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Environmental Contamination and Toxicology

Distribution and Concentration of Trace Metals in Tissues of Three Penaeid Shrimp Species from Altata-Ensenada del Pabellón Lagoon (S.E. Gulf of California)

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In the last decades, accelerated population growth in coastal areas has increased in comparison with inland areas; such growth is associated to environmental impacts from a wide range of sources: industrial activity, agriculture, aquaculture and domestic effluents. These activities produce important amounts of toxic materials like pesticides, hydrocarbons and trace metals. Important sources of trace metals to the environment are solid wastes and wastewaters (Nriagu and Pacyna 1988). One important concern is that fishery products in Mexico constitute high revenues, in this sense, some tropical countries are suffering multi-million dollar losses every year for not complying with standards set in importing countries and hence their products refuse entry into the market. Some of these losses were obviously attributable to lack of information on contaminant standards (Nauen 1983).

Altata-Ensenada del Pabellón lagoon is located in the central part of the state of Sinaloa, Mexico (Fig. 1); the water body is impacted mainly by wastes from intensive agriculture, industry and the domestic effluents from the surrounding towns. Previous investigations on the presence of trace metals in penaeid shrimps from the lower Gulf of California have focused on wild shrimps from estuarine (Páez-Osuna and Ruiz-Fernández 1995a; 1995b) and marine environments (Páez-Osuna and Tron-Mayen 1995) and from farmed shrimps (Páez-Osuna and Tron-Mayen 1996; Méndez et al. 1998). In the present study, concentrations of Cd, Cu, Fe, Mn, Pb and Zn in exoskeleton, hepatopancreas and muscle of three species of penaeid shrimps are presented. These shrimp species are the most important resources from fisheries and aquaculture in northwestern Mexico.

MATERIALS AND METHODS

Shrimp samples were obtained from local fishermen in Altata-Ensenada del Pabellón lagoon between December 10, 1998 and January 22, 1999. Shrimps were identified according to Hendrickx (1995). Depending on the availability of specimens, pooled samples (consisting of 30-44 shrimps) of organisms of the same species, size interval and sex were used for the analysis (Table 1). Size intervals of specimens from the different species were: for *F. californiensis* 12.5 to 16.8 cm, for *L. stylirostris* 15.4 to 19.4 cm and for *L. vannamei* 13.9 to 16.6 cm.

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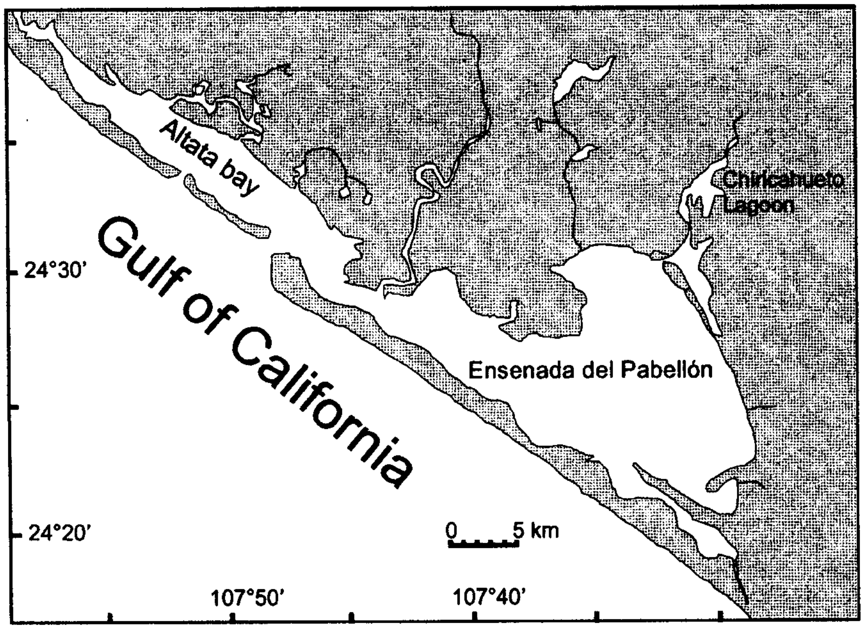

Figure 1. Location of sampling sites of penaeid shrimps in the SE Gulf of California.

Samples were stored frozen (-25°C) before analysis. All glassware and plastic utensils were acid-washed thoroughly (Moody and Lindstrom 1977). In the laboratory, shrimps were measured, weighed and dissected for the extraction of hepatopancreas, muscle and exoskeleton. Samples were freeze-dried (Labconco Freeze-dry System) at –40°C and 133 x 10^{-3} mbar (72 h), followed by automatic grinding (Retsch RM100 mortar grinder) for 10 min and acid digestion (quartz distilled concentrated HNO_3) of duplicate subsamples with a microwave digestion system (CEM, MDS-2000), according to the procedure given by UNEP (1993).

Analyses were made by flame atomic absorption spectrophotometry for Cu, Fe, Mn and Zn; in the case of Cd and Pb, graphite furnace atomic absorption spectrophotometry was used. All determinations were carried out in a Varian SpectrAA 220 spectrophotometer. Levels of the different elements were expressed as $\mu g\ g^{-1}$ on a dry weight basis. In order to assess the precision of the employed method, reference materials (MA-A-3/TM and SRM 2976) were analyzed (IAEA 1987). Concentrations of analyzed elements were within certified values of reference materials. Differences between average metal concentrations in tissues of male and female shrimps were assessed by a t-Student test ($p<0.05$). In the case of average metal concentrations in every tissue, significant differences among species were defined by a one-way ANOVA ($p<0.05$) (Miller and Miller 1988).

Table 1. Biometric data of the penaeid shrimps from Altata-Ensenada del Pabellón lagoon (SE Gulf of California).

Species	Sex	Common name	Average length (cm)	Average weight (g)	Groups	Date
F. californiensis	M	Yellow leg shrimp	13.4 ± 0.3	14.7 ± 1.3	2 (30, 32)	Jan, 1999
F. californiensis	F	Yellow leg shrimp	15.0 ± 1.5	22.0 ± 6.8	2 (42, 40)	Jan, 1999
L. stylirostris	M	Blue shrimp	17.1 ± 1.6	36.7 ± 8.0	3 (40, 42, 40)	Dec, 1998
L. stylirostris	F	Blue shrimp	17.6 ± 1.7	38.6 ± 10.3	3 (36, 32, 30)	Dec, 1998
L. vannamei	M	White leg shrimp	15.8 ± 0.7	24.6 ± 3.1	2 (42, 38)	Jan, 1999
L. vannamei	F	White leg shrimp	15.1 ± 1.1	21.8 ± 4.8	2 (44, 42)	Jan, 1999

M, male; F, female; numbers within parentheses indicate the individuals per group.

RESULTS AND DISCUSSION

All the specimens were in an adult and intermoult stage. Average length and weight of individuals were higher in males of *Litopenaeus vannamei*; the opposite tendency occurred in *Farfantepenaeus californiensis* and *Litopenaeus stylirostris* (Table 1). An overall ranking of average trace metal levels in the analyzed tissues resulted as hepatopancreas>exoskeleton>muscle for Cu, Fe and Pb; in the case of Cd and Zn the sequence was hepatopancreas>muscle>exoskeleton; and in the case of Mn the order was exoskeleton>hepatopancreas>muscle. With the exception of Mn, it can be seen that hepatopancreas functions as a target organ for metal accumulation. In this sense, Del Wayne et al. (1977) analyzed Cd levels in the pink shrimp *Penaeus monodon* under laboratory conditions; they found that Cd concentrations in the analyzed tissues followed an order hepatopancreas> exoskeleton>muscle.

Kargin et al. (2001) found that hepatopancreas contained the highest levels of Cd, Cu, Fe and Zn; they attributed the high levels of metals in hepatopancreas to the binding of metals to methalotionein proteins. In the particular case of Mn, exoskeleton was the tissue with the highest levels; a similar trend was found in *F. californiensis* (Páez-Osuna and Tron-Mayen 1995) and in the lobster *Panulirus inflatus* (Páez-Osuna et al. 1995) from the northwest coast of Mexico. The above results are supported by the fact that, in general, Mn concentrations are highest in calcified tissues of crustaceans (Eisler 1981). The highest metal levels in the muscle tissue of analyzed species corresponded to Fe and Zn while the lowest values corresponded to Cd and Pb (Figs. 2a, 3a and 4a).

For this tissue *F. californiensis* showed the highest levels of Cd; *L. stylirostris* accumulated the highest levels of Cu, Pb and Zn and *L. vannamei* showed the

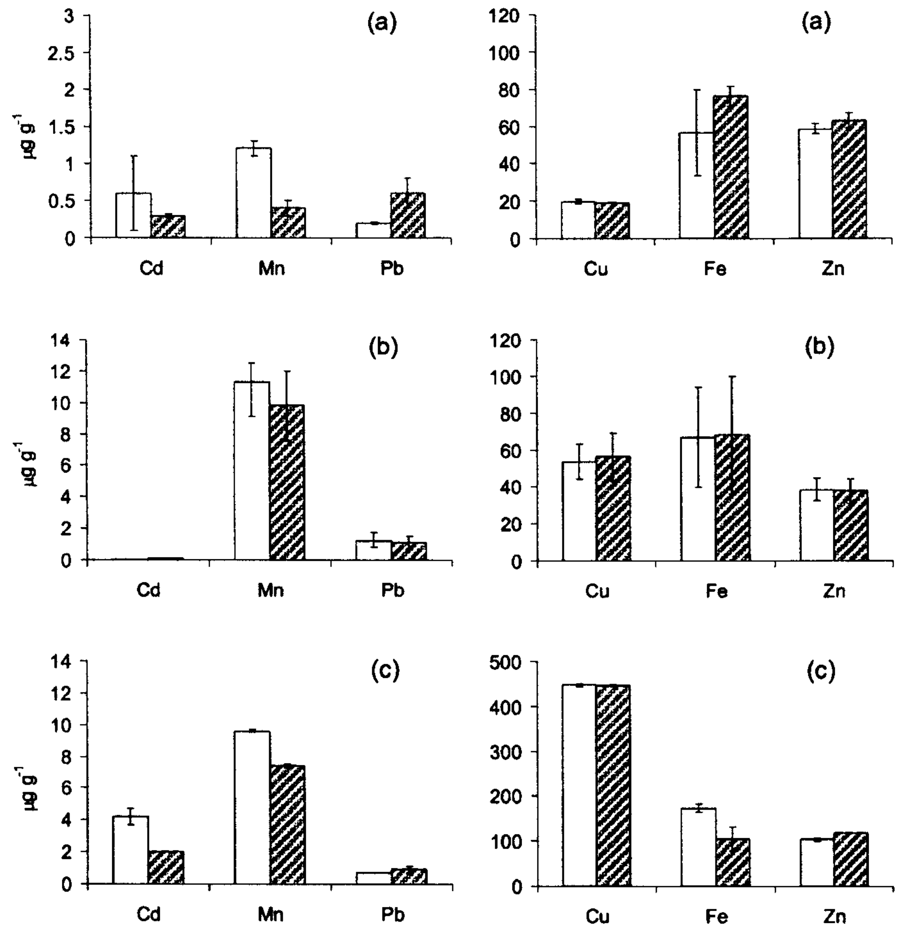

Figure 2. Concentration of trace metals in diverse tissues of female (▨) and male (□) shrimps L. stylirostris (a-muscle, b-exoskeleton, c-hepatopancreas) from Altata-Ensenada del Pabellón lagoon.

highest values of Fe and Mn. In the case of exoskeleton, Fe and Cu were the metals with the highest levels while Cd and Pb were in the lowest concentrations (Fig. 2b, 3b and 4b). Regarding hepatopancreas, Cu and Fe occurred in high values, contrasting with low concentrations of Pb (Figs. 2c, 3c and 4c). As can be seen from Figs. 2 to 4, the overall Cd concentrations were relatively low; in this sense, a number of studies have shown that the concentrations of Cd in the aquatic organisms depend mainly of their environmental levels (Amiard et al. 1987; Bryan and Langston 1992), and since no role of this element in metabolic activities is known, its levels expected to be lower than other metals participating in biochemical and physiological processes.

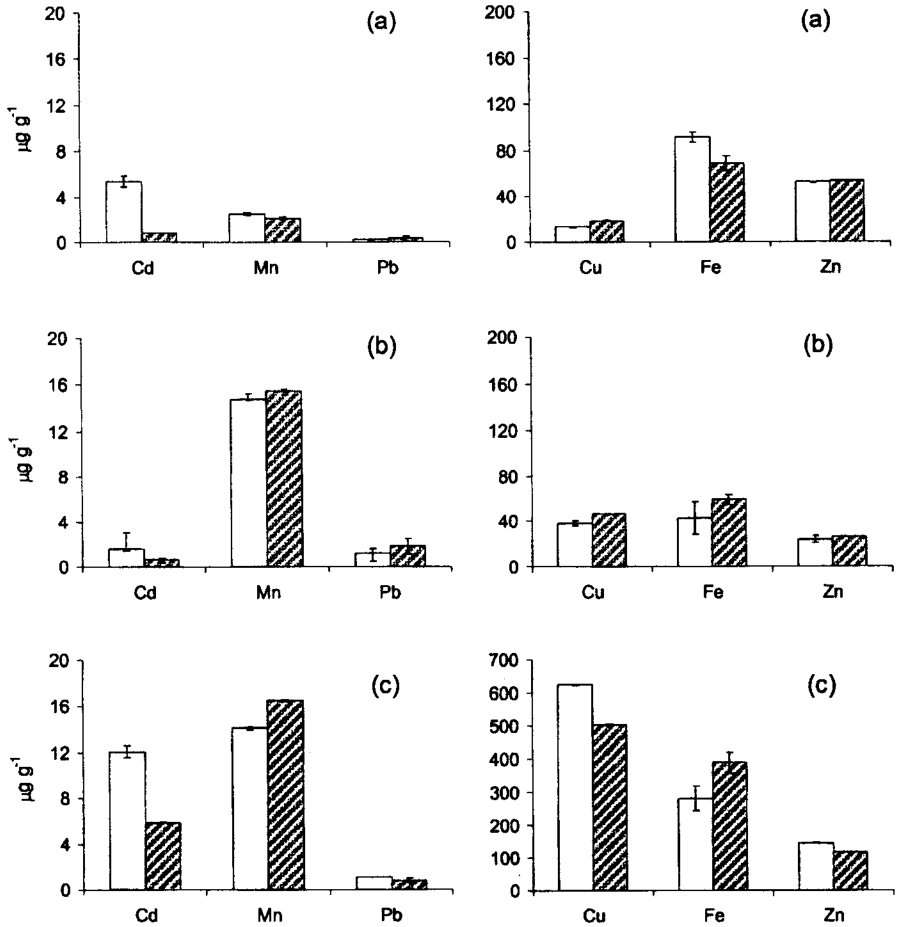

Figure 3. Concentration of trace metals in diverse tissues of female (▨) and male (☐) shrimps *L. vannamei* (a-muscle, b-exoskeleton, c-hepatopancreas) from Altata-Ensenada del Pabellón lagoon.

After comparing metal levels in some of the shrimp species studied here with other results, it can be said that regarding the edible portion, i. e. muscle, *L. vannamei* in this study showed higher levels of Cd (an order of magnitude) than *L. vannamei* from the southern coast of Sinaloa (Páez-Osuna and Ruiz-Fernandez 1995b) and. comparable values of Cu, Fe, Mn and Zn; in comparison with *Penaeus monodon* from Sunderban, India (Guhathakurta and Kaviraj 2000) values were very similar.

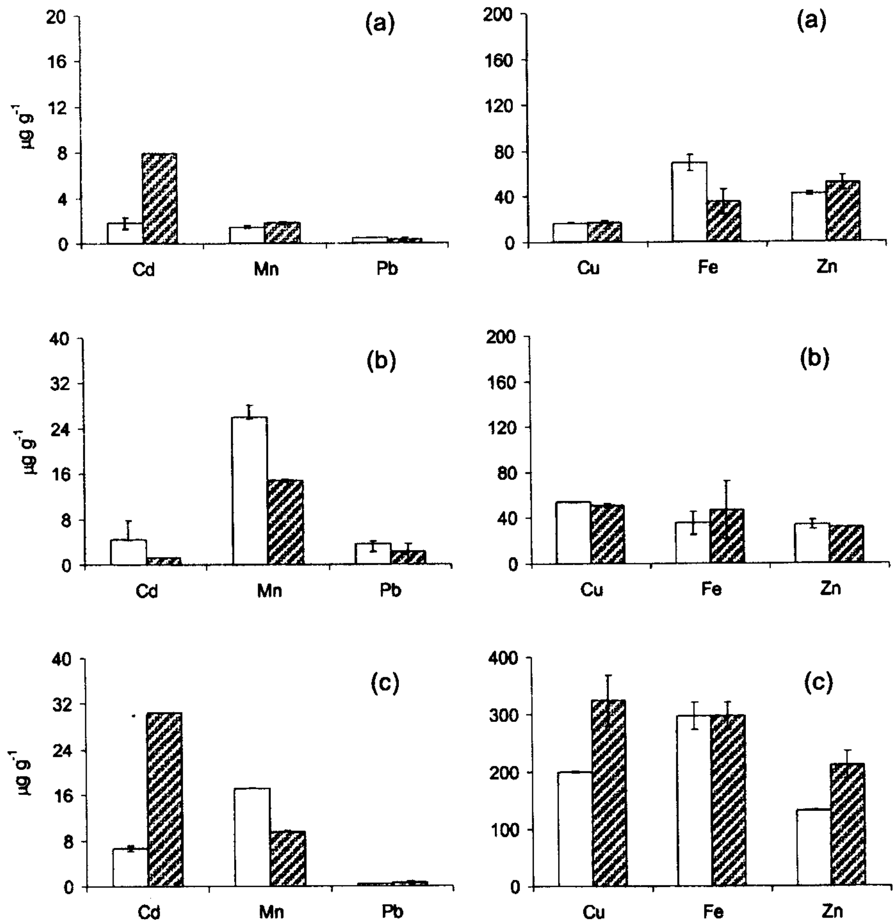

Figure 4. Concentration of trace metals in diverse tissues of female (▨) and male (☐) shrimps *F. californiensis* (a-muscle, b-exoskeleton, c-hepatopancreas) from Altata-Ensenada del Pabellón lagoon.

L. stylirostris in this study showed similar values of Cd, Cu, Fe and Zn and lower values of Mn (an order of magnitude) than the concentrations given in the same species from the southern coast of Sinaloa by Páez-Osuna and Ruiz-Fernandez (1995a).

The statistical comparison ($p<0.05$) of average trace metal levels between both sexes of *L. stylirostris* resulted in the following: in muscle, Mn levels were higher in males; an opposite trend occurred with Pb; in hepatopancreas Fe and Mn concentrated more in males, while females accumulated more Zn; in the case of exoskeleton, Cd levels were higher in females. In *L. vannamei*, Cd and Fe were significantly higher ($p<0.05$) in muscle tissue of males, while females accumulated more Zn; in hepatopancreas Cd, Cu and Zn were detected in higher amounts in males but Fe occurred more in females; for exoskeleton, only Cu showed higher levels in females. In *F. californiensis*, the statistical comparison ($p<0.05$) resulted as follows: Fe levels in muscle were higher in males; in hepatopancreas Cd, Cu and Zn were more concentrated in females and only Mn was in higher levels in males; regarding exoskeleton, Mn levels were higher in males.

In general, males and females showed significant differences ($p<0.05$) in diverse tissues and metals for every species in about the same ratio, only in the case of *L. vannamei*, males presented higher levels of metals than females in a higher ratio. In this context, it is known that females of *P. vannamei* grow faster and larger than males (Páez-Osuna and Tron-Mayen 1996), this could account as a decreasing factor for metal accumulation in females. Another factor that might contribute to differences between sexes is the diet preference but more studies on this matter are necessary. Regarding ANOVA tests of average metal concentrations among the same tissue for the analyzed species, results were as follows: in muscle; Mn had significantly higher levels ($p<0.05$) in *L. vannamei* than in *L. stylirostris*, the inverse situation occurred in the case of Zn; in exoskeleton Cd and Mn were significantly higher ($p<0.05$) in *F. californiensis* than in *L. stylirostris*; in hepatopancreas, only Cu had significantly higher levels ($p<0.05$) in *F. californiensis* than in *L. vannamei*.

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