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Total Mercury Levels in Selected Tissues of Some Marine Crustaceans from Persian Gulf, Iran: Variations Related to Length, Weight and Sex

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Abstract Much of the variation in trace metal tissue concentrations in marine invertebrates has been attributed to the variety in individual organism size, age and sex. This study assessed the relationship between total mercury (Hg) concentrations in edible tissue, exoskeleton and viscera with length, weight and gender for 69 samples of crustaceans, *Penaeus semisulcatus* (n = 30), *Thenus orientalis* (n = 21) and *Portunus pelagicus* (n = 18) from the northern part of the Persian Gulf. Significant increase in the Hg level in muscle and viscera ($r > 0.65$, $p < 0.01$) with an increase in length and weight for all three species. No relationship was found between the Hg level in exoskeleton and length or weight. Significantly higher Hg levels ($p < 0.01$) were found in female *P. semisulcatus* than in males (muscle and viscera), but no gender differences were found for the other two species.

Keywords Mercury · Length · Sex · Crustacean

Mercury came to the forefront of environmental concerns in the 1960s and 1970s with cases of mercury poisoning that occurred in Minamata Bay, Japan, and in Iraq (Evans et al. 2000). It is known that certain forms of Hg can readily accumulate within crustacean tissues at much higher concentrations than those in the water column and in sediment (Beltrame and Marco 2010). Much of the variation in trace metal tissue concentrations in marine invertebrates has been attributed to variations in size, as well as age of individuals, sex and feeding habits (Yilmaz and Yilmaz 2007; Beltrame and Marco 2010). It is commonly believed that a contaminant/length relationship occurs in fish due to the older age of larger fish, which have possibly had a longer exposure period to contaminants. However, the relationship can be confounded by a multitude of other variables that affect contaminant bioaccumulation, such as changes in growth rate, diet, and activity (Gewurtz et al. 2011).

The Persian Gulf is located in the south and southwest of Iran (Fig. 1) with an average area and depth of 240,000 km^2 and 35 m, respectively. In terms of pollution, the water quality of the Persian Gulf is influenced by various industries that discharging their wastewater directly to the sea and estuaries (Agah et al. 2010). Chlor-alkali plants that use Hg in their manufacturing process represent one such industry that discharges Hg in its wastewater. The Persian Gulf has a vast area of shallow water, and is known to be a preferred habitat for demersal species. Such marine species are very important natural resources for this region (Carpenter et al. 1997).

All three selected species in this study (*Penaeus semisulcatus*, *Thenus orientalis* and *Portunus pelagicus*) are demersal decapod crustaceans of regional economic importance (Valinassab et al. 2006). In terms of commercial catch, *P. semisulcatus* remains the most important species in the Persian Gulf, representing 80% of the landed catch in Iran (Niamaimandi et al. 2008). *Thenus* is the most economically significant of the seven scyllarid genera (Jones 1993). In Iran, *P. pelagicus* is treated as an incidental catch and is eaten as a food only in some areas, but in other countries, it has a special part in nutrition and is an

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Fig. 1 Location of sampling area within the Persian Gulf

important part of the commercial catch (Jazayeri et al. 2011). In this study, we investigated the relationship between Hg content in edible tissue (muscle), viscera and exoskeleton with organism length, weight and gender for these three crustacean species.

Materials and Methods

Samples were collected in the northern Persian Gulf (Fig. 1) by bottom-trawling during a 1-week cruise with the research vessel 'Ferdows-1' in January 2009. Sixty-nine individuals were collected: 30 green tiger prawns (*P. semisulcatus*), 21 flathead locust lobsters (*T. orientalis*), and 18 blue swimming crabs (*P. pelagicus*). Their characteristics are presented in Table 1.

Collected specimens were immediately placed on ice in an insulated box and transported to the laboratory. Upon arrival at the laboratory, samples were washed with double distilled deionized water to remove loosely adherent external contamination, and the sex of each individual was determined according to morphological characteristics. In the male prawns gonopores are situated at the base of the coxae of the fifth pereopods and are covered by flaps, while female gonopores appear as oval apertures on the coxae of the third pereopods and are covered with a membrane (New et al. 2010). In the female lobsters, the sexual openings are visible on the base of the third pereiopods and in the males these openings are on the base of the fifth pereiopods (Holthuis 1991). Male crabs are bright blue and their abdomens (womb area) are narrow and in the form of a spear, while female crabs are green–brown and have round abdomens (Potter and Lestang 2000). Measurements of total length were made for the prawns and lobsters, and of carapace length for the crabs. Total weight for all individual was also recorded. Each specimen was dissected to separate body flesh (about 3 g), exoskeleton (about 2 g) and intestine (whole). After dissection, samples were freeze-dried to a powder, and homogenized (Houserova et al. 2007). The total Hg concentration was determined in the dried samples using a LECO AMA 254 Advanced Mercury analyzer (USA). This method requires no chemical pretreatment of the sample. Several certified NIST standard materials were used (SRM 1633b, SRM 2709 and SRM 2711) and recovery varied between 93.6% and 105%. The detection limit of the method used was 0.001 mg/kg dry weight (dw) (Zamani-Ahmadmahmoodi et al. 2009). The statistical analyses were carried out using SPSS software version 11.5. Normality of data was assessed by Shapiro–Wilks test. Bivariate correlation analysis (Pearson and Spearman tests for normally and non-normally distributed data, respectively) was used to investigate the relationship between Hg concentrations and length. Hg concentrations in tissues were tested for mean differences between males and females using parametric and non-parametric tests for normally and non-normally distributed data, respectively. All concentrations are reported in $\mu g\ g^{-1}$ dry weight, and a probability of $p = 0.05$ was set to indicate statistical significance.

Table 1 Species and specific characteristics

Common name	Scientific name	Sex	n	Reproductive state	Length (cm) (Mean ± SE)	Weight (g) (Mean ± SE)
Green tiger Prawn	*Penaeus semisulcatus*	Female	15	5 Matures	18.60 ± 0.47[a]	61.73 ± 4.87
		Male	15	4 Matures	15.40 ± 0.31[a]	32.16 ± 1.57
Flathead locust lobster	*Thenus orientalis*	Female	14	5 Matures with eggs	16.25 ± 0.53[a]	159.37 ± 13.56
		Male	7	2 Matures	14.07 ± 0.69[a]	108.53 ± 14.49
Blue swimming crab	*Portunus pelagicus*	Female	10	4 Matures with eggs	6.63 ± 0.22[b]	239.32 ± 18.12
		Male	8	4 Matures	6.45 ± 0.29[b]	229.66 ± 33.10

[a] Total length

[b] Carapace length

Results and Discussion

In all three species, significant correlations (r = 0.96, 0.95 and 0.84) were found between length and weight in green tiger prawn, flathead locust lobster and blue swimming crab, respectively (Fig. 2). Therefore, we used only total length for prawn and lobster and carapace length for crab, to investigate their relationship with Hg concentrations in muscle, exoskeleton and viscera tissues.

In all three species, positive significant relationships ($p < 0.05$) between length and Hg concentrations in muscle and viscera were found (all r > 0.65) (Fig. 3).

The primary biological factors governing the accumulation of Hg include age, weight and diet, and numerous field studies have shown that the concentration of total Hg in fish correlates positively with age, length and weight (Leah et al. 1992). Storelli et al. (2007) found that mercury levels increased with size for 7 species of marine fish from the Adriatic Sea. There was a positive correlation between size and mercury levels for 11 of 14 species of marine fish collected in the western Aleutians (Bering Sea/North Pacific) (Burger et al. 2007). Additionally, because larger/older Crustacean specimens have been exposed a longer time compared of smaller/younger and thus bioaccumulated higher Hg levels (usually size is used as a surrogate for age). Larger/older specimens are also more dependent to bed (benthic) and less to surface (pelagic) in comparison to smaller/younger specimens and thus are longer present in polluted sediment (Holthuis 1991, 1980; Carpenter et al. 1997; Lavalli and Spanier 2007; Wickins and Lee 2002). However, total Hg concentrations may not always correlate with size due to differences associated with diet and residence time in a contaminated habitat (Francesconi and Lenanton 1992).

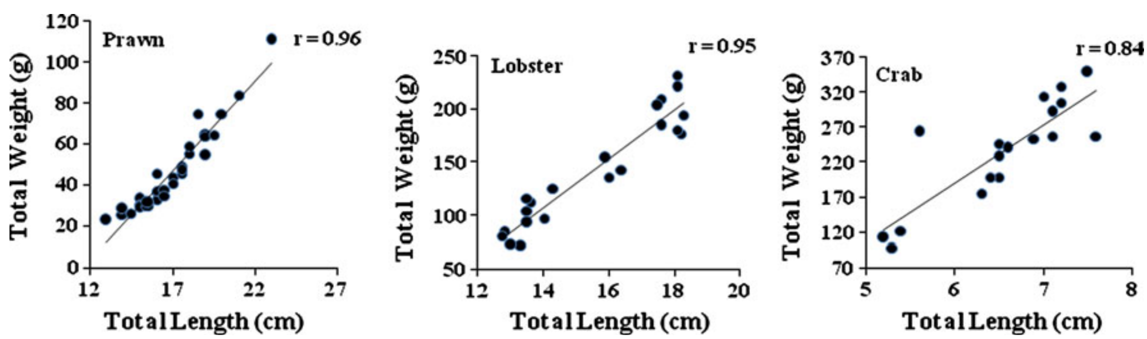

Fig. 2 Relationship between length and weight for three species studied

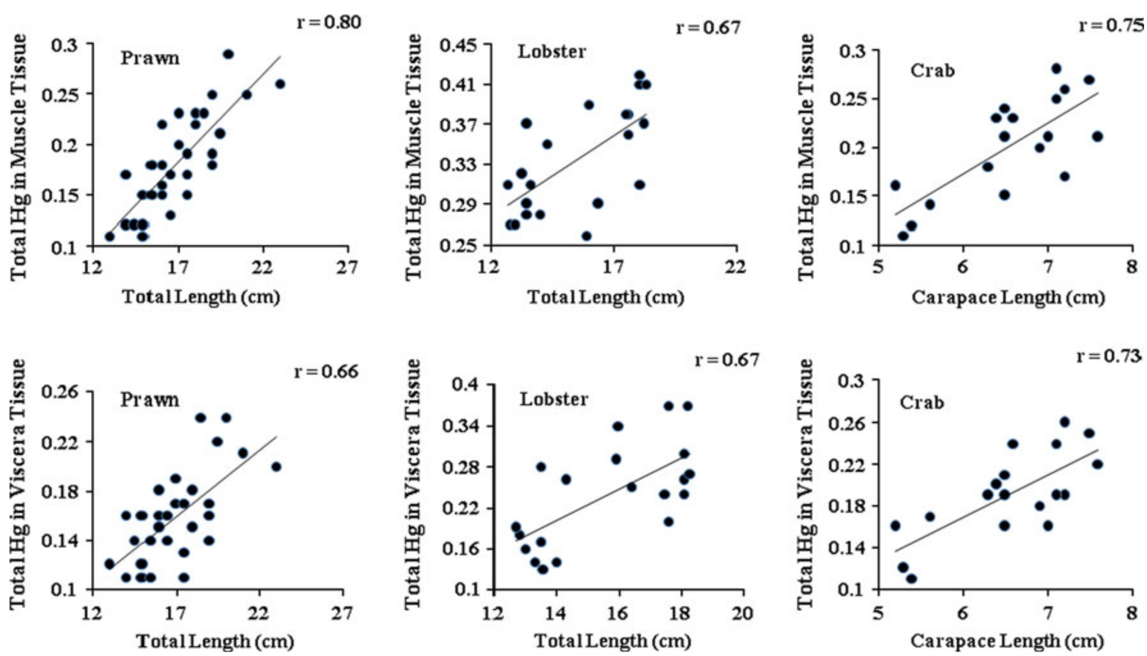

Fig. 3 Relationship between length (cm) and total mercury (mg/kg dry weight) in muscle and viscera for the three species studied

In contrast to muscle and viscera tissues, there were no significant correlations between length and Hg concentrations in exoskeleton tissue in any of the three species (all $r < 0.32$). This is probably due to the moulting process. Since crustaceans have several moulting stages in their life, the bioaccumulation process in the exoskeleton is also cycling and each time, new bioaccumulation starts in a new exoskeleton. Therefore, one does not expect any relationship between length and Hg in exoskeleton.

The Hg level in muscle and viscera tissues of female prawns (*P. semisulcatus*) was significantly higher than males but such gender differences were not observed in other species (Fig. 4).

Gender differences in the Hg tissue concentrations have been reported in some fish and invertebrate species. Differences in accumulation between the genders have been mainly attributed to differences in diet (Beckvar et al. 1996), or due to differences in habitat (Gewurtz et al. 2011). Canli and Furness (1993) had investigated influences of gender and size on the Hg accumulation in muscle and cephalothorax in Norway lobster (*Nephrops norvegicus*). They showed that there was a positive linear relationship between Hg concentration in muscle and carapace length for both males and females. The Hg level in female muscle was also higher than in males. Our results are in agreement with those of Bu-Olayan et al. (1998), who investigated the relationship between Hg level with total length, total weight and sex in *T. orientalis* from the Persian Gulf. Both of these studies show that Hg concentrations in females *T. orientalis* are higher than males, but the difference is not significant in this study ($p > 0.05$). It was also found that a linear relationship existed between total weight/length and Hg level. Meanwhile, comparing this study with their results shows that Hg concentration in *T. orientalis* from Persian Gulf has increased significantly since 1998–2009 (0.12 and 0.33 mg/kg dry wt., respectively).

In red shrimp (*Aristeus antennatus*), a significant correlation was found between weight and carapace length with Hg concentration, while total Hg in females was higher than males (Drava et al. 2004). In the brown crab (*Cancer pagurus*), Hg concentrations in muscle and hepatopancreas tissues in males were significantly higher than females (Barrento et al. 2009). Endo et al. (2009) have suggested that these differences may reflect slower growth rates of one of the genders, implying that at a specified size, the slower growing gender tends to be older than the faster growing one, and has accumulated Hg over a longer period of time. Additionally, Gewurtz et al. (2011) have shown that higher Hg levels in female fish were due to the increased consumption of food, relative to males, to meet the increasing demands of reproduction. Other studies showed that length and weight of female crustaceans (e.g. *P. semisulcatus*, *A. antennatus,* and *T. orientalis*) were higher than of males (Yilmaz and Yilmaz 2007; Drava et al. 2004). As shown in Table 1, females of all three species were both longer and heavier than males, and these differences in size may have caused differences in the Hg levels.

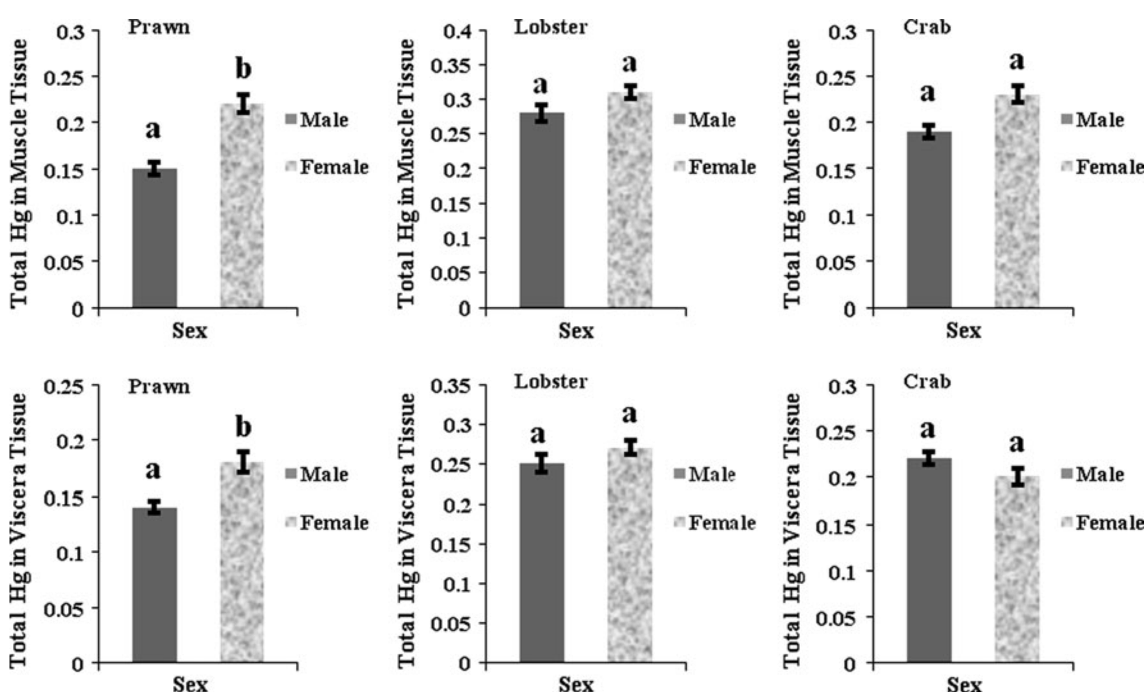

Fig. 4 Comparison of total mercury levels (mg/kg dry weight) between sexes for the three species studied

Finally, levels of Hg in edible tissues of the all three species showed the ranges 0.06–0.1 (Mean = 0.08) mg/kg wet wt. in *T. orientalis*, 0.03–0.07 (Mean = 0.05) mg/kg wet wt. in *P. pelagicus* and 0.03–0.08 (Mean = 0.05) mg/kg wet wt. in *P. semisulcatus*. In general, *T. orientalis* was the species with the highest levels of mean Hg in edible tissue, and fortunately, all were below the WHO guideline of 0.5 mg/kg wet wt.

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