

Effects of pollutant discharges on the aquatic mammal populations of Terminos Lagoon, Campeche, Mexico

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Abstract

Terminos Lagoon was made a protected ecosystem by the Mexican government in 1994, but it is also the most important center for oil extraction and transportation companies in the Gulf of Mexico, besides several rivers carrying on city effluents along with agricultural and cattle residuals into the lagoon. The main goal of this study is to analyze the potential for aquatic mammal species such as bottlenose dolphins, manatees and river otters to be environmental sentinels. While data showed that levels of heavy metals and pesticides contained in bottlenose dolphins blubber samples – lead (< 1.1 mg/l) and cadmium (< 0.08 mg/l) – were low, heptachlor epoxies showed the highest values (359.67 $\mu\text{g/g}$), followed by endosulfan sulfate and methoxychlor, p-DDE, which was recorded in a sample with concentrations of 239.542 $\mu\text{g/g}$, along with p 'p-DDD and p' p-DDT, with values of 1.2 and 13.63 $\mu\text{g/g}$, respectively. Analysis of heavy metals in Manatee bones showed that zinc, lead and cadmium presented higher concentrations (102.60 ± 27.19 $\mu\text{g/g}$, 14.54 ± 1.77 $\mu\text{g/g}$ and 3.92 ± 0.5 $\mu\text{g/g}$, respectively). Values of both heavy metals and pesticides in samples were low compared to those recorded in other studies. Water quality analysis at the fluvial-lagoon system POM-Atasta found concentrations of BOD₅ of up to 270 mg/l, COD 640 mg/l and SST 245 mg/l. These environmental and biological parameters, combined with the health assessment results for bottlenose dolphins, indicate that dolphins have a good health condition but human activities such as agriculture, livestock, fishing and boat traffic seem to have a chronic impact on the ecosystem and, subsequently, on the aquatic mammals found in Terminos Lagoon.

Keywords: bottlenose dolphins, manatee, pesticides, Terminos Lagoon.



1 Introduction

Terminos Lagoon and its associated wetlands are one of the most important ecological and fishing regions of Mexico. The primary productivity of this ecosystem extends to the adjacent marine ecosystem, and close to 80% of the fish in the Campeche Sound depends on the lagoon for reproduction and food (Sánchez-Velasco *et al.* [1]). In terms of biodiversity, Términos Lagoon is one of the most extensive, best conserved and most important wetlands (5,000 km²) in Mexico and in Mesoamerica.

Socio-economic development in Terminos Lagoon has increased considerably in the last few decades due to the growth of the oil industry (Vázquez-Luna [2]). Worldwide, Mexico ranks third place in oil production, first place in offshore oil production, and ninth in crude reserves. Currently, 80% of its production comes from the Terminos Lagoon region and adjacent marine area. One of the consequences of this increase has been the heavy metal contamination, which anthropogenic input has exceeded natural levels derived from geological processes (Vázquez *et al.* [3], Sastre Conde *et al.* [4], Gold-Bouchot *et al.* [5]). Besides the agricultural activities inland harvesting rice, and sugar cane using a wide variety of chemical pesticides is very important in this region. The seasonal sessions for insect control have been an important source of pesticides in Mexican coastal areas (Albert [6]).



Figure 1: Study area in the Gulf of México.



2 Methods

2.1 Biological and field sampling

In order to get samples from live bottlenose dolphins a capture-release program and tissue sampling from stranded dolphins and manatees was developed. All marine mammal species are protected under Mexican law, therefore this study operated with a federal governmental permit. Blubber samples obtained from dolphins and manatees were frozen until the laboratory analysis procedures. Water samples were taken during boat surveys along Terminos Lagoon, stored on ice and analyzed according with de Environmental Mexican regulations NMX (NMX-AA-028-SCFI-2001) for water analyses.

2.2 Samples analyses

Dolphin and manatee blubber samples were kept frozen until analysis. These samples were later processed according to EPA 3051 method.

Manatee bone samples were analyzed following metal determination by wet digestion procedures (Helrich [7]). Atomic absorption spectrophotometer (Perkin-Elmer, model Analyst 3110 and 100) was used with air-acetylene flame and hydrides generation. Calibration was performed with each element's standards of. Blank replicate, calibration curves and reference material from the National Institute of Standards and Technology (NIST) were used to verify the accuracy of the procedure.

3 Results and discussion

3.1 Dolphin samples

The content of heavy metals in bottlenose dolphins blubber samples were as follows: lead (< 1.1 mg/l) and cadmium (< 0.08 mg/l) were low, while heptachlor epoxies showed the highest values (359.67 $\mu\text{g/g}$), followed by endosulfan sulfate and methoxychlor, p-DDE was recorded in a sample with concentrations of 239.542 $\mu\text{g/g}$, along with p' p-DDD and p' p-DDT with values of 1.2 and 13.63 $\mu\text{g/g}$ respectively (table 1).

3.2 Heavy metals contents in Manatee bone samples

Analysis of heavy metals in Manatee bones shows that zinc, lead and cadmium presented higher concentrations (102.60 ± 27.19 $\mu\text{g/g}$, 14.54 ± 1.77 , $\mu\text{g/g}$ and 3.92 ± 0.5 $\mu\text{g/g}$ respectively) (Romero-Calderón *et al.* [8]). Values of both heavy metals and pesticides in biopsies were low compared to those recorded in other studies. Analyses of heavy metals in Manatee bones shows that zinc, lead and cadmium presented higher concentrations (102.60 ± 27.19 $\mu\text{g/g}$, 14.54 ± 1.77 $\mu\text{g/g}$ and 3.92 ± 0.5 $\mu\text{g/g}$, respectively) (Romero-Calderón *et al.* [8]). Values of both heavy metals and pesticides in biopsies were low compared to those recorded in other studies.



Table 1: Pesticides values in bottlenose dolphin blubber samples collected during 2010–2011.

Sample	Chemical compound	Concentration (µg/g)
Dolphin 1	Epoxide Heptachlor	359.672
	Metoxichlor	22.891
Dolphin 2	Endosulfan II (b)	16.260
	Endrin Ketone	16.786
	Epoxide de Heptachlor	287.993
	Gama HCH	8.241
	pp DDT	13.637
Dolphin 3	Endosulfan II (b)	27.390
	Endosulfan Sulfate	37.290
	Endrin Ketone	19.512
	Epoxide Heptachlor	174.553
	Gama HCH	13.818
	Heptachlor	12.568
	Metoxichlor	52.580
Dolphin 4	Dieldrin	64.172
	Endrin Ketone	16.643
	Epoxide de Heptachlor	275.322
Dolphin 11	Dieldrin	2.353
	Pp DDT	1.441
Dolphin 12	Endosulfan Sulfate	3.052
	Endrin	0.803
	Dieldrin	0.696
	Endosulfan I (a)	0.855
	pp DDE	1.401
Dolphin 13	Endosulfan Sulfate	20.628
	Beta HCH	44.984
	pp DDE	22.725
Dolphin 14	Pp DDT	16.681
Dolphin 15	Delta HCH	13.778
	pp DDE	1.633
	Endosulfan Sulfate	4.614
	Endrin aldehyde	3.835
	Heptachlor	1.108
	Metoxichlor	17.764
Dolphin 16	Delta HCH	57.977
	Aldrin	0.668
	Endosulfan I (a)	1.106
	Endosulfan II (b)	2.065

Table 2: Heavy metals values ($\mu\text{g/g}$) in *Trichechus manatus manatus* bone samples found in Campeche, México.

Locality	Sex	Cd	Cr	Cu	Pb	Ni	Zn
Campeche	M	3.528	8.844	3.878	12.767	9.206	77.414
Campeche	M	3.569	6.850	3.473	13.337	8.196	81.418
Campeche	M	4.608	8.024	4.068	15.622	9.601	120.367
Campeche	I	3.967	10.012	4.114	16.453	10.265	131.220
Mean		3.918	8.432	3.883	14.545	9.317	102.605
Std. Dev.		0.501	1.334	0.292	1.772	0.866	27.189

In the Terminos Lagoon area, high Cadmium has not been found in fish and sea turtles egg samples, but in shrimp, bottlenose dolphins (blubber) and manatee (blubber) the mean concentrations were 0.1027, 0.3069 and 0.0159 ppm, respectively (Benítez *et al.* [9]). Delgado-Estrella *et al.* [10] reported low levels in cadmium and no traces of lead, however zinc concentrations were very high.

Benítez *et al.* [9] reported that cadmium, lead and chrome highest levels were found in sediments and some crustaceans near Ciudad del Carmen, Campeche when they performed a heavy metals spatial analysis at the Terminos Lagoon, suggesting an anthropogenic source for these pollutants.

The concentrations in all metals in bone tissues were predominantly higher, compared with distinct types of bones in other aquatic mammal species around the world.

Differences were found in metal concentrations of manatees between the two regions Caribbean and Gulf of México. In the x Gulf of Mexico group, Cr, Cu, Zn and Pb showed higher concentrations. The use and production of fertilizers and pesticides, domestic effluents and production of oil in this region (Páez-Osuna *et al.* [11]) could be the main source of these metals. Earlier studies have shown higher concentrations of Pb in fish, shrimp and crocodiles of the Gulf of Mexico (Vázquez *et al.* [12], Trillanes *et al.* [13]).

3.3 Water samples

Water quality analysis at fluvial-lagoon system POM-Atasta found concentrations of BOD₅ up to 270 mg/l, COD 640 mg/l and SST 245 mg/l, these high concentrations can be explained as the area is located next to the industrial fishing port and the river flows. This area is a coastal system that has high influence by tides and fluvial stream conditions because the presence of many small and medium cities along the river basin.

4 Conclusions

With these results, it is clear that the long-term effects of pesticides and heavy metals are reflected in aquatic mammals inhabiting Terminos Lagoon. For this reason, the continuous monitoring of these species is vital to understanding the historical and current adverse effects of human activities in the region, which is

considered to be an area of great environmental importance for the conservation of the Southern Gulf of Mexico flora and fauna. The deterioration of dolphins and manatees habitat conditions for reflects the degree of conservation of natural resources which can be used as a tool for the conservation of wetlands.

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