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Heavy Metal Concentrations in the Banana Prawn, *Penaeus merguiensis,* and Leader Prawn, *P. monodon,* in the Townsville Region of Australia

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Trace amounts of heavy metals are normal in marine organisms and some, such as copper, iron, zinc and manganese, are essential for normal growth and development (Martin 1974; Martin *et al* 1977). Other metals such as cadmium and mercury have no known use in physiological processes. Toxic concentrations of heavy metals in the marine environment are mostly caused by industrial pollution, by which their residual products increase in concentrations in aquatic organisms. For example, high concentrations of cadmium and zinc have been reported in some species of aquatic organisms in Port Pirie, Australia (Ward *et al.* 1986).

In the following study a baseline survey was undertaken to establish the range of metal levels in field populations of juvenile banana prawns *Penaeus merguiensis* and farmed stocks of juvenile leader prawn, *P.monodon*. Concentrations of ten trace elements (viz. Cu, Zn, Fe, Mn, Cd, Ag, Mg, Pb, Ni, Co and Hg) were determined in wild and farmed prawn stocks and a preliminary assessment of inter-element relationships within tissues was also made.

MATERIALS AND METHODS

Forty-eight and forty-six wild juvenile banana prawns (*P. merguiensis*) were collected in 1986 from the estuaries of Three Mile Creek (19°12'42"S;146°46'30"E; as a recreation area) and mouth of the Bohle river (19°12'40"S;146°45'50"E; near nickel refinery), respectively, near Townsville, using a 1-cm sieve seine net. The prawns were grouped into batches ranging in size from 45 to 54 (47.2 ± 2.5), 55 to 64 (57.3 ± 2.5), 65 to 74 (68.1 ± 2.1), 75 to 84 (78.3 ± 2.4), and 85 to 95 (88.1 ± 3.5) mm. Each group contained a maximum of ten animals and a minimum of seven animals. They were than dissected, using high quality stainless steel instruments, into hepatopancreas, gills and muscle. Muscle samples were analysed individually whereas the hepatopancreas and the gills were pooled within each group. All tissues were kept at -20°C for about two to three weeks, until required for analysis.

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Ninety juvenile *P. monodon* (90-110; 107.7 ± 4.9 mm) were collected from an aquaculture farm, South Townsville (19°13'30"S;146°46'49"E) near Ross river. All tissues were dissected and kept as for the wild prawns.

Samples were thawed at room temperature and weighed into 100-mL Erlenmeyer glass flasks (Pyrex), loosely capped with Teflon stoppers and digested with 5 mL of silica-glass distilled nitric acid on a hot plate at 135°C for 24 h. The solutions were evaporated to dryness, redissolved in 2N nitric acid and analysed for zinc, copper, manganese, silver, iron, cadmium, nickel, cobalt and lead by atomic absorption spectrophotometry. Blanks were treated similarly. Standards made up in 10% nitric acid and correction for non-atomic absorption were made simultaneously by the instrument. All glassware was cleaned by refluxing with hot nitric acid and thoroughly rinsed with double-distilled water before use. The procedure for Hg analysis was used according to Denton and Breck (1981).

Data were calculated on a ug/g wet weight basis. Differences in tissue levels of heavy metal in banana prawns were compared by Student's t-test. Pearson correlation coefficients were used to determine significant metal interrelationships within and between tissues. Linear regression analysis was used to determine size-related variations in metal levels.

RESULTS AND DISCUSSION

Tissue distribution of trace elements in *P. merguiensis* (wild) and *P. monodon* (aquaculture) in 1986 were as follows (Table 1). Compared with the other tissues examined, muscle of both species of prawns contained the lowest levels of Zn, Cu, Fe, and Mn. Zinc was always the most abundant element closely followed by copper. Manganese preceded Fe in order of abundance in *P. merguiensis* while the reverse was shown for cultured *P. monodon*. In both species Hg was the least abundant element detected, while concentrations of Ag, Ni, Pb, Cd, and Co were consistently below the limits of analytical detection.

The hepatopancreas contained the highest levels of Zn, Fe, and Cd in both species. In wild *P. merguiensis*, the highest levels of Cu and Mn were also encountered in this tissue. The most abundant elements were Cu, Zn, Fe, and Mn although once again slight interspecific variations were noted in their rank order of concentration (Table 1). Enrichment of the gills with a range of metals was evident and the elemental order of abundance was identical in both species. In *P. monodon*, Cu was concentrated to the greatest extent in the gill tissue (Table 2).

The concentrations of Zn in the muscle of prawns examined were much lower than in crustaceans (prawns and crabs) from suspected polluted waters in South Australia (Ward *et al.* 1986). The high concentration of Zn in the hepatopancreas appears to be the case among crustaceans generally although levels are sometimes more variable than observed here.

Zinc concentrations found in the muscle in *P. merguiensis* and *P. monodon* were similar to those in the prawn, *P. monodon* from Goa, India (21.5-70 ug/g dry weight, equal to 5-15 ug/g wet weight, assuming a wet:dry weight ratio of 4:5, Zingde *et al* 1976). They are also similar to levels found in the lobster *Austropanobius pallipes* (12.0 ug/g), the shrimp *Crangon vulgaris* (14.0 ug/g) and *Palaemonetes varians* (14.0 ug/g) from Plymouth U.K. Zinc levels in the hepatopancreas and gills were generally similar to those reported for many other crustaceans by Bryan (1968).

The concentrations of copper in the muscle of *P. merguiensis* and *P. monodon* were higher than in the crabs *Aselecyclus septemdentatus* (3.9 ug/g) and *Carsinus maenas* (5.7 ug/g), but similar to that in the crabs, *Cancer pagurus* (7.5 ug/g) and *Portunus puber* (8.4 ug/g), lobster, *Galathea squamifera* (7.2 ug/g Bryan 1968) and the prawn, *P. monodon* (21-48 ug/g dry weight Zingde *et al.* 1976). Levels were lower than found in the muscle of the crab, *C. irroratus* (13-25 ug/g), from the New York Bight U.S.A. (Greig *et al.* 1977).

Copper levels are known to vary widely between crustacean species, and it is therefore of interest to note that the levels reported here for the hepatopancreas of wild prawns from Three Mile Creek are among the highest recorded in the literature.

Manganese levels in muscle and the hepatopancreas of *P. merguiensis* and *P. monodon* in this study were similar to that of the lobster, *Homarus vulgaris* (2.4 ug/g), although the gills contained much higher concentrations (8.6-23.3 ug/g) in the latter species (Bryan and Ward 1965). The concentrations were also similar to those in whole *P. monodon* (14.9-21.3 ug/g dry weight) from Indian estuaries (Zingde *et al.* 1976).

Among the highest levels of iron reported is a value of 5200 ug/g dry weight given by Fujita *et al* (1969) for whole *Acartia clausi*, the planktonic copepod. In the

Table 1. Mean concentrations of metals (ug/g wet weight) in the tissues of wild *P. merguiensis* in two locations and their size relationship.

Tissue	Location	n	Zn	Cu	Fe	Mn	Cd	Ag	Hg
Muscle	T.M.C.	48	12.60 (-)	9.10	0.61	1.09	ND	ND	0.02
	B.R.C.	46	12.22	8.60	0.64	1.07	ND	ND	0.01
Hepato-	T.M.C.	5	51.68	199.10**(+)	39.31	6.07 (-)	1.60*	9.91**	0.02
panc.	B.R.V.	5	41.25	81.08	31.25	4.88 (-)	0.67 (+)	2.68 (+)	0.03
Gill	T.M.C.	5	22.40	61.92*(+)	24.63	2.44	ND	ND	0.01
	B.R.C.	5	23.30	39.71	20.36	2.88 (-)	ND	ND	0.01

T.M.C.= Three Mile Creek, B.R.C.= Bohle River Creek, *= Significant different between two locations (P<0.05), **= Significant (P<0.01). (+)= Positive relationship between length of prawn and metal concentration, (-)= Negative relationship. ND= below detection limits (Cd <0.05; Ag <0.6 ; Co <0.5; Pb <0.7; Ni <0.6 ug/g).

Table 2. Mean concentrations of metals (ug/g wet weight) in the tissues of *P. monodon* from prawn farm

Tissue	n	Zn	Cu	Fe	Mn	Cd	Hg
Muscle	90	16.07	7.23	2.07	0.49	ND	0.01
Hepatopancreas	45	58.16	16.30	49.12	3.66	1.39	0.02
Gills	45	23.38	46.29	13.41	3.96	ND	0.01

ND= below detection limits (Cd <0.05; Ag <0.06; Co< 0.5; Pb <0.7; Ni <0.6 ug/g) present study mean levels in muscle tissue of *P. merguiensis* and *P. monodon* were 0.64 and 2.07 ug/g, respectively. Similar values were also given for a lobster, *Jasus lalandi* (2.9 ug/g) from South Africa (Van As *et al.* 1973).

From the literature it is clear that the highest levels of cadmium are generally found in the hepatopancreas whilst low levels always occur in the muscle tissue. The data reported here follow this general pattern with levels in edible muscle tissue below the limits of analytical detection. Levels in the hepatopancreas corresponded to those found in the digestive gland of the crab, *C. irroratus* (1.1 ug/g Greig *et al.* 1977).

Silver, a non-essential element, usually occurs in highest concentrations in the hepatopancreas as shown here. However relatively high levels (0.79 ug/g) have also been reported in muscle of the crab *C. irroratus* (Greig *et al.* 1977). Interestingly, the silver concentrations found in the hepatopancreas of *P. merguiensis* from Three Mile Creek were higher than other values reported in the literature for this element in crustacean species.

Crustaceans from clean environments contain very low levels of mercury. However, they can accumulate substantial quantities of this element under polluted conditions. For example Matida and Kumada (1969) reported levels of 41-100 ug/g dry weight in two crustacean species from Minamata Bay in Japan. Mercury levels in prawn tissue found during the present investigation are representative of non-polluted conditions and are similar to those reported by Cheevaparanapivat and Menasveta (1979) for shrimp *Penaeus sp* (0.002-0.016 ug/g) from Thailand. The concentrations were, however, much lower than reported crustacean tissue from other areas of the world (Greig *et al.* 1978; Santoro and Koepp 1986).

A comparison was made between the tissue metal concentration of *P. merguiensis* collected from both creeks. Concentrations of all detectable metals in the muscle tissue of prawns from both locations were similar (Table 1). However, prawns from Three Mile Creek contained significantly higher levels of Cu in the gills and of Cu, Ag, and Cd in the hepatopancreas.

Although *P. merguiensis* from both locations were of a similar size range they were collected at different season (dry and rainy season) and therefore temporal differences may have obscured or enhanced relatively small variations between sites. Nevertheless, the significantly higher levels of copper, cadmium and silver in the hepatopancreas, and copper in the gills of prawns from Three Mile Creek may well be attributed to the close proximity of urban development in addition to boating and other recreational activities. Moreover, avail-ability type and abundance may be important considera-tions. Differences between sites may account for the location-dependent relationship between metals with respect to prawn size and tissue type.

A detailed assessment of interspecific differences in metal concentrations was not possible because of locational differences and variations in the size range of populations sampled. Notwithstanding these constraints, a preliminary comparison revealed approximately similar levels of all detectable metals in both species with the exception of Cu which was 5 - 10 times higher in the hepatopancreas of wild *P. merguiensis*.

The relationship between body length and metal levels in all tissues of *P. merguiensis* was found to be metal, tissue, and site dependent (Table 1). In any one tissue the only consistent relationship observed in prawns from both sites was a significantly negative relationship for manganese in the hepatopancreas.

Little information exists on the relationship between size and metal levels in crustaceans. Garcia and Fowler (1972) found that levels of Co, Cu, Mn and Zn in the shrimp *P. californianus* from the Gulf of California tended to be higher in smaller individuals. In the crab *C. irroratus*, only Mn exhibited higher levels in larger individuals (Martin 1974).

In the present study, only Mn in muscle tissue was found to be consistently correlated with size and, in keeping with Garcia and Fowler's observation, the relationship was negative. These data contrast with the finding of Martin (1974), who found that Mn levels in the crab was positively correlated with size.

An analysis of correlation coefficient between metal pairs in prawn tissue revealed species and location dependent differences. The only interspecific consistency was a significantly positive correlation between Fe and Cu in the muscle tissue. Intraspecific consistencies were only shown between Ag and Mn, and between Cu and Mn in the hepatopancreas. In both cases a negative relationship was indicated.

With respect to correlations between metal pairs, Mason and Simkiss (1983) have suggested that a consistent association between particular groups of metals can be regarded as indicative of particular biochemical pathways or, at its simplest, as demonstrating that the binding of certain metals in animals indicates the occurrence of particular ligands. Specific metals can be expected to accumulate and correlate at each site.

In the present study consistent correlations between metal pairs were only evident for Mn:Cu and Mn:Ag. However, the relationship was negative suggesting that there may be competition between these elements for a limited supply of ligands (See Mason and Simkiss 1983).

From these results, we conclude that concentrations of selected heavy metals in prawns from three different locations were indicative of a relatively clean coastal environment when compared with reported values for locations where pollution was suspected. Although a relatively high concentration of copper occurred in the hepatopancreas of prawns from Three Mile Creek, this level is not regarded as dangerous for man as a consumer or the animals themselves. Levels of Zn, Cu, Hg and Cd in the muscle were below the maximum levels of 150, 10, 0.5, 0.05 mg/kg wet weight, respectively, set by the Australian National Health and Medical Research Council for human consumption. No prescribed maximum concentration guide line exists for Mn, Co, Ni, and Ag.

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