). Núñez-Noriega (2005) also analyzed the concentration of mercury in *R. terraenovae*, obtaining average values of 3.04 µg g^{-1} dw, which were lower than those found in similar species from the Gulf of California, such as *R. longurio* (5.2 µg g^{-1} dw of Hg in muscle).

The average concentration of mercury in the muscle tissue of the batoids (rays and torpedoes) was lower than the concentration found in sharks (approximately 1.23 and 4.01 µg g^{-1} dw of Hg, respectively), probably because sharks belong to a level highest trophic. Sharks feed mainly on fish, and batoids feed on organisms with lower trophic levels, such as crustaceans and mollusks and, to a lesser extent, on fish (Ruelas-Inzunza *et al*., 2013b), which could explain the differences in Hg levels. The highest concentrations were found in *Dasyatis longa*, with 2.84 µg g^{-1} dw, in 2003-2004, and 4.46 µg g^{-1} dw in 2012. *Urolophus* spp. batoid's muscle had concentrations of Hg in the muscle of 1.37-3.71 µg g^{-1} dw in 2012. The lowest concentrations were found in *Mobula japanica* in 2012, with 0.04-0.56 µg g^{-1} dw.

Other groups of aquatic animals that have also been used as biomonitors of aquatic pollution in Mexico include sea turtles, aquatic birds, crocodiles, and marine mammals. Table 1 shows the average mercury concentrations reported in sea turtles, aquatic birds, crocodiles, and marine mammals. Regarding aquatic birds, piscivorous species such as *Pelecanus occidentalis* and *Phalacrocorax brasilianus* had higher concentrations than non-piscivorous birds such as *Anas discors* and *A. clypeata* (Table 1). In Mexico, studies with aquatic reptiles such as sea turtles and crocodiles are very scarce. Only two studies with crocodiles were found, by Trillanes *et al*. (2014) and Buenfil-Rojas *et al*. (2015), who reported mercury concentrations of 3.1-4.3 µg g^{-1} dw in *Crocodylus moreletti* in the Champotón-Petenes-Celestún River, and of 0.33 µg g^{-1} ww in the Hondo River, respectively. Only three studies with sea turtles were found, one for the Gulf of California area (*Chelonia mydas*, *C. caretta*, and *Lepidochelys olivacea*), another for the Central Pacific area (*L. olivacea*), and another for the Gulf of Mexico area (*C. mydas* and *Eretmochelys imbricata*). Different tissues (muscle, egg, and blood) were used in these studies to evaluate the concentration of pollutants, which could serve as the basis for future research.

Cadmium and lead in biota

Table 2 shows the concentrations of Cd and Pb in aquatic organisms. As in the case of macrophytes, most of the studies about the presence of Cd and Pb in biota focused on the Gulf of California area, but a higher number of biomonitoring studies focused on Cd and Pb. Several sites along the Gulf of California coast were monitored using macrophytes, finding average concentrations of Cd of 0.14-6.2 µg g^{-1} dw, and 0.19-8.8 µg g^{-1} dw of Pb. The highest average concentrations of Cd were found in *Rupia maritima* (6.2 µg g^{-1} dw) collected in the San Ignacio Lagoon (Baja California Sur), while the lowest concentrations were found in *Caulerpa sertularioides* (0.14 µg g^{-1} dw) collected in the Urías Lagoon (Sinaloa). In Pb's case, the lowest average concentrations were found in *Gracilaria subsecundata* (0.19 µg g^{-1} dw) in Altata-Ensenada del Pabellón, while the highest concentrations were found in *R. maritima* (8.8 µg g^{-1} dw) collected in the San Ignacio Lagoon. There were also cases, such as those reported by

Orduña-Rojas & Longoria-Espinoza (2006), in which average Pb concentrations of 174 µg g^{-1} dw was found in *U. lactuca* collected in the Ignacio-Navachiste Lagoon (Sinaloa), suggesting the possible influence of the small fishing boats used in the region. Of the sites evaluated in the coastal area of the Gulf of California, the ones with the lowest concentrations of Cd and Pb, simultaneously, were the Guaymas bay with 0.54 and 0.35 µg g^{-1} dw, and Altata-Ensenada del Pabellón with 0.18 and 0.19 µg g^{-1} dw in *G. subsecundata* and *U. lactuca*, respectively, both species collected in the period 1998-1999. In general, the concentration of Cd and Pb varied from one species to another. For example, Riosmena-Rodríguez *et al.* (2010) reported concentrations of 3.16, 1.36, and 4.5 µg g^{-1} dw for Cd and 0.9, 0.8, and 2.15 µg g^{-1} dw for Pb in *G. textorii, G. vermiculophylla*, and *R. maritima*, respectively, collected in the Banderitas Estuary (Baja California Sur) in 2004-2005. Ruelas-Inzunza & Páez-Osuna (2006) reported concentrations of 0.18, 0.23, and 0.87 µg g^{-1} dw for Cd and 0.19, 4.9, and 3.1 µg g^{-1} dw for Pb in G. *subsecundata*, *Gracilaria* sp., and *Polysiphonia* sp., respectively, collected in Altata-Ensenada del Pabellón (Sinaloa) in 2004-2005. There were only a few other studies that used macrophytes in other areas of the country. Avelar *et al.* (2013) reported Cd concentrations of 0.72 µg g^{-1} dw in *T. testudinum* in the Yalahau Lagoon, an area with relatively little contamination in the Mexican Caribbean; however, the authors reported maximum concentrations of Cd higher than 5 µg g^{-1} dw in leaves of *Thalassia testudinum*, suggesting how important underground infiltration of contaminants is in this type of sites. It is thought that macrophytes reflect greater accuracy in the amount of contamination in the fraction dissolved in the water column (Orduña-Rojas & Longoria-Espinoza, 2006). Natural sources such as upwellings and hydrothermal chimneys (Riosmena-Rodríguez *et al*., 2010), or anthropic sources such as gasoline in fishing vessels (Soto-Jiménez *et al*., 2008), can significantly alter the content of metals in macrophytes.

Studies of the content of Cd and Pb in bivalves were the most abundant. Close to 30 sites on the Gulf of California's coastal area were studied using bivalves as biomonitors. The average concentrations of Cd and Pb were 0.22-17.23 and 0.001-17.4 µg g^{-1} dw, respectively; countrywide, the highest concentrations of both Cd and Pb were found in this area. The typically high Cd concentrations present in the Gulf of California area sites were mainly associated with upwelling events that occurred in the winter season. Phosphorus pesticides and fertilizers, used for more than 50 years in intensive agriculture in this area, have generated large quantities of residues rich in Cd and other metals, which have been deposited in the continental slope's sediments, and reintroduced to the coastal zone during upwelling events. The sites with the highest average Cd concentrations were Bacochibampo Bay and Kuu Kaak Bay, 22.54, and 57.12 µg g^{-1} dw, respectively; these two sites are frequently affected by upwelling events. As we have seen before, the ability to accumulate pollutants varies from one species to another; for example, García-Hernández *et al*. (2005) found Cd levels of 0.4, 0.4, 2.44, and 8.16 µg g^{-1} dw in *Megapitaria squalida*, *Chione californiensis*, *Pinna rugosa* and *Anadara multicostata* collected in the Kuu Kaak Bay (Sonora), respectively. The highest average concentrations of Pb in bivalves living on the coastal area of the Gulf of California were found mostly in sites with intense fishing activity, mainly in the Sinaloa coast, where the highest concentrations were associated with the fuel used by small fishing boats. Other studies that used bivalves were conducted in areas outside the Gulf of California. For example, Segovia-Zavala *et al*. (2004) reported concentrations of 17.23 µg g^{-1} dw of Cd in *Mytilus californianus* transplanted to Punta Banda (Baja California Norte), an area affected by upwelling events. Castañeda-Chavez *et al*. (2014) reported concentrations of 42 and 189 µg g^{-1} dw of Cd and Pb, respectively, in *C. virginica* collected in the Mecoacán Lagoon in the state of Veracruz, in an area historically impacted by the Petrochemical industry. Nearly 80% of the cases showed average concentrations of 0.2-6.9 µg g^{-1} dw for Cd and 0.001-6.8 µg g^{-1} dw for Pb, similar to values reported worldwide. For example, Lino *et al*. (2016) reported Cd concentrations of 0.15 and 0.6 µg g^{-1} dw in *Perna perna* from Sepitaba Bay and Cabo do Arraial, and 1.2 and 0.8 µg g^{-1} dw of Cd in *Nodipecten nodosus* from Ilha Grande Bay and Cabo do Arraial, in southern Brazil. Liu *et al.* (2017) reported average concentrations of 5.9-7.8 µg g^{-1} dw for Cd and 0.4-0.5 µg g^{-1} dw for Pb in muscle tissue of *Mactra veneriformis* in the Laizhou Bay in China. It is worth remembering that China and Brazil are countries with emerging economies and intense industrial activity. About 10% of the cases showed high concentrations of Pb and Cd: 10-34 µg g^{-1} dw and 10-57 µg g^{-1} dw for Cd, respectively. These atypically high concentrations were influenced by upwelling events, fishing activities, or contaminated urban or industrial effluents.

Average Cd and Pb levels in crustaceans are shown in Table 2. There were very few studies on the concentration of Cd and Pb in freshwater crustaceans. Mendoza-Carranza *et al*. (2016) evaluated Cd's concentration in muscle tissue of *Macrobrachium acanthurus*, finding values of 0.72 µg g^{-1} dw in the San Pedrito Lagoon, Tabasco, in the year 2009. Similarly, García-Hernández *et al.* (2001) found average whole-body concentrations of 0.2 and 0.4 µg g^{-1} dw for Cd and 0.001 and 1.8 µg g^{-1} dw for Pb in *Procambarus clarkii* and *Palaemonetes paludosus*. These values were lower than other values reported in other areas of the world for freshwater crustaceans. For example, Rabiul-Islam *et al.* (2017) reported values of 2.38 and 4.64 µg g^{-1} dw of Cd and Pb, respectively, in muscle tissue of *M. rosenbergii* collected in the Satkhira Basin in southern Bangladesh. In coastal ecosystems, the only studies found in this review focused on the Gulf of California and Mexico's Gulf. Lango-Reynoso *et al.* (2013) found concentrations of 0.05 and 0.4 µg g^{-1} dw for Cd and 0.5 and 0.5 µg g^{-1} dw for Pb in muscle tissue of *Penaeus setiferus* and *Farfantepenaeus aztecus*, respectively, in the Alvarado Lagoon (Veracruz). Vázquez *et al*., 2001 found concentrations of Cd and Pb of 3.64 and 4.22 µg g^{-1} dw, respectively, in muscle tissue of *F. aztecus* collected on the coast of Campeche. Aguilar-Ucán *et al.* (2014) reported concentrations of Cd and Pb of 0.25 and 1.7 µg g^{-1} dw, respectively, in muscle tissue of *Callinectes sapidus* collected in the Terminos Lagoon (Campeche). Soto-Jiménez *et al.* (2008) reported concentrations of Pb of 23 µg g^{-1} dw in muscle tissue of *C. arcuatus* collected in the Urías Lagoon (Sinaloa). No other studies were found for other blue crab species; however, several studies were conducted throughout Sinaloa and Nayarit using shrimp as biomonitors, with average muscle concentrations of 0.36-4.94 µg g^{-1} dw for Cd and 0.4-6.39 µg g^{-1} dw for Pb. In general, the concentration of Cd and Pb varied between different tissues. For example, Frías-Espericueta *et al.* (2009) reported values of 0.36-0.76 µg g^{-1} dw for Cd and 4.21-6.93 µg g^{-1} dw for Pb in muscle tissue of *P. vannamei* collected in six lagoons in the coastal zone of Sinaloa and Nayarit, while in hepatopancreas, they reported values of 1.10-7.97 µg g^{-1} dw for Cd and 5.45-18.84 µg g^{-1} dw for Pb. Similarly, Vázquez *et al.* (2001) reported values of 3.6 and 4.2 µg g^{-1} dw for Pb and Cd respectively in muscle tissue of *P. setiferus*, and 15.03 and 11.6 µg g^{-1} dw for Cd and Pb respectively in hepatopancreas, results that indicate the high capacity of this organ to bioaccumulate metals.

Table 2 shows the concentrations of Cd and Pb in fish. In general, the number of Cd and Pb biomonitoring studies in fish was considerably lower than Hg's biomonitoring studies. In the case of freshwater fish, the average concentrations of Cd in muscle tissue were 0.28-2.24 µg g^{-1} dw; for Pb, the average concentrations were <0.001-0.55 µg g^{-1} dw in ecosystems located in southeastern Mexico. The highest Pb concentrations were 9.6 µg g^{-1} dw in muscle tissue of *Dormitator latifrons* collected in the Tres Palos Lagoon, in state of Veracruz. Average levels of Cd and Pb of 0.28 and 2.12 µg g^{-1} dw, respectively, were also found in the muscle tissue of *Oreochromis aureus* collected in the Salto Dam (Sinaloa). Cd and Pb concentrations in marine fish's muscle tissue belonging to the lower trophic levels were lower than those found in crustaceans collected in the same areas. For example, Frías-Espiricueta *et al.* (2011) evaluated Cd and Pb's concentration in muscle tissue of *Mugil cephalus* collected in seven coastal lagoons located in the state of Sinaloa and found values of 0.13-0.26 and 1.38-2.10 µg g^{-1} dw, respectively. In the same sites, Frías-Espiricueta *et al.* (2009) reported levels of 0.36-0.76 and 4.21-6.93 µg g^{-1} dw for Cd and Pb, respectively, in muscle tissue of *P. vannamei*. Concerning predatory fish, Vázquez *et al.* (2001) reported values of <0.001 and 1.6 µg g^{-1} dw for Cd and Pb, respectively, in muscle tissue of *Syacium gunteri*. In muscle tissue of *P. zetiferus*, the same authors reported values of 3.6 and 4.2 µg g^{-1} dw; however, in the case of *Lutjanus analis*, the reported concentrations were <0.001 for Cd and 4.68 for Pb µg g^{-1} dw. Similarly, Ruelas-Inzunza & Páez-Osuna (2008) reported values of 3.1 and 0.5 µg g^{-1} dw for Cd and Pb in muscle tissue of *P. vannamei*, respectively, and 0.5 and 0.9 µg g^{-1} dw in *P. stylirostris*. In *L. colorado* and *Cynoscion xanthulus*, the reported Cd levels were 0.2 and 0.9 µg g^{-1} dw, while the values of and Pb were 1.3 and 2.6 µg g^{-1} dw, respectively. These results are consistent with the low transfer efficiency from lower to higher trophic levels, and even with the predator-prey ratio, at least in the case of fish.

The number of biomonitoring studies focused on Cd and Pb's concentration in elasmobranchs was considerably lower than the number of studies focused on mercury and other biomonitors. In the Gulf of California, the reported levels of Cd and Pb were <0.001-1.48 µg g^{-1} dw for Cd and 0.16-0.28 µg g^{-1} dw for Pb. In the Gulf of Mexico, the reported levels were 1.4-1.48 µg g^{-1} dw for Cd and 10.04-13.24 µg g^{-1} dw for Pb; it is worth noting that the latter value of Pb was approximately 40 times higher than the value found in the Gulf of California. As in other fish, the concentrations of Cd and Pb in the muscle tissue of sharks were not higher than the concentrations found in organisms of lower trophic levels. The tendency to bioaccumulate higher Cd and Pb concentrations in the liver than in muscle was also observed in sharks. Barrera-Garcia *et al.* (2013), for example, reported concentrations of Cd in the liver nearly 140 times higher than the concentrations reported in muscle by Barrera-Garcia *et al.* (2012). Terrazas-López *et al.* (2016) also reported Cd >900 times higher in the liver, probably due to the high content of lipids in the liver and to its ability to synthesize metallothioneins (rich in cysteine), which are present in lower quantities in the muscles. In general, Cd and Pb tended to bioconcentrate in the liver and to biodilute in muscle.

The concentration of Cd and Pb in sea turtles, waterfowl, and crocodiles is shown in Table 2. The average concentration of Cd in muscle tissue of sea turtles sampled in the Gulf of California ranged from 0.01 to 2.6 µg g^{-1} dw, while the average concentration of Pb ranged from not detect to 8.9 µg g^{-1} dw. In blood, Cd levels were ranged between 0.15 and 6.65 µg g^{-1} dw. In the central area of the Mexican Pacific, Cd levels ranged from 0.45 to 0.85 µg g^{-1} dw. The transfer of contaminants between mother and offspring is a current subject of study, but relatively little is known about the effect that mother-transmitted contaminants have on the offspring's development. Páez-Osuna *et al.* (2010a) found in *Lepidochelys olivacea*, that the maternal transfer of Cd was 0.20% of the Cd content in the whole body (for a spawn of 200 eggs). García-Hernández *et al.* (2006) evaluated the concentration of Cd and Pb in eggs and embryos (in different stages) of aquatic birds living in the Colorado River Delta (Sonora) and found concentrations of 0.13-0.78 and 0.06-0.20 µg g^{-1} dw for Cd and Pb respectively. Similarly, Ceyca *et al.* (2016) reported values of 1-1.6 µg g^{-1} dw for Cd in seabird eggs in the coastal zone of Sinaloa, similar values to those found in the muscle tissue of several seabirds collected in the Altata-Ensenada de Pabellón Lagoon (Sinaloa), with concentrations of 0.2-1.6 µg g^{-1} dw, which suggests that a high percentage of this contaminant is transferred via the mother.

Organochlorine pesticides (POCs) in aquatic organisms

The results of the average concentration of POCs in different aquatic organisms in Mexico are shown (Table 3). The number of biomonitoring studies of POCs was considerably lower than the number of heavy metals' biomonitoring studies. The most studied compound was ∑DDTs. In the case of marine mollusks, the highest concentrations (282 ng g^{-1} dw) were found in the soft tissue of *Moluchia strigata* collected in the San Ignacio-Navachiste-Macapule lagoon complex. The lowest concentrations (<0.01 ng g^{-1} dw) were found in *C. californiensis* collected in the lagoons Altata-Ensenada del Pabellon and Santa María-La Reforma.

In the case of freshwater mollusks, *Corbicula* sp. collected in the Colorado River had average concentrations of 350-1050 ng g^{-1} dw. The highest ∑DDTs (50-300 ng g^{-1} dw) concentrations in crustaceans were found in *P. clarkii* collected at different sites and the Colorado River system. García-Hernández *et al.* (2015) conducted a biomonitoring study of POCs in several coastal lagoons of southern Sonora and northern Sinaloa, using *C. bellicosus* biomonitor. They found average concentrations of <0.01-180 ng g^{-1} dw of ∑DDTs, <0.01-355 ng g^{-1} dw of ∑HCHs, <0.01-405 ng g^{-1} dw of ∑Drines, <0.01-1035 ng g^{-1} dw of ∑Endosulfans, and <0.01-310 ng g^{-1} dw of ∑Heptachlor. The authors point out that these concentrations are relatively high and may be associated with the intense agricultural activity in the area and pesticides to control infectious vectors.

In the case of fish, the species associated with sediments showed high concentrations of POCs. Uresti-Marín *et al.* (2008), for example, found average ∑DDT concentrations of 1060 and 1245 ng g^{-1} dw in muscle tissue of *Ictalurus punctatus* and *Cyprinus carpio* collected in the Vicente Guerrero Dam (Chihuahua), respectively. Similarly, García-Hernández *et al.* (2001) reported average whole-body concentrations of 875 ng g^{-1} dw of ∑DDTs in *I. punctatus* collected in the Colorado River area. Furthermore, Reyes-Montiel *et al.* (2013) found average ∑HCH concentrations of 1015 ng g^{-1} dw in muscle tissue of *M. cephalus* from the San Ignacio-Navachiste-Macapule lagoon system. There were very few cases showing the behavior of POCs in the predator-prey relationship. In muscle tissue of *M. cephalus*, Reyes-Montiel *et al.* (2013) found average concentrations of 155 ng g^{-1} dw of ∑DDTs, 625 ng g^{-1} dw of ∑Drines, 215 ng g^{-1} dw of ∑Endosulfans, and 75 ng g^{-1} dw of ∑Heptachlor. Granados-Galván *et al.* (2015) reported average concentrations of <0.01 -50 ng g^{-1} dw of ∑DDTs, 115-190 ng g^{-1} dw of ∑HCHs, 15-20 ng g^{-1} dw of ∑Drines, 45-75 ng g^{-1} dw of ∑Endosulfans, and 30-40 ng g^{-1} dw of ∑Heptachlor in three species of snappers. Both studies were conducted in the San Ignacio-Navachiste-Macapule lagoon system in the period 2011-2013.No biomagnification was observed, which may be related to the different detoxification rates of the various species. Moreover, low concentrations of POCs were observed in large pelagic fish, including sharks.

In marine mammals, a large amount of adipose tissue in them, their large size, longevity, and high trophic level allows them to bioaccumulate huge POCs amounts. Gallo-Reinoso *et al.* (2014), for example, found maximum concentrations of 87,300 ng g^{-1} lw (lipid weight) in biopsies of *Delphinus capensis*, while Niño-Torres *et al.* (2009) found maximum concentrations of 11,000 ng g^{-1} lw in a biopsy of *Zalophus californianus*. The transfer of POCs via the mother became evident in sea turtles and aquatic birds. Average concentrations of 12-61 ng g^{-1} ww were found in seabird eggs collected throughout the Mexican Pacific. Carvalho *et al.* (2002) found higher levels of ∑DDTs, ∑HCHs, ∑Drines, and ∑Endosulfans in eggs in the muscle and liver tissue of *Phalacrocorax* sp.

Table 3. Average concentration of POCs (ng g^{-1} dw, D or ww, W or LW, L) in different tissues of organisms from various aquatic ecosystems in Mexico. UR: Estero Urías; AEP: Altata- Ensenada del Pabellón; GCFR: Golfo de California; BGY: Bahía Guaymas; GSNR Granjas de Sonora; GSNL: Granjas de Sinaloa; INM: Laguna San Ignacio-Navachiste-Macapule; BCT: Bahía de Cueta; BBCN: Bocana; LTM: Laguna de Términos; SMR: Santa María- LA Reforma; PNGC: Parte Norte del Golfo de California; PXN: Punta Xen; LSI: Laguna de San Ignacio; PAO: Punta Abreojos; LAV: Laguna Alvarado; LVT: Laguna Vega de La Torre; BAP: Laguna Agiabampo; BOH: Bahía de Ohuria; CSC: Cienega Santa Clara; BMGD: Bahía Magdalena; SCY: Sacubay; CLSNR: Canal Sonora; DRC: Delta del Río Colorado; LTSC: Laguna de Terminos - Sistema Candelaria-Panlau; LSCL: Laguna San Cristóbal; LMD: Laguna Madre; EPR: Estero Pozo del Rey; BYV: Laguna de Yavaros; LGVT: Laguna Grande- Laguna Vega de La Torre; BPZ: Bahía La Paz; ERCZ: estero del Rio Coatzacoalcos; RCL: Río Colorado; LCTC: Lago de Catemaco; SGJ: San Jorge; SPMT: San Pedro Mártir; SIF: San Ildefonso; IISB: Isla Isabel; IMT: Isla Marieta; ICND: Islas Coronado; BLB: Bahía de Lobos; RMYR: El Mayor; ZCO: Zona Costera de Oaxaca; IPR: Isla Pajarera; IPB: Isla Peña Blanca; CCP: Cucapa; LMCN: Lago Mechoacán; LMTT: Lago Metztitlán; IMP: Morro El Postosí; LTMH: Laguna de Tamiahua; LMCH: Laguna de la Mancha; LMXT: Laguna de Mexcaltitlan; XNH: Xnoha; MCU: Mocu; CDOC: El Doctor; CHPTN: Río Champoton-Los Petenes; PVG: Presa Vicente Guerrero; PAL: Presa Agua Limpia; RHD: Rio Hardy; LMDG: Laguna Mandinga.

DG05: Díaz-González *et al*. (2005); C02: Carvalho *et al.* (2002); GB07: Gold-Bouchot *et al.* (2007); C09: Carvalho *et al.* (2009); OL09: Osuna-López *et al.* (2009); CC11: Castañeda-Chavez *et al.* (2011); LR13: Lango-Reynoso *et al.* (2013); VB14: Vazquez-Boucard *et al*. (2014); GH01: Garcia-Hernández *et al*. (2001); VG16: Vargas-Gonzales *et al*. (2016); GH15: García-Hernández *et al.* (2015); GM10: Gonzalez-Mille *et al.* (2010); ER12: Espinosa-Reyes *et al.* (2012); RM13: Reyes-Montiel *et al.* (2013); GG15: Granados-Galván *et al.* (2015); MV14: Martínez-Villa *et al.* (2014); FB08: Fernández-Bringas *et al*. (2008); UM08: Uresti-Marín *et al.* (2008); AZ11: Aranguré-Zúniga *et al.* (2011); HG16: Hinojosa-Garro *et al*. (2016); GH13: García-Hernández *et al.* (2013); CV01: Calderon-Villagomez *et al.* (2001); G02: Gardner *et al*. (2003); LM11: Labrada-Martagón *et al.* (2011); GB14: García-Besné *et al.* (2014); GH06: García-Hernández *et al*. (2006); M09: Mellink *et al*. (2009); RR-RE11: Rivera-Rodríguez & Rodríguez-Estrella (2011); GR14: Gallo-Reinoso *et al.* (2014); NT07: Niño-Torres *et al.* (2009); GJ12: González-Jauregui *et al.* (2012); RM06: Robledo-Marenco *et al*. (2006); C09: Carvalho *et al.* (2009). SON: Sonora; SIN: Sinaloa; NAY: Nayarit; JAL: Jalisco; COL: Colima; MIC: Michoacán; GRO: Guerrero; OAX: Oaxaca; CHP: Chiapas; CAM: Campeche; ROO: Quintana Roo; YUC: Yucatán; TAB: Tabasco; VER: Veracruz; TAM: Tamaulipas; BCS: Baja California Sur; BCN: Baja California Norte; AGU: Aguascalientes; MEX: Mexico; CMX: Ciudad de México. N/E: not specified; ND: not detect, -: not analized; D: dry weight; W: wet weight; M: muscle; ST: soft tissue; T: whole body; S: blood; B: biopsy; H: eggs.

∑DDTs: refers to the sum of Dichlorodiphenyltrichloroethane (DDT), DDE (dichlorodiphenyldichloroethylene), and DDD (dichlorodiphenyldichloroethane). ∑HCHs: refers to the sum of Alpha-hexachlorocyclohexane (α-HCH), beta-hexachlorocyclohexane (β-HCH), gamma-hexachlorocyclohexane (γ-HCH), delta-hexachlorocyclohexane (δ-HCH). ∑Drines: refers to the sum of Dialdrine, Aldrine, endrine, endrin aldehyde, endrin ketone. ∑Endosulfans: refers to the sum of Endosulfan I, Endosulfan II, Endosulfan sulfate. ∑Heptachlors: refers to the sum of Heptachlor, heptachor hepoxide.

Species	Place	DDTs	HCHs	Drines	Endosulfanes	Heptacloros	Cite
Primary producers							
Ruppia sp.	LTSC (CAM)	59.6^{D} (1988-89)	4.8^{D} (1988-89)	51.3^{D} (1988-89)	ND (1988-89)	2^{D} (1988-89)	DG05
Nimphaea sp.	LTSC (CAM)	19.7^{D} (1988-89)	30^{D} (1988-89)	313^{D} (1988-89)	ND (1988-89)	90^{D} (1988-89)	DG05
Halodule sp.	LTSC (CAM)	193^{D} (1988-89)	88^{D} (1988-89)	1009^{D} (1988-89)	129^{D} (1988-89)	18^{D} (1988-89)	DG05
Mollusks							
Mytella strigata	AEP (SIN)	32.4^{D} (1989) ST	2.9^{D} (1989) ST	13.6^{D} (1989) ST	-	0.07D (1989) ST	C02
	INM (SIN)	282^{D} (1996) ST	-	-	-	-	OL09
	AEP SIN)	99^{D} (1996) ST	-	-	-	-	OL09
	BCT SON)	147^{D} (1996) ST	-	-	-	-	OL09
	UR (SIN)	12^{D} (1996) ST	-	-	-	-	OL09
	LMXT (NAY)	4.8^{D} (1996) ST	-	-	-	-	OL09
	LSCL (NAY)	69^{D} (1996) ST	-	-	-	-	OL09
Crassostrea virginica	LTM (CAM)	9.1^{D} (2002) ST	16.3^{D} (2002) ST	22.4^{D} (2002) ST	-	-	GB07
	LTMH (VER)	114^{L} (2005) ST	-	-	-	-	CC11
	LVT (VER)	103^{L} (2005) ST	-	-	-	-	CC11
	LAV (VER)	53^{L} (2001-02) ST	-	-	-	-	CC11
	LMCH VER)	99^{L} (2001-02) ST	-	-	-	-	CC11
	LMD (TAM)	22^{L} (2008) ST	63L (2008) ST	355^{L} (2008) ST	13^{L} (2008) ST	-	LR13
	LMDG (VER)	89^{L} (2008) ST	1614^{L} (2008) ST	347^{L} (2008) ST	136^{L} (2008) ST	-	LR13
	LMCN (TAB)	20^{L} (2009) ST	23^{L} (2008) ST	57^{L} (2008) ST	14^{L} (2008) ST	-	LR13
Crassostrea gigas	AEP (SIN)	29^{D} (1989) ST	0.7^{D} (1989) ST	18.9^{D} (1989) ST	-	-	C02
	GSNR (SON)	3^{D} (N/E) ST	72^{D} (N/E) ST	-	-	-	VB14
	GSNL (SIN)	1.1^{D} (N/E) ST	44^{D} (N/E) ST	-	-	-	VB14
Crassostrea sp.	LTM (CAM)	5.8^{D} (N/E) ST	1.4^{D} (N/E) ST	0.2^{D} (N/E) ST	0.38^{D} (N/E) ST	0.08^{D} (N/E) ST	C09
Chione sp.	PNGC (SON)	ND (1998-00) ST	-	-	-	-	GH01
Corbicula sp.	RCL (SON)	350^{D} (1998-00) ST	-	-	-	-	GH01

continuation

Species	Place	DDTs	HCHs	Drines	Endosulfanes	Heptacloros	Cite
Corbicula sp.	CLSNR (SON)	1050^{D} (1998-00) ST	-	-	-	-	GH01
Chione californiensis	BYV (SON)	73^{D} (2009) ST	ND (2009) ST	33^{D} (2009) ST	ND (2009) ST	63^{D} (2009) ST	VG16
Chione californiensis	AEP (SIN)	ND (2009) ST	ND (2009) ST	7D (2009) ST	ND (2009) ST	8.19^{D} (2009) ST	VG16
Chione californiensis	SMR (SIN)	ND (2009) ST	ND (2009) ST	ND (2009) ST	ND (2009) ST	ND (2009) ST	VG16
Chione subrogosa	AEP (SIN)	2.3^{D} (1989) ST	1.2^{D} (1989) ST	7.5^{D} (1989) ST	32.2^{D} (1989) ST	ND (1989) ST	C02
Pomacea patula	LCTC (VER)	ND (1993) M	ND (1993) M	96.5^{D} (1993) M	-	-	CV01
Crustaceans							
Penaeus vannamei	AEP (SIN)	1.1^{D} (1989) M	ND (1989) M	1.1^{D} (1989) M	3^{D} (1989) M	ND (1989) M	C02
Penaeus stylirostri	AEP (SIN)	6.6^{D} (1991) M	1.3^{D} (1991) M	1^{D} (1991) M	0.7^{D} (1991) M	-	C02
Penaeus sp.	BOH (SIN)	0.02^{D} (1995-96) M	0.17^{D} (1995-96) M	-	1.06^{D} (1995-96) M	0.14^{D} (1995-96) M	OF-R02
Litopenaeus sp.	EPR (NAY)	26^{D} (1996-97) M	21^{D} (1996-97) M	28^{D} (1996-97) M	25^{D} (1996-97) M	18^{D} (1996-97) M	RM06
Litopenaeus sp.	LCSL (NAY)	26^{D} (1996-97) M	42^{D} (1996-97) M	4.6^{D} (1996-97) M	45^{D} (1996-97) M	0.01^{D} (1996-97) M	RM06
Callinectes sp.	ERCZ (VER)	2.5^{D} (2006) M	15^{D} (2006) M	-	-	-	ER12
Callinectes bellicosus	BYV (SON)	ND (2012) M	355^{D} (2012) M	405^{D} (2012) M	340^{D} (2012) M	ND (2012) M	GH15
	BAP (SON)	180^{D} (2012) M	ND (2012) M	425^{D} (2012) M	855^{D} (2012) M	130^{D} (2012) M	GH15
	BLB (SON)	ND (2012) M	195^{D} (2012) M	ND (2012) M	ND (2012) M	310^{D} (2012) M	GH15
	BOH (SIN)	ND (2012) M	41^{D} (2012) M	ND (2012) M	1035^{D} (2012) M	100^{D} (2012) M	GH15
Callinectes rathbunae	LGVT (VER)	267^{L} (2008) M	-	-	-	-	LR13
Procambarus clarki	RMYR (SON)	135^{D} (1998-00) T	-	-	-	-	GH01
	CCP (SON	300^{D} (1998-00) T	-	-	-	-	GH01
	CSC (SON)	50^{D} (1998-00) T	-	-	-	-	GH01
Paleomonetes paludosus	BBCN (SON)	ND (1998-00) T	-	-	-	-	GH01
Fishes							
Mugil cephalus	AEP (SIN)	20^{D} (1991) M	3.5^{D} (1991) M	1.4^{D} (1991) M	4.6^{D} (1991) M	ND (1991) M	C02
	ERCZ (VER)	0.98^{D} (2006) M	1.6^{D} (2006) M	-	-	-	GM10
	ERCZ (VER)	1^{D} (2006) M	2.5^{D} (2006) M	-	-	-	ER12
	INM (SIN)	155^{D} (2010-11) M	1015^{D} (2010-11) M	625^{D} (2010-11) M	215^{D} (2010-11) M	75^{D} (2010-11) M	RM13
	CSC (SON)	250^{D} (1998-00) T	-	-	-	-	GH01
Arius melanopus	LTSC (CAM)	116^{D} (1999) M	26^{D} (1999) M	509^{D} (1999) M	49^{D} (1999) M	300^{D} (1999) M	DG05
Lepisosteus tropicus	LTM (CAM)	15^{D} (N/E) M	-	-	-	-	C09
Cyprinus carpio	PAL (NAY)	1.9^{D} (2004) M	ND (2004) M	7.1^{D} (2004) M	1.5^{D} (2004) M	ND (2004) M	AZ11
	CSC (SON)	275^{D} (1998-00) T	-	-	-	-	GH01
	PVG (CHH)	1245^{D} (2004) M	-	27^{D} (2004) M	-	ND (2004) M	UM08
Eugerris axillaris	ERCZ (VER)	0.5^{D} (2006) M	11^{D} (2006) M	-	-	-	ER12
	ERCZ (VER)	0.49^{D} (2006) M	12.8^{D} (2006) M	-	-	-	GM10
Oreochromis aureus	PAL (NAY)	0.5^{D} (2004) M	ND (2004) M	3^{D} (2004) M	4.3^{D} (2004) M	ND (2004) M	AZ11
Oreochromis niloticus	XNH (CAM)	16739^{L} (2011) M	335^{L} (2011) M	473^{L} (2011) M	376^{L} (2011) M	-	HG16
	PVG (CHH)	155^{D} (2004) M	-	30.5^{D} (2004) M	-	ND (2004) M	UM08
Oreochromis sp.	ERCZ (VER)	1^{D} (2006) M	1.5^{D} (2006) M	-	-	-	ER12
	ERCZ (VER)	0.99^{D} (2006) M	2^{D} (2006) M	-	-	-	GM10
	LMTT (HID)	4^{D} (2001) M	20^{D} (2001) M	0.5^{D} (2001) M	6^{D} (2001) M	1.5^{D} (2001) M	FB08
	LMTT (HID)	4^{D} (2002) M	1.2^{D} (2002) M	1.5^{D} (2002) M	1.5^{D} (2002) M	43^{D} (2002) M	FB08
Centropomus parallelus	ERCZ (VER)	0.5^{D} (2006) M	6.5^{D} (2006) M	-	-	-	ER12
	ERCZ (VER)	0.5^{D} (2006) M	7.5^{D} (2006) M	-	-	-	GM10
Arius felis	ERCZ (VER)	1^{D} (2006) M	2^{D} (2006) M	-	-	-	ER12
	ERCZ (VER)	0.99^{D} (2006) M	1.9^{D} (2006) M	-	-	-	GM10
Poecilia latipinna	RCL (SON)	1300^{D} (1998-00) T	-	-	-	-	GH01
	CSC (SON)	1350^{D} (1998-00) T	-	-	-	-	GH01
Ictalurus punctatus	RHD (SON)	100^{D} (1998-00) T	-	-	-	-	GH01
	CCP (SON)	875^{D} (1998-00) T	-	-	-	-	GH01
	PVG (CHH)	1060^{D} (2004) M	-	16.5^{D} (2004) M	-	ND (2004) M	UM08
	PAL (NAY)	ND (2004) M	3.8^{D} (2004) M	7.6^{D} (2004) M	0.18^{D} (2004) M	ND (2004) M	AZ11
Micropterus salmoides	PAL (NAY)	ND (2004) M	0.1^{D} (2004) M	3.6^{D} (2004) M	3.5^{D} (2004) M	0.5^{D} (2004) M	AZ11
	PVG (CHH)	865^{D} (2004) M	-	22.5^{D} (2004) M	-	60^{D} (2004) M	UM08
Gambusia affinis	RMYR (SON)	1600^{D} (1998-00) T	-	-	-	-	GH01
	CSC (SON)	300^{D} (1998-00) T	-	-	-	-	GH01
	CDOC (SON)	850^{D} (1998-00) T	-	-	-	-	GH01
Dorosoma petenense	LCTC (VER)	6.5^{D} (1993) M	ND (1993) M	33.5^{D} (1993) M	-	-	CV01
Cichlasoma urophthalmus	MCU (CAM)	19047^{L} (2011) M	442^{L} (2011) M	521^{L} (2011) M	405^{L} (2011) M	-	HG16
Lepomis macrochirus	RHD (SON)	310^{D} (2010) M	DL (2010) M	60^{D} (2010) M	ND (2010) M	ND (2010) M	GH13
Lutjanus argentiventris	INM (SIN)	40^{D} (2012-13) M	120^{D} (2012-13) M	15^{D} (2013-13) M	50^{D} (2013-13) M	40^{D} (^{2013}-13) M	GG15
Lutjanus novemfasciatus	INM (SIN)	ND (2012-13) M	190^{D} (2012-13) M	15^{D} (2013-13) M	45^{D} (2013-13) M	30^{D} (2013-13) M	GG15
Lutjanus colorado	INM (SIN)	50^{D} (2012-13) M	115^{D} (2012-13) M	20^{D} (2013-13) M	75^{D} (2013-13) M	40^{D} (2013-13) M	GG15
Euthynnus lineatus	ZCO (OAX)	31^{D} (2010-11) M	16.5^{D} (2010-11) M	18^{D} (2010-11) M	43^{D} (2010-11) M	15^{D} (2010-11) M	MV14
Thunnus albacares	ZCO (OAX)	22.5^{D} (2010-11) M	7.5^{D} (2010-11) M	ND (2010-11) M	30.5^{D} (2010-11) M	14^{D} (2010-11) M	MV14
Sarda orientalis	ZCO (OAX)	6^{D} (2010-11) M	ND (2010-11) M	9.5^{D} (2010-11) M	ND (2010-2011) M	12.5^{D} (2010-11) M	MV14
Coryphaena hippurus	ZCO (OAX)	60^{D} (2010-11) M	ND (2010-11) M	18^{D} (2010-11) M	55^{D} (2010-11) M	14^{D} (2010-11) M	MV14

continuation

Species	Place	DDTs	HCHs	Drines	Endosulfanes	Heptacloros	Cite
Sharks							
Sphyrna lewini	ZCO (OAX)	4.4^{D} (2010-11) M	5.6^{D} (2010-11) M	5.6^{D} (2010-11) M	ND (2010-11) M	16^{D} (2010-11) M	MV14
Carcharhinus leucas	ZCO (OAX)	9.6^{D} (2010-11) M	8.4^{D} (2010-11) M	4.5^{D} (2010-11) M	ND (2010-11) M	6^{D} (2010-11) M	MV14
Turtles							
Chelonia mydas	BPZ (BCS)	7^{W} (N/E) M	4.8^{W} (N/E) M	2^{W} (N/E) M	3.8^{W} (N/E) M	-	G02
	PAO (BCS)	0.7^{W} (2005-07) S	2.8^{W} (2005-07) S	3.4^{W} (2005-07) S	ND (2005-07) S	8.6^{W} (2005-07) S	LM11
	BMGD (BCS)	ND (2005-07) S	11^{W} (2005-07) S	10^{W} (2005-07) S	ND (2005-07) S	4.5^{W} (2005-07) S	LM11
	PXN (CAM)	14^{L} (N/E) S	4.3^{L} (N/E) S	17^{L} (N/E) S	12^{L} (N/E) S	2^{L} (N/E) S	GB14
	PXN (CAM)	729^{L} (N/E) H	335^{L} (N/E) H	1470^{L} (N/E) H	672^{L} (N/E) H	78^{L} (N/E) H	GB14
Lepidochelys olivacea	BPZ (BCS)	8.6^{W} (N/E) M	14^{W} (N/E) M	3^{W} (N/E) M	14^{W} (N/E) M	-	G02
Caretta caretta	BPZ BS)	3^{W} (N/E) M	3^{W} (N/E) M	3^{W} (N/E) M	3^{W} (N/E) M	-	G02
Eretmochelys imbricata	SCY (CAM)	25^{L} (N/E) S	6.6^{L} (N/E) S	17^{L} (N/E) S	^{9L} (N/E) S	19^{L} (N/E) S	GB14
Eretmochelys imbricata	SCY (CAM)	8066^{L} (N/E) H	665^{L} (N/E) H	4818^{L} (N/E) H	1132^{L} (N/E) H	1284L (N/E) H	GB14
Birds							
Athene cunicularia	DRC (SON)	48^{W} (N/E) H	14^{W} (N/E) H	0.5^{W} (N/E) H	-	8.26^{W} (N/E) H	GH06
Zenaida macroura	DRC (SON)	61^{W} (N/E) H	32^{W} (N/E) H	3.7^{W} (N/E) E	-	2.7^{W} (N/E) H	GH06
Sula leucogaster	SGJ (SON)	53^{W} (2006) H	-	-	-	-	M09
	SPMT (SON)	52^{W} (2006) H	-	-	-	-	M09
	SIF (SIN)	34^{W} (2006) H	-	-	-	-	M09
	IISB (NAY)	38^{W} (2006) H	-	-	-	-	M09
	IMT (JAL)	49^{W} (2006) H	-	-	-	-	M09
	IPR (JAL)	22^{W} (2006) H	-	-	-	-	M09
	IPB (COL)	12^{W} (2006) H	-	-	-	-	M09
	IMP (MCH)	14^{W} (2006) H	-	-	-	-	M09
Pandion haliaetus	LSI (BCS)	0.9^{W} (2001) S	0.4^{W} (2001) S	2.3^{W} (2001) W	0.09^{W} (2001) S	0.2^{W} (2001) H	RR-RE11
Phalacrocorax sp.	AEP (SIN)	5824^{D} (1991) M	284^{D} (1991) M	13.5^{D} (1991) M	1.2^{D} (1991) M	-	C02
	AEP (SIN)	12047^{D} (1991) H	1200^{D} (1991) H	45^{D} (1991) H	1.1^{D} (1991) H	-	C02
Mammals							
Delphinus capensis	BGY (SON)	18000^{L} (1999) B	-	-	-	-	GR14
Zalophus californianus	GCFR (N/A)	2750^{L} (2005-06) B	35^{L} (2005-06) B	-	-	-	NT07
Crocodiles							
Crocodylus moreletti	CHPTN (CAM)	1800^{L} (2005-06) S	550^{L} (2005-06) S	-	ND (2005-06) S	-	GJ12

García-Besné *et al*. (2014) reported concentrations of POCs hundreds of times higher in eggs of *E. imbricata* and *C. mydas* than in blood. However, long-term effects on the embryo exposure to these contaminants via the mother have not been thoroughly studied yet.

Effect of PBTSs on aquatic organisms and human health

The effect of acute exposure to many substances on different aquatic organisms (micro and macroinvertebrates, fish, reptiles, amphibians, birds, and mammals) has been well studied. Despite this, the effect of such exposure on wild organisms is not yet well known, mainly due to the technical complexity of the field experiments, and to the fact that, in the vast majority of cases, the concentrations in which the pollutants occur in different environmental matrices are barely noticeable, which means their effects are not observable in the short term. However, these compounds' bioaccumulation in different tissues reveals chronic exposure to wild organisms.

The concentration of contaminants in different tissues can be correlated with direct observations made in the field (biometric, reproductive and behavioral, among others), or compared with reference values for residual concentrations in tissue or tissue residue guidelines (TRG), which establish the maximum concentration (quantitatively) of a substance in different tissues (including food) that is recommended for wildlife protection (CCME, 1998). These TRGs are based on many field and laboratory experiments and aim to link measurements made in wild organisms with robust experimental toxicological information to predict the populations under study's potential risks.

This review shows the reported concentrations of the main PBTS in many aquatic species (Tables 1-3). Weng & Wang (2017) found that Cd concentrations between 17-27 µg g^{-1} dw in *Crassostrea hongkongensis* were associated with low fertility rates and slow larval growth compared to organisms sampled at reference sites. In the present review, we found that, in 93% of cases, Cd's average concentration in bivalves was 0.2-17 µg g^{-1} dw, reaching up to 22, 28, 36, 42, and 57 µg g^{-1} dw in particular sites and dates. Wiener *et al*. (2003) indicated that Hg concentrations of 6-20 µg g^{-1} ww in muscle tissue of adult fish were associated with sublethal effects, including behavioral alterations, brain lesions, and deterioration of gonadal development.

All cases of Hg in fish muscle reviewed here were below this concentration. In birds, Ceyca *et al*. (2016)

indicated that Hg concentrations of 0.5-1 µg g^{-1} ww in sea bird eggs could cause mortality, malformations, and neurological damage. Ceyca *et al.* (2016) also reported maximum Hg values of 0.55-187 µg g^{-1} ww in eight species of seabirds collected on the coast of Sinaloa. Zhang *et al*. (2013) reported that the lowest probable adverse effect (LOAEL) of Hg on aquatic birds' blood occurred at 0.73 µg g^{-1} ww. Lerma *et al.* (2016) reported Hg values of 1.1 ppm dw in the blood of *Sula leucogaster* collected on the coast of Sinaloa.

Niño-Torres *et al*. (2009) reported that DDT values <980,000 µg g^{-1} lw in fatty tissue of marine mammals were associated with premature deliveries, while PCB concentrations <17 µg g^{-1} lw in fatty tissue could cause endocrine disruption and immunosuppression. Gallo-Reinoso *et al.* (2014) reported DDT concentrations of 21 µg g^{-1} lw in the biopsy of a common dolphin sampled in the Gulf of California. Regarding TRGs, the Canadian Council of Ministers of the Environment (CCME) establishes a reference value of 0.033 µg g^{-1} ww for Hg in food for all wildlife that consumes aquatic organisms. The reference value for ∑DDTs is set at 14 ng g^{-1} ww in food. In the present work, we found that 41% of bivalves, 76% of crustaceans, 76% of fish, and 96% of sharks and rays exceeded the limit for Hg, while 15% of bivalves, 26% of crustaceans, and 40% of fish exceeded the limit for ∑DDTs. These results show the risks that wildlife face in aquatic ecosystems in Mexico.

The potential risk to human health from the consumption of PBTS through food consumption of aquatic origin is a global concern. Various diseases have been associated with exposure to low concentrations of contaminants, such as cancer, neurotoxicity, cardiovascular diseases, endocrine disruption, and immunological disorders (Dórea, 2008). As a result, various national and international agencies have established maximum permissible limits, seeking to protect consumers from the adverse effects of consuming toxic residues. The USEPA, for example, establishes maximum permissible limits of 1 and 0.1 µg g^{-1} ww for Cd and Hg in fish, respectively. The European Community (EC) establishes maximum permissible of 1, 0.5, and 0.5 µg g^{-1} ww for Hg, Cd, and Pb in fish muscle, respectively. In contrast, the INECC (Mexico) establishes maximum permissible limits of 1, 0.5, and 1 µg g^{-1} ww for Hg, Cd, and Pb, respectively.

In the present review, we found that close to 90% of the cases of mollusks, crustaceans, fish, sharks, and rays did not involve average concentrations exceeding the limit of 0.5 µg g^{-1} ww for Hg. In the case of fish, only *Caranx caninus* collected in Topolobampo Bay, Sinaloa, in 2004, exceeded this limit, with a Hg concentration in the muscle of 1 µg g^{-1} ww. However, about 35% of shark cases exceeded this value, even exceeding the reference value of 1 µg g^{-1} ww for Hg. An extreme case involved a specimen of *S. zygaena* collected in the Gulf of California, with Hg levels exceeding 8 µg g^{-1} ww. In contrast, about 90% of fish, sharks, and crustaceans showed Cd levels in muscle lower than 0.5 µg g^{-1} ww. Regarding mollusks, about 45% of the organisms reviewed exceeded the limit of 0.5 µg g^{-1} ww for Cd, while 18% exceeded 1 µg g^{-1} ww, and close to 20% exceeded the limit of 1 µg g^{-1} ww for Pb. For ∑DDTs, the EC establishes a maximum permissible limit of 1000 ng g^{-1}, while the Codex Alimentarius Guidelines of the Food and Agriculture Organization of the United Nations (USFDA) and the World Health Organization (WHO) establishes a maximum permissible limit of 5,000 ng g^{-1}. All the cases reviewed in this work were below the limit of 1,000 ng g^{-1} for ∑DDTs.

The potential risk of fish consumption to human health can be evaluated considering a risk ratio (HQ) defined by the equation $HQ = E / RfD$ (Newman & Unger, 2002); where RfD is the reference dose (in µg kg^{-1} kg^{-1} of weight d^{-1}), and E is the level of exposure or consumption of the contaminant, which is calculated using the equation $E = C \times I / W$, where C is the concentration of the contaminant (in µg g^{-1} ww), I is the *per capita* intake rate (in g d^{-1}), and W is the average weight (in kg). Considering an RfD of 0.3, 0.5, 0.5, 1, and 3.5 for ∑HCHs, ∑DDTs, Hg, Cd, and Pb, respectively, I of 30 g d^{-1} for Mexicans consumers, and W of 70 kg, only in about 5% of cases does the value of HQ exceeds 1 for all contaminants. However, in some communities with high fish consumption rates, with an RfD of 200-400 g/d, the risk increases considerably, especially in infants and pregnant women (Zamora-Arellano *et al.*, 2017; Astorga-Rodríguez *et al.*, 2018).

CONCLUSIONS

This review synthesizes a large amount of information on the biomonitoring of the main PBTS in aquatic ecosystems in Mexico, and this information can serve as a basis for future research. In general, the levels of pollution found in Mexico's aquatic ecosystems are similar to those found in other regions of the world. However, given Mexico's enormous ecological wealth, especially its aquatic ecosystems, there is insufficient information on environmental pollutants. Moreover, there is a great disparity in the amount of information available between the country's different areas. Just the Gulf of California concentrates about 80% of the studies reviewed here, which shows the need to increase research efforts in the country's currently neglected areas such as the Central Pacific or the

Mexican Caribbean, whose participation in this work did not exceed 5%.

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