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Distribution of Heavy Metals in Tissues of the Shrimp *Penaeus californiensis* from the Northwest Coast of Mexico

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The brown shrimp, Penaeus californiensis Holmes, is an Eastern Pacific species which is geographically distributed from San Francisco, California, U.S.A., including the Gulf of California, to Callao, Perú. In México and particularly in the Pacific Coast, this crustacean supports 75% of the commercial catch of shrimp (Hendrickx 1994).

Knowledge of the distribution of metals in isolated tissues of marine organisms is useful in order to identify specific organs that may be particularly selective and sensitive to accumulation of heavy metals (Szefer et al. 1990). This paper presents data on the levels of Fe, Mn, Ni, Cu, Cd, and Zn in five different tissues of the P. californiensis populations from the northwest coast of México. Additionally, the accumulation of metals by males and females is examined.

MATERIALS AND METHODS

One population of P. californiensis was sampled from the Mexican Pacific coast in February 1992, at one site (Fig. 1) (Lat. 25° 32′ 5″ and Long. 112° 11′) located on the Baja California continental shelf (water depth of 40 m). Adult shrimp were collected by trawl. The organisms were frozen in the field (-30°C) and transported to the laboratory where they were maintained at -20° C until analysis. The identification and sex separation of individuals were done by direct examination of morphologic characteristics (Hendrickx 1994). While choosing shrimp for the preparation of composite samples, emphasis was placed on organisms of nearly equal body size. The mean weight ± standard deviation was 23.0±1.0 and 23.3±1.7 g for the female and male group, respectively, and each one contained fifty individuals (n=50). All were in intermolt condition.

The shrimp were then dissected to separate abdominal muscle, gills, exoskeleton, hepatopancreas (or digestive gland), antennal organs and the remainder. Antennal organs include eyes, antennae and antennules, and

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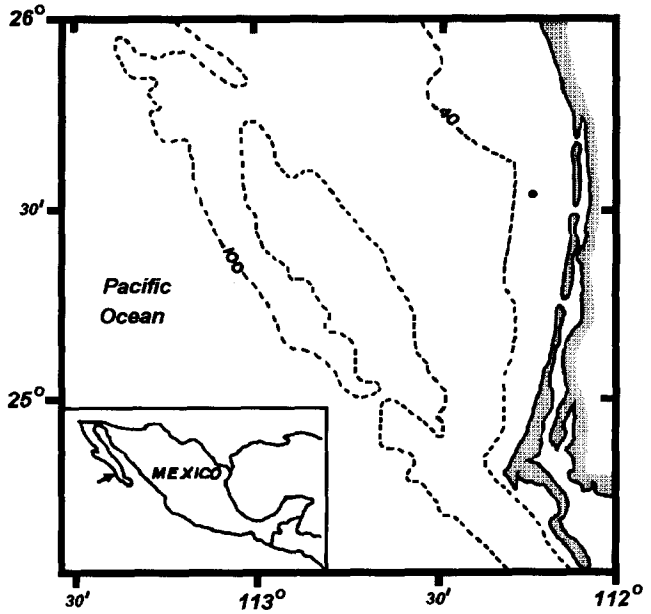

Figure 1. Collection site ( ) on the Northwest coast of México (bathymetric contours in meters).

The remainder included telson, uropods, pleopods, pereopods and the remnant portion of cephalothorax. Each tissue subsample of 50 individuals was weighed and then dried to constant weight at 60°C. Homogenization and pulverization were achieved by grinding in a teflon mortar. Triplicate tissue aliquots (duplicate in gills) of 0.5 to 1.0 g, were digested with concentrated and distilled nitric acid in silica beakers. The digests were slowly evaporated to dryness (100 °C) and the remainder dissolved in 1 M HNO_3. After centrifugation (4000 rpm), the solutions were diluted to a final volume of 20 ml and placed in acid-washed polyethylene bottles (Moody and Lindstrom 1977). They were then aspirated into a Shimadzu Model AA-630 atomic absorption spectrophotometer using standard flame conditions for each metal. The amount of each metal was determined quantitatively by the method of internal standard additions. In general, the standard addition method was used with every other sample (half of the samples) and the blanks. The samples were spiked with roughly 1, 2 and 4 times the expected amount of metal in a 1.00 ml aliquot of the dissolved sample; thus, the average intensities of the added standard additions were used to calculate the concentrations of all of the tissue samples processed together. The accuracy and precision of the method employed was estimated by means of a material shrimp homogenate MA-A-3TM (IAEA 1987). The recoveries and coefficients of variation in parentheses were as follows: Cd, 105% (6.2%); Cu, 93% (4.7%); Ni, 110% (8.4%); Mn, 67% (2.4%); Fe, 98% (3.8%); and Zn, 97% (11.8%). All metal concentrations

Table 1. Concentrations of heavy metals ($\mu g\ g^{-1}$ dry weight) in tissues of Penaeus californiensis from the Northwest Coast of México.

Tissue or organ	Percentage of tissue in whole body	Cu	Mn	Cd	Ni	Fe	Zn
			Females				
Muscle	52.9	11.8±1.8*	1.1±0.3	-	-	27±5	60±5*
Exoskeleton	8.7	32.0±2.5	4.1±1.2	0.3±0.1	4.3±0.8	76±9	96±7
Gills	1.3	63.7±4.6	3.5±0.4	2.2±0.6	1.3±0.1*	161±13	115±11
Hepatopancreas	4.0	40.3±3.9	2.9±0.5	20.8±2.8*	11.3±1.5	215±16	426±19*
Antennal	6.6	45.6±4.3	4.7±0.2	1.1±0.4	3.1±0.2	174±13	157±16
Remainder	26.5						
			Males				
Muscle	55.6	24.6±0.6*	1.1±0.3	-	-	29±5	88±8*
Exoskeleton	7.9	34.2±4.2	6.0±2.2	0.3±0.1	9.6±1.3	86±7	105±8
Gills	1.1	65.8±6.6	3.7±0.1	2.5±0.6	3.3±0.2*	135±12	128±12
Hepatopancreas	2.4	38.3±4.9	2.8±0.3	13.6±1.9*	9.0±1.3	247±20	168±11*
Antennal	6.5	54.6±5.3	4.9±0.3	1.3±0.4	3.1±0.2	143±11	136±15
Remainder	26.5						

-Below the level of detection (Cd<0.1 and Ni<0.4 $\mu g\ g^{-1}$); *Means differ (P<0.05) between males and females.

were expressed as $\mu g\ g^{-1}$ dry weight. Differences in levels of trace metals between shrimp tissues were compared by Student's t-test (Miller and Miller 1988).

RESULTS AND DISCUSSION

Measured concentrations (mean ± standard deviation) of the six metals in muscle, exoskeleton, gill, hepatopancreas, and antennal organs of females and males of P. californiensis are presented in Table 1. The concentrations of the six metals were lowest in the muscle of both female and male shrimps. The highest concentrations of Cd, Ni, Fe and Zn were observed in hepatopancreas. Concentrations of Cd and Ni in muscle tissue were below the levels of detection of <0.1 and <0.4 $\mu g\ g^{-1}$, respectively. Comparable concentrations of the six elements examined in the muscle of various shrimp species have been reported; in the wild Penaeus merguiensis and farmed Penaeus monodon (Darmono and Denton 1990), in the wild Penaeus vannamei (Páez-Osuna and Ruiz-Fernández 1994a) and the wild Penaeus stylirostris (Páez-Osuna and Ruiz-Fernández 1994b). The higher levels of Cu in this study were found in gills and antennal organs. Frenet and Alliot (1985) and Depledge et al. (1993) reported high

concentrations of Cu in gills of Palaemonetes varians and Dorippe granulata, respectively. In other crustaceans Bryan (1968), Szefer et al. (1990), Darmono and Denton (1990) and Peerzada et al. (1992) found that hepatopancreas exhibited the highest concentrations of Cu. Mn concentrations were highest in calcified tissues and lowest in muscle of the P. californiensis. This same tendency has been observed in Palaemonetes varians by Frenet and Alliot (1985).

The concentrations of Cd found in the hepatopancreas of P. californiensis were higher than values reported in other crustaceans, e.g., in the Australian shrimps P. merguiensis and P. monodon (Darmono and Denton 1990), or the benthic crab Dorippe granulata from Tolo Harbour (Hong Kong), which is considered to be polluted with Cd and other chemicals (Depledge et al. 1993). Several authors have found that squids are characterized by elevated concentrations of Cd (e.g., Martin and Flegal 1975). Penaeids have been described as oportunistic omnivores in which the diet may vary seasonally. Fish and squid form a major part of the diet of several species of penaeids (Dall et al. 1990). This may be true with P. californiensis, but, specific studies of the diet in this species do not exist. These relatively elevated concentrations in hepatopancreas of P. californiensis may be consequently explained by a natural enrichment of this element in the Eastern Pacific food chain with squid as key species. Considering the literature and results obtained here, one can suggest that high concentrations of Cd might be promoted by natural factors, though the influence of some anthropogenic factor cannot be totally excluded.

Several authors (e.g., Hepper 1967) have reported different rates of growth for lobsters; in general, they found that males grow faster and larger than females. This same tendency was infered by Nuñez-Pasten (1988) in P. californiensis, who noted that very small differences (<1 % in weight) are evident starting from sizes of 23 mm CL (cephalothorax length) (7.7 g). Therefore, only small differences in heavy metal accumulation between individuals of different sex could occur because of the variation in growth rates between the sexes. With the pattern of faster growth in males, one would suspect this to infer small decreased trace metal levels in males compared with females, if the metabolism and the metal quantities ingested were similar. This was noted in P. californiensis only for Cd and Zn in the hepatopancreas. Although, in the case of Cu and Zn in the abdominal muscle, and Ni in the gills, the reverse tendency was present (Table 1). Sex-based differences in trace metal concentrations may similarly be due also to differences in the preferred diets of males and females, though in P. californiensis detailed information on diet is unknown.

The relative proportions of each tissue in females and males of P. californiensis are shown in Table 1. Muscle represented 52.9 and 55.6%

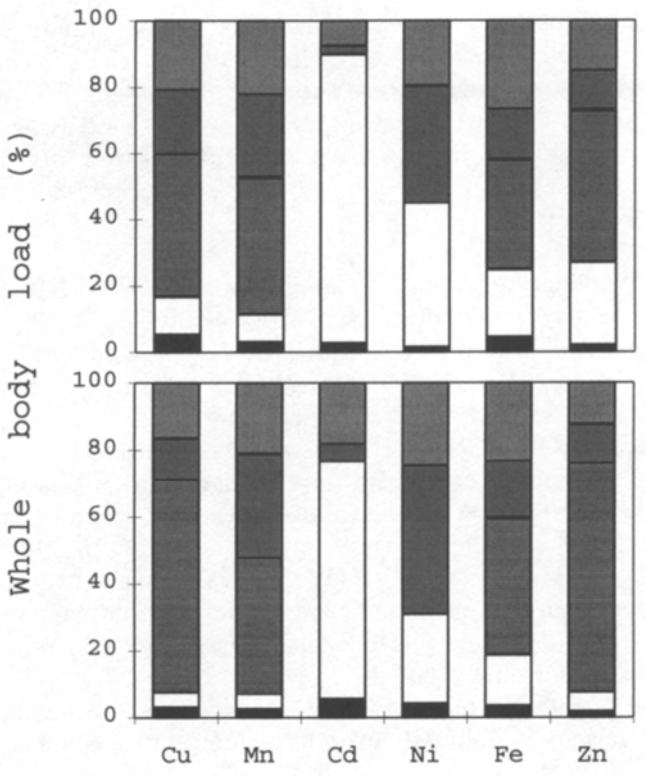

Figure 2. Percentage distribution of the body loads of heavy metals among the tissues of Penaeus californiensis. Exoskeleton, ■ ; Muscle, ■ ; Gills, ■ ; Hepatopancreas, □ ; Antennal organs, ■ . Females (above) and males (under), respectively.

of the total body weight in females and males, respectively, while exoskeleton 8.7 and 7.9%. The remaining body parts constituted 26.5% in both sexes. The hepatopancreas and gills constituted only 2.4-4.0 and 1.1-1.3%, respectively, and the antennal organs represented 6.6% of the total body. With the exception of the remainder that was not analyzed for heavy metals, the relative intra-organismal distributions of the elements were estimated using the concentrations obtained and the relative tissue proportions (Fig. 2). Muscle contained the highest load of Cu (43.2-63.6%), Mn (40.6-41.3%), Fe (33.2-40.8%) and Zn (46.0-68.6%), while the hepatopancreas contained Cd at 71.1-87.0%. In a comparison between sexes, hepatopancreas of females contained higher whole-body metal proportions than males; in the case of Cu, Fe and Zn in abdominal muscle the opposite was observed. The exoskeleton of females also contained higher load of Cu than males, and vice versa in the case of Mn, Cd, Ni and Fe.

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REFERENCES

Bryan GW (1968) Concentrations of zinc and copper in the tissues of decapod crustaceans. J Mar Biol Assoc (UK) 48:303-321

Dall W, Hill BJ, Rothlisberg PC, Sharples DJ (1990) The biology of the Penaeidae. In: Blaxter JHS, Southward AJ (eds) Advances in Marine Biology, vol 27, Academic Press, San Diego, p 489

Darmono D, Denton GRW (1990) Heavy metal concentrations in the banana prawn, Penaeus merguiensis, and leader prawn, P. monodon, in the Townsville region of Australia. Bull Environ Contam Toxicol 44:479-486

Depledge MH, Forbes TL, Forbes VE (1993) Evaluation of cadmium, copper, zinc, and iron concentrations and tissue distributions in the benthic crab, Dorippe granulata (De Haan, 1841) from Tolo Harbour, Hong Kong. Environ Pollut 81:15-19

Frenet M, Alliot A (1985) Comparative bioaccumulation of metals in Palaemonetes varians in polluted and non-polluted environments. Mar Environ Res 17:19-44

Hendrickx ME, (1994) Los Camarones. In: Fisher W (ed) Identification sheets for the tropical Central Pacific. FAO, Roma, (In press)

Hepper BT (1967) On the growth at moulting of lobsters (Homarus vulgaris) in Cornwall and Yorkshire. J Mar Biol Assoc (UK) 47:629-643

IAEA, International Atomic Energy Agency (1987) Intercalibration of analytical methods on marine environmental samples. Trace element measurements on shrimp homogenate. Results of the Worldwide Intercomparison Run MA-A-3TM and of the MEDPOL Exercise MA (5) MED 86/TM. Report No. 34, Monaco

Martin JH, Flegal AR (1975) High copper concentrations in squid livers in association with elevated levels of silver, cadmium, and zinc. Mar Biol 30:51-55

Miller JC, Miller JN (1988) Statistics for analytical chemistry. John Wiley & Sons, New York

Moody JR, Lindstrom PM (1977) Selection and cleaning of plastic containers for storage of trace element samples. Anal Chem 49: 2264-2267

Nuñez-Pasten A, (1988) Crecimiento del Camarón Penaeus vannamei P. stylirostris, P. californiensis y su relación con factores ambientales (temperatura y salinidad) en las lagunas de Huizache y Caimanero, Sinaloa, México. Master of Science Thesis, UACPP, CCH, UNAM

Páez-Osuna F, Ruiz-Fernandez AC (1994a) Trace metals in the

Mexican shrimp Penaeus vannamei from estuarine and marine environments. Environ Pollut 86: (in press)
Páez-Osuna F, Ruiz-Fernandez AC (1994b) Comparative bioaccumulation of trace metals in Penaeus stylirostris in estuarine and coastal environments. Estuar Coast Shelf Sci 39: (in press)
Peerzada N, Nojok M, Lee C (1992) Distribution of heavy metals in prawns from northern territory, Australia. Mar Pollut Bull 24:416-418
Szefer P, Szefer K, Skwarzec B, (1990) Distribution of trace metals in some representative fauna of the Southern Baltic. Mar Pollut Bull 21:60-62