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Metal Concentrations in Two Commercial Fish from Persian Gulf, in Relation to Body Length and Sex

Mohammad Seddiq Mortazavi · Salim Sharifian

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Abstract The relationship between sex, size (length and weight) and metal concentrations in the tissues of two commercially valuable fish species (silver pomfret, *Pampus argenteus* and tiger tooth croaker, *Otolithes ruber*) from Persian Gulf were evaluated. Concentrations of the metals in fish species ranged as follows: Mn 0.743–11.279; Cd 0.175–2.375; Pb 2.406–11.297; Zn 10.837–80.389; Fe 2.263–86.110; Cu 1.503–6.333 µg/g dry weight, respectively. Metal content in both fish varied with type of metals, organ, and sex. Results showed that, except in a few cases, significant relationships between metal concentrations and fish size were negative.

Keywords Metals · Fish · Length · Sex · Accumulation · Iran

Marine organisms including fish, mussels, clams, barnacles, and other independent aqua fauna, accumulate contaminants from the environment in their different tissues dependent on water concentrations of metals, exposure period, and other environmental factors such as salinity, pH, hardness and temperature (Canli and Atli 2003). It is also found that ecological needs, sex, size, and moulting of marine animals affect metal accumulation in their tissues (Kalay et al. 1999; Saei-Dehkordi et al. 2010; Saei-Dehkordi and Fallah 2011).

In general, metals can be divided into two categories: essential and non-essential. Essential metals such as iron, copper, zinc and manganese have an important role in biological systems, while non-essentials like mercury, lead and cadmium are toxic, even in traces and have no known role in biological systems (Tűrkmen et al. 2005). The essential metals can also produce toxic effects when the metal intake is excessively elevated. Under certain environmental conditions, metals might accumulate up to toxic concentrations and cause ecological damage. Several marine organisms have been used in marine pollution monitoring programs (Wang and Rainbow 2005), but fish have been popular targets of metal monitoring programs because sampling, sample preparation and chemical analysis are usually simpler, more rapid and less expensive than alternative choices such as water and sediments (Rayment and Barry 2000).

It is well known that size of marine animals play an important role in metal contents of tissues. Especially, this evidence was consistent generally for mercury in marine animals. However, this consistent relationship may not be seen for other metals (Al-Yousuf et al. 2000). Therefore, it is important to understand better the relationships between animal size and concentration of metals. Fish is considered as a valuable source of protein in the human diet. They have long been a favourite meal for people living around the Persian Gulf and Oman Sea. The Persian Gulf is shallow basin with an average depth of 30–45 m and a total area of round 240 sq km (Saeidi et al. 2008). Fish from this aqua resource serve as the main source of animal protein for the population surrounding the Gulf in Iran and Arabian countries. Silver pomfret (*Pampus argenteus*) and tiger-tooth croaker (*Otolithes rubber*) are two commercially valuable fish species that exist in the human diet of the region. To our knowledge, Fish of northeast Persian Gulf have not been examined on the relationships between tissue metal concentrations and fish size. Therefore, the aims of this study was to determine metal (Mn, Cd, Pb, Zn, Fe, Cu)

M. S. Mortazavi (✉) · S. Sharifian
Persian Gulf and Oman Sea Ecological Research Institute,
P.O.Box: 79145-1597, Bandar Abbas, Iran
e-mail: mseddiq1@yahoo.com

concentrations in muscle and skin of silver pomfret and tiger-tooth croaker and to investigate the relationships between fish sex (male and female), size (length and weight) and metal concentration in the tissues.

Materials and Methods

One hundred sixty silver pomfret (*Pampus argenteus*), and tiger tooth croaker (*Otolithes rubber*) used in this study were caught from the northern part of Persian Gulf (Hormozgan Province, Iran) during 2010. The fish were brought to the laboratory on ice immediately and then frozen at −25°C until dissection. The fish samples were then thawed and their total and standard lengths and weight were recorded to the nearest millimeter and gram before dissection (Table 1). Whole fish were dissected on a clean bench shortly after thawing with the aid of a stainless steel knife which had been cleaned with acetone and hot distilled water prior to use. Sex was determined by inspection of gonads after opening the body cavity. The fish samples were finally preserved in clean dry polyethene bottles prior to analysis.

All muscle samples were dried at 80°C and skin samples were dried at 105°C for 12 h. Homogenized samples (0.5 g) were weighted and then digested, using a microwave digester (Milestone ETHOS1 advanced microwave digestion system, Italy) with 1 mL H_2O_2 (30 %) and 7 mL HNO_3 (65 %). The shorter time, less consumption of acid and keeping volatile compounds in the solutions are the advantages of microwave digestion against the classical methods (Sures et al. 1994). Samples were digested for 30–40 min at 200°C according to system instruction. After digestion, the residues were diluted to 50 mL with distilled water in volumetric flasks. All digested samples were analyzed three times for the metals Mn, Cd, Pb, Zn, Fe, and Cu using Furnaco auto sampler atomic absorption spectrometer (FS95). Calibration of instrument was done by standard solutions prepared from commercial materials. Analytical blanks were run in the same way as the samples and concentrations were determined using standard solutions prepared in the same acid matrix. The quality of data was checked by the analysis of standard reference material (DORM-2 National Research Council, Canada) (Table 2).

Statistical analysis of data was carried out using SPSS 13 statistical package programs. Normality test of data and their graphs showed mostly normal distribution or close to normal distribution and therefore, no transformation was done for statistical analyses. The linear regression analyses were applied to data to compare the relationships between size and metal concentrations in the tissues. The same tissues from the fish (male and female) were also compared by one way ANOVA. Homogeneity of variances was evaluated with the Levene-test. The Tamhane-T2- test was applied since variances were not homogeneous. Significance was tested at $p < 0.05$ level.

Results and Discussion

Several studies have shown that mean concentrations of essential and nonessential metals in the various tissues of fish species show great variations (Tűrkmen et al. 2005; Canli and Atli 2003) and various factors such as season (Saei-Dehkordi and Fallah 2011), sex (Al-Yousuf et al. 2000), length and weight, physical and chemical status of

Table 1 Gender, length, and weight of silver pomfret (*P. pampus*) and tiger-tooth croaker (*O. ruber*) (mean ± SE)

Fish	Sex	n	Total length (mm)	Standard length (mm)	Weight (g)
P. pampus	Male	40	13.93 ± 0.96	11.46 ± 0.29	84.87 ± 6.07
	Female	40	16.09 ± 0.63	13.95 ± 0.56	184.18 ± 22.86
O. ruber	Male	40	19.99 ± 0.51	16.93 ± 0.41	88.66 ± 7.07
	Female	40	22.41 ± 1.03	17.42 ± 0.35	90.19 ± 4.30

Table 2 Observed and certified values of elemental concentrations, as, in Standard Reference Material DORM-2 from the National Research Council, Canada (all data shown as means ± standard errors, in μg/g dry weight)

Value	Manganese	Cadmium	Lead	Zinc	Iron	Copper
Certified	3.66	0.043	0.065	26.6	142	2.34
SE	0.34	0.008	0.007	2.3	10	0.16
Observed[a]	3.57	0.041	0.063	26.50	139.8	2.31
SE	0.28	0.005	0.003	2	6.7	0.11
Recovery (%)	97.5	95.34	96.92	99.62	98.45	98.71

[a] Each value is the average of ten determinations

Table 3 Means concentrations (±SE) of metals (μg/g dw), and comparisons in muscle (M) and skin (S) of male (M) and Female (F) Silver pomfret *Pampus argenteus* (PA) and tiger tooth croaker *Otolithes ruber* (OR)

Fish	Tissues	Sex	N	Mn	Cd	Pb	Zn	Fe	Cu
PA	M	M	20	1.313 ± 0.106^{a}	0.175 ± 0.021^{a}	3.247 ± 0.556^{ab}	14.222 ± 0.834^{a}	2.531 ± 0.267^{a}	3.111 ± 0.588^{a}
		F	20	1.183 ± 0.181^{a}	0.259 ± 0.077^{ab}	2.406 ± 0.502^{a}	14.665 ± 1.409^{a}	2.263 ± 1.547^{b}	3.489 ± 0.522^{ab}
	S	M	20	2.855 ± 0.561^{b}	ND	5.107 ± 0.892^{c}	37.959 ± 4.648^{b}	23.636 ± 3.499^{c}	5.023 ± 0.671^{c}
		F	20	11.279 ± 1.153^{c}	1.099 ± 0.341^{b}	11.297 ± 1.927^{b}	80.389 ± 9.112^{c}	21.980 ± 3.375^{c}	1.503 ± 0.320^{b}
	Total		80	4.613 ± 0.678	0.494 ± 0.125	5.840 ± 0.740	38.705 ± 4.274	17.039 ± 2.143	3.264 ± 0.311
OR	M	M	20	0.743 ± 0.100^{a}	0.379 ± 0.034^{a}	2.601 ± 0.290^{a}	10.837 ± 0.434^{a}	4.455 ± 0.254^{a}	3.721 ± 0.440^{a}
		F	20	1.275 ± 0.168^{b}	0.426 ± 0.073^{a}	3.155 ± 0.358^{ab}	14.290 ± 1.670^{a}	4.479 ± 1.349^{a}	1.011 ± 0.111^{b}
	S	M	20	4.532 ± 0.448^{c}	0.540 ± 0.053^{a}	3.960 ± 0.679^{b}	34.262 ± 2.310^{b}	35.977 ± 8.520^{b}	6.333 ± 0.737^{c}
		F	20	3.289 ± 0.485^{c}	ND	4.609 ± 0.654^{b}	40.332 ± 3.445^{b}	86.110 ± 13.374^{c}	2.304 ± 0.225^{d}
	Total		80	2.338 ± 0.237	0.425 ± 0.031	3.567 ± 0.265	24.488 ± 1.808	32.673 ± 5.475	3.226 ± 0.301

[a] Metal concentrations among the tissues of two fish (both male and female) were compared statically using one-way ANOVA

[a–d] Significant differences ($p < 0.05$)

water can play a role in the tissue accumulation of metals. The concentrations and comparisons of manganese, cadmium, lead, zinc, iron, and copper in muscle and skin tissues of male and female silver pomfret and tiger-tooth croaker are shown in Table 3 with means and SE. The contents of investigated metals in the two fish species were found to be in the range of 0.743–11.279 μg/g for manganese, 0.175–2.375 μg/g for cadmium, 2.406–11.297 μg/g for lead, 10.837–80.389 μg/g for zinc, 2.263–86.110 μg/g for iron, and 1.503–6.333 μg/g for copper.

The highest concentration of manganese in the muscle (1.313 μg/g) and skin (11.279 μg/g dw) of silver pomfret (1.833 μg/g dw) were detected in the male and female, while highest concentration in the muscle (1.275 μg/g dw) and skin (4.532 μg/g dw) of tiger-tooth croaker were measured in the female and male, respectively. As shown in Table 3, there were significant differences ($p < 0.05$) among levels of Mn in different tissues and sexes of both fish species.

Cadmium concentrations varied significantly among different tissues silver pomfret ($p < 0.05$), while tiger-tooth croaker different tissues showed no significant difference ($p > 0.05$). The concentration was not available in male silver pomfret's muscle and female tiger-tooth croaker's skin (Table 3).

Lead concentrations in the tissue of silver pomfret ranged from 2.406 to 11.297 μg/g dw, while concentrations of tiger-tooth croaker were in the range of 2.601–4.609 μg/g dw (Table 3). Lead concentrations did not vary significantly ($p > 0.05$) in muscles and skins of both sexes of both fish species, except in silver pomfret's skin. Higher concentrations of lead were observed in skin tissues of both fish than those in muscle.

The highest (80.389 μg/g dw) and lowest (10.837 μg/g dw) zinc levels were detected in female silver pomfret's skin and male tiger tooth croaker's muscle (Table 3). Zinc levels in the skin tissues of the male silver pomfret were significantly higher than those of females ($p < 0.05$) while no significant difference observed between male and female tiger tooth croaker.

Higher concentrations of iron were observed in the skin of all fish than in the muscle ($p < 0.05$) and whereas lower concentrations of this metal were noted in the muscle (Table 3). There were significant differences ($p < 0.05$) between iron concentrations in females and males in muscle silver pomfret and skin tiger tooth croaker.

Copper concentrations in the tissues of male and female silver pomfret and tiger tooth croaker were observed to vary between 1.503 to 5.023 μg/g dw, and 1.011 to 6.333 μg/g dw, respectively (Table 3). There were considerable differences in the copper levels of the samples of different tissues and sexes in tiger tooth croaker.

In the present study, the distribution pattern of Mn, Pb, Zn, and Fe in two fish (Table 3) were similar and follows the order: skin > muscle; while cadmium in two fish were different and follow the sequences: skin > muscle, in silver pomfret and skin < muscle in tiger-tooth croaker. Results showed that generally metal accumulation is higher in skin than muscle. The reason for high metal concentrations in the skin could be due to the metal complexing with the mucus that is impossible to remove completely from the tissue before analysis (Yilmaz 2003). Similar distribution pattern was reported by Saeidi et al. (2008) and Al-Yousuf et al. (2000). Also, the differences in metal concentrations of the tissues might be as a result of their capacity to induce metal-binding proteins such as metallothioneins (Canli and Atli 2003).

Metal contents in fish are usually specific to a species and differences in metal concentration between species may be related to habitat, fish mobility, diet, or to other characteristic behavior (Henry et al. 2004). Total mean concentrations of manganese (4.613 ± 0.678), cadmium (0.494 ± 0.125), lead (5.840 ± 0.740), zinc (38.705 ± 4.274) and copper (3.264 ± 0.311) in silver pomfret were higher than those (Mn: 2.338 ± 0.237, Cd: 0.425 ± 0.031 Pb: 3.567 ± 0.265, Zn: 24.488 ± 1.808, Cu: 3.226 ± 0.301) of tiger-tooth croaker, while iron was less in tiger-tooth croaker. Previous data from the same study area also showed that different fish species contained strikingly different metal levels in their tissues (Agah et al. 2009; Saei-Dehkordi and Fallah 2011).

The relationships between metal concentrations and fish size are shown in Table 4. The relationship between metal levels and weight were also carried out and since the significances of data were exactly the same except a few cases, only these were indicated in the table. Significant negative relationships were found between fish length and manganese levels in the muscle ($p < 0.05$), manganese ($p < 0.05$), and lead levels in the skin ($p < 0.05$) of *Pampus argenteus* (Table 4). All the other rest relationships in the tissues of *P. argenteus* were negative, except cadmium and copper in the muscle and zinc and iron relationships in the skin ($p > 0.05$). No significant relationships were observed between length and metal levels in the muscle tissue of *Otolithes rubber*, while lead, zinc, and copper levels in the skin tissue showed significant relationships ($p < 0.05$). The relationships between weight and metal levels (lead, zinc, iron and copper) were also significant ($p < 0.01$) in the skin of *O. rubber*. Cadmium and iron levels in the muscle showed a positive relationship with length (Table 4).

Our results showed that there were negative relationships between metals and two parameters of fish (length and weight) in most cases which means that the contamination level decreases with fish size. In fact most of the metals were more accumulated in younger silver pomfret and tiger tooth croaker. In theory, the concentration of metals in fish will increase with increasing size provided that growth is slow relative to the rate of accumulation of that element (Leung et al. 2001). However, the negative relationships between metal levels in the tissues and fish sizes were supported by several authors. Canli and Atli (2003) examined the relationships between metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species and found negative relationships between fish sizes

Table 4 The relationships between metal concentrations and total fish lengths and weights (only *p* values are given in parenthesis) in the tissues of silver pomfret *Pampus argenteus* (PA) and tiger tooth croaker *Otolithes ruber* (OR)

Fish	Tissue	Data	Manganese	Cadmium	Lead	Zinc	Iron	Copper
PA	Muscle	DF	31	29	30	31	14	31
		Equation	Y = −0.030X +1.722	Y = 0.004X +0.153	Y = −0.088X +4.257	Y = −0.202X +17.498	Y = −0.383X +8.022	Y = 0.032X + 2.767
		R^2 value	0.146	0.019	0.078	0.110	0.195	0.010
		p value	(NS)*	NS	NS	NS	NS	NS
	Skin	DF	29	14	36	37	37	37
		Equation	Y = −0.747X +19.308	Y = −0.098X +2.442	Y = −0.817X +19.780	Y = 1.403X +39.351	Y = 0.289X +18.731	Y = −0.27X +7.076
		R^2 value	0.160	0.075	0.138	0.015	0.004	0.094
		p value	(NS)*	NS	(NS)*	NS	NS	NS
OR	Muscle	DF	39	33	39	39	39	39
		Equation	Y = 0.004X +0.930	Y = 0.001X +0.378	Y = 0.010X +2.652	Y = −0.011X +12.814	Y = −0.014X +4.774	Y = −0.023X +2.866
		R^2 value	0.004	0.001	0.008	0.001	0.002	0.021
		p value	NS	NS	NS	NS	NS	NS
	Skin	DF	34	9	36	36	37	36
		Equation	Y = 0.135X +1.103	Y = −0.005X +0.613	Y = −0.412X +12.637	Y = 1.760X +1.692	Y = −5.275X +169.275	Y = −0.391X +12.082
		R^2 value	0.034	0.010	0.188	0.164	0.078	0.154
		p value	NS	NS	** (**)	*(**)	NS (*)	* (*)

In the equations, Y is metal concentration (mg/g dw) and X is total fish length (cm). Asterisks indicate significant results

NS not significant, $p > 0.05$

* $p < 0.05$

** $p < 0.01$

and metal levels in most cases. In other studies, Al-Yousuf et al. (2000) examined trace metal (Zn, Cu and Mn) accumulation in tissues (liver, skin and muscle) of *Lethrinus lentjan* fish species, captured from Persian Gulf, in relation to body length and sex, and concluded that the average metal concentrations in tissues of female fish are higher than those in male fish, due to differences in metabolic activities of the two sexes. Metabolic activity is one of the most important factors that play an important role in the accumulation of metals in marine animals and because metabolic activity of a young individual is normally higher than that of an older individual, metal accumulation is higher in younger individuals than older ones metabolic activity of a young individual is normally higher than that of an older individual (Canli and Atli 2003; Pourang et al. 2005). Negative correlations have been also related to (1) faster growth than metal accumulation or thus a tissue dilution effect (Leung et al. 2001) and (2) feeding habits (Pourang et al. 2005).

Present study provides new information on the distribution of metals and relationship between metals accumulation and length (and weight) in fish from the Persian Gulf. Based on the data analyzed, average metal concentrations found in female fish were higher than those in male fish and there was a negative relationship between metals accumulation and fish length, in most cases. The levels of analyzed metals (except lead) in the tissues of two examined species in the present study were found lower than the legal values for fish and fishery products proposed by FAO (1983).

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