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Influences of sex and seasons on levels of heavy metals in tissues of green tiger shrimp (*Penaeus semisulcatus* de Hann, 1844)

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Abstract

Seasonal changes in heavy metal (Ag, Cr, Ni, Pb, Cu, Fe, Zn) concentrations in muscle, gill, hepatopancreas and gonad tissues of both male and female green tiger shrimp (*Penaeus semisulcatus*) from Iskenderun Bay (Northern East Mediterranean Sea, Turkey) were measured for a year period by using ICP-AES. The relationships in various heavy metal concentrations in organs were compared according to sex and seasons. Heavy metal content varied with type of metals, seasons and sex. Accumulations also differed significantly in certain organs. Metal concentrations (as μg g^{-1} w.w.) were highest in male gonads whereas lowest in the muscle of all shrimp species. From the human consumption point of view, heavy metal concentrations except for copper in male and female green tiger shrimp's muscle were below the admissible limits. Thus, precautions should be taken on account of higher content of heavy metals as well as in other organs that could be affected by industrial pollution.

Keywords: Shrimp (*Penaeus semisulcatus*); Heavy metals; Seasonal changes; Accumulation

1. Introduction

Heavy metals naturally occur in seawater in very low concentrations, but their concentration levels have increased due to anthropogenic pollutants (Kargın, Dönmez, & Çoğun, 2001) over time. Industrial activities as well as agriculture and mining create a potential source of heavy metals pollution in aquatic environment (Gümgüm, Ünlü, Tez, & Gülsün, 1994; Ünlü, Akba, Sevim, & Gümgüm, 1996). As a result, living things inhabiting contaminated waters show rather high metal concentrations. It is well known that heavy metals accumulate in tissues of aquatic animals and hence heavy metals measured in tissues of aquatic animals can reflect past exposures (Canlı & Atlı, 2003; Kalay, Ay, & Canlı, 1999; Yılmaz, 2003, 2005). Much of the variation in trace metal tissue concentrations in aquatic organisms has been attributed to the variety in size as well as age of individuals (Farkas, Salanki, & Specziar, 2003), sex (Al-Yousuf, El-Shahawi, & Al-Ghais, 2000; Canli & Furness, 1995; Pourang & Amini, 2001), feeding habits (Canli, Kalay, & Ay, 2001; Yılmaz, 2005) and the season of capture (Kargın, 1996; Kargın et al., 2001). Sublethal effects of heavy metals are of concern as they accumulate and are transferred through food-chain to humans. These metal levels in marine environment should be monitored regularly to check water quality, animal health and in view of the quality of public food supplies.

The importance of marine shrimp for environmental monitoring studies as bioindicators of heavy metal pollution has been emphasized by several investigators (Guhathakurta & Kaviraj, 2000; Hashmia, Mustafa, & Tariq, 2002; Kargın et al., 2001; Pourang, Dennis, & Ghourchian, 2004). Shrimp, different from most fish in its feeding habit, is a scavenger that feeds on a wide range of materials including debris and other bottom-dwelling animals (Canli et al., 2001). *Penaeus semisulcatus* (green tiger shrimp) is an Indo-Pacific species distributed along

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the coast of the Eastern Mediterranean Sea and is one of the most promising species for aquaculture on the Northeastern Mediterranean coast of Turkey (Aktaş, Kumlu, & Eroldoğan, 2003). It is also an important shrimp species for the consumers around İskenderun Bay-Turkey. Situated on the Eastern Mediterranean coast Turkey (36°20′N-35°30′E; 36°50′N-35°00′E) (Yılmaz, 2003), İskenderun Bay is subject to various anthropogenic activities, such as industrial plants including steel mills, oil transfer docks, agricultural chemicals runoff and uncontrolled disposal.

There have been a large number of studies on heavy metals in marine animals recently, particularly in heavily polluted areas of Mediterranean Sea (Canlı & Atlı, 2003; Canli et al., 2001; Kargın, 1996; Kargın et al., 2001; Yılmaz, 2003, 2005).

This study was undertaken to determine the seasonal variation in levels of Ag, Cr, Ni, Pb, Cu, Fe and Zn in the muscle, gill, liver and gonads tissues of both male and female shrimps (*P. semisulcatus*) and to compare them with the previous studies (Canli & Furness, 1993; Darmono & Denton, 1990; Kargın et al., 2001; Paul & Gupta, 1995; Pourang & Amini, 2001). The relationship between the heavy metal concentrations of organs with sex and season was compared.

2. Materials and methods

Green tiger shrimps were collected from İskenderun Bay in Spring (April), Summer (July) and Autumn (October) of 2003 and Winter (January) of 2004 by gillnetting. The samples were brought to the laboratory on ice immediately and then frozen at −25 °C until dissection. Male (♂) and female (♀) shrimps were grouped in sex and size. Fifteen samples from each sex were obtained for each season.

Total shrimp length and weight were measured to the nearest millimetre and gram before dissection. For analysis, whole gonads, hepatopancreas, gills and tail muscle of each shrimp were dissected, weighed and dried at 120 °C until they reached a constant weight. All samples were placed in decomposition beakers and pure sulphuric acid and nitric acid–hydrogen peroxide (1:1) v/v according to FAO methods were added to each. They were evaporated to dry on a hot plate. The residues were then dissolved and diluted to 50 ml with 2.5% of nitric acid. The chemicals used for sample dissolution were analytical grade. Double distilled water was used throughout the study.

Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) (Varian Model-Liberty Series II), was employed to determine silver, chromium, copper, iron, nickel, lead and zinc. Following absorption lines were used; silver 328.068 nm, chromium 283.6 nm, copper 324.7 nm, iron 259.9 nm, nickel 232.0 nm, lead 283.3 nm, zinc 213.9 nm.

Data analyses were carried out using the SPSS statistical package. One-way ANOVA and Duncan's Multiple Comparison Test were utilized to compare the data according to seasons at the significant level of 0.05.

3. Results and discussion

Table 1 shows sampling months, sex, the mean body weight and total length as well as the standard deviations for the green tiger shrimp samples.

Metal concentrations were calculated in microgram per gram wet basis (μg g^{-1} w.w.). In order to check the validity of the measurements, reference material (Multi-4, Merck) was used. The recovery was 90–100% for most of the analyzed metals, 85% and 105% for Cr and Fe, respectively.

Mean concentrations and associated standard deviations of silver, chromium, copper, iron, nickel, lead and zinc in the gill, hepatopancreas, gonads and muscle of male and female green tiger shrimp collected for four seasons in the İskenderun Bay are given in Table 2.

Levels of silver concentrations in the studied tissues for all of the shrimp samples were undetected in April and January (Table 2). Silver accumulation in the muscle tissue of shrimps ranged from 1.5 to 2.8 μg g^{-1} w.w., while concentrations in the gonads were in the range of 1.2–11.8 μg g^{-1} w.w.. The silver concentrations in the gill of the male and the female shrimps were observed to be between 8.9 and 12.5 μg g^{-1} w.w., and between 7.6 and 11.7 μg g^{-1} w.w., respectively. Silver concentrations varied significantly ($P < 0.05$) for July and October.

Though not detected in April, Chromium concentrations were measured in the tissues of green tiger shrimps in July, October and January (Table 2). Chromium levels detected on the studied tissues of the male species were higher than those of females. Heavy metal level in gills presented higher values: they varied between 57.6 and 78.2 for males and between 47.0 and 61.7 for females, whose Cr levels in the muscles of males and females ranged between 6.8–13.1 and 5.9–9.3, respectively. Chromium concentrations varied significantly ($P < 0.05$) between seasons.

Table 1
Sample characteristics (the sampling months, male and female, average wet weights and total lengths of *Penaeus semisulcatus* were measured[a])

	$L \pm$ SD				$W \pm$ SD			
Seasons	April	July	October	January	April	July	October	January
Samples								
Male (♂)	15.4 ± 0.7	14.3 ± 0.3	16.7 ± 1.0	15.2 ± 1.0	30.5 ± 5.7	22.5 ± 1.4	40.1 ± 3.0	27.8 ± 3.4
Female (♀)	18.1 ± 0.9	17.6 ± 1.4	22.6 ± 1.6	16.4 ± 0.5	53.5 ± 6.8	48.7 ± 11.1	83.4 ± 10.5	39.1 ± 4.6

[a] *W* – mean body weight (g); SD – standard deviation; *L* – mean total length (cm).

Table 2
Mean concentrations (μg metal g^{-1} w.w.) and their standard deviations (Mean ± SD) of Ag, Cr, Ni, Pb, Cu, Fe and Zn in the gill, hepatopancreas, gonads and muscle of male and female green tiger shrimp collected for four seasons in the İskenderun Bay

Metals	Tissues	Sex	April	July	October	January
Ag	Gill (Mean ± SD)*	Male (♂)	N.d.**	12.5 ± 2.9^{b}***	8.9 ± 0.9^{a}	N.d.
		Female (♀)	N.d.	11.7 ± 4.9^{b}	7.6 ± 0.4^{a}	N.d.
	Hepatopancreas	Male (♂)	N.d.	9.8 ± 2.4^{b}	5.8 ± 1.3^{a}	N.d.
		Female (♀)	N.d.	5.9 ± 1.3^{b}	3.2 ± 0.4^{a}	N.d.
	Gonad	Male (♂)	N.d.	11.8 ± 5.7^{b}	6.3 ± 1.9^{a}	N.d.
		Female (♀)	N.d.	3.6 ± 1.9^{b}	1.2 ± 0.4^{a}	N.d.
	Muscle	Male (♂)	N.d.	2.8 ± 0.3^{b}	1.6 ± 0.4^{a}	N.d.
		Female (♀)	N.d.	2.1 ± 0.7^{b}	1.5 ± 0.3^{a}	N.d.
Cr	Gill	Male (♂)	N.d.	65.4 ± 32^{b}	78.2 ± 38.9^{b}	57.6 ± 23.8^{a}
		Female (♀)	N.d.	61.7 ± 29.5^{b}	47.0 ± 11^{a}	49.2 ± 12.6^{a}
	Hepatopancreas	Male (♂)	N.d.	46.1 ± 18.0^{b}	35.3 ± 14.5^{b}	23.1 ± 3.5^{a}
		Female (♀)	N.d.	54.1 ± 12^{b}	29.6 ± 4.5^{a}	22.4 ± 1^{a}
	Gonad	Male (♂)	N.d.	23.2 ± 8.3^{c}	17.9 ± 8.5^{b}	8.0 ± 5.0^{a}
		Female (♀)	N.d.	13.8 ± 1.2^{c}	7.8 ± 2.6^{b}	2.2 ± 0.9^{a}
	Muscle	Male (♂)	N.d.	6.8 ± 3.8^{a}	12.0 ± 1.3^{b}	13.1 ± 3.1^{b}
		Female (♀)	N.d.	5.9 ± 2.5^{a}	9.3 ± 6.3^{b}	6.7 ± 0.9^{a}
Ni	Gill	Male (♂)	23.5 ± 1.1^{a}	24.7 ± 3.4^{a}	33.8 ± 3.3^{b}	24.6 ± 2.5^{a}
		Female (♀)	28.5 ± 1.0^{a}	30.2 ± 21.5^{a}	33.2 ± 5.7^{b}	27.3 ± 17.6^{a}
	Hepatopancreas	Male (♂)	3.2 ± 1.0^{a}	2.3 ± 1.1^{a}	13.9 ± 4.3^{b}	10.6 ± 4.8^{b}
		Female (♀)	3.7 ± 1.0^{a}	4.7 ± 1.4^{a}	7.7 ± 1.9^{b}	7.3 ± 1.4^{b}
	Gonad	Male (♂)	9.4 ± 2.2^{ab}	4.8 ± 2.0^{a}	18.2 ± 15.7^{b}	27.3 ± 10.3^{c}
		Female (♀)	0.7 ± 0.3^{a}	2.4 ± 1.0^{a}	6.0 ± 2.0^{b}	10.8 ± 2.7^{c}
	Muscle	Male (♂)	0.6 ± 0.4^{a}	0.6 ± 0.2^{a}	3.4 ± 3.9^{b}	1.6 ± 0.8^{a}
		Female (♀)	0.6 ± 0.2^{a}	3.0 ± 1.2^{a}	3.6 ± 3.0^{b}	1.4 ± 0.2^{a}
Pb	Gill	Male (♂)	0.7 ± 0.5^{a}	0.6 ± 0.4^{a}	0.8 ± 0.4^{a}	0.9 ± 0.1^{a}
		Female (♀)	1.7 ± 1.4^{a}	1.6 ± 1.1^{a}	0.7 ± 0.3^{a}	1.1 ± 0.1^{a}
	Hepatopancreas	Male (♂)	1.1 ± 0.1^{a}	1.3 ± 0.6^{a}	1.3 ± 0.5^{a}	1.2 ± 0.4^{a}
		Female (♀)	0.9 ± 0.5^{b}	0.7 ± 0.2^{ab}	0.5 ± 0.3^{ab}	0.4 ± 0.2^{a}
	Gonad	Male (♂)	2.6 ± 0.6^{b}	3.0 ± 0.7^{b}	0.9 ± 0.5^{a}	1.4 ± 0.9^{a}
		Female (♀)	0.2 ± 0.1^{a}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	1.1 ± 0.6^{b}
	Muscle	Male (♂)	0.4 ± 0.4^{a}	0.6 ± 0.4^{b}	0.5 ± 0.2^{ab}	0.3 ± 0.1^{a}
		Female (♀)	0.2 ± 0.1^{a}	0.6 ± 0.2^{b}	0.4 ± 0.2^{a}	0.2 ± 0.1^{a}
Cu	Gill	Male (♂)	32.1 ± 7.6^{a}	37 ± 14.1^{a}	44.3 ± 17.6^{a}	40.2 ± 12.4^{a}
		Female (♀)	30.8 ± 17.2^{a}	48.8 ± 20.1^{a}	27.9 ± 16.1^{a}	43.3 ± 15.5^{a}
	Hepatopancreas	Male (♂)	24.2 ± 6.3^{a}	61.8 ± 27.2^{b}	31.6 ± 1.9^{a}	101 ± 19^{c}
		Female (♀)	56.2 ± 9.6^{a}	59.8 ± 13.9^{a}	51.5 ± 7.1^{a}	64.1 ± 19.7^{a}
	Gonad	Male (♂)	76.5 ± 11^{ab}	88.8 ± 20^{b}	55.9 ± 18.6^{a}	114 ± 20^{c}
		Female (♀)	22.9 ± 4.6^{a}	65.1 ± 18.5^{c}	24.7 ± 14.6^{a}	43.5 ± 6.8^{b}
	Muscle	Male (♂)	17.2 ± 4.4^{a}	25.7 ± 10.4^{ab}	41.0 ± 5.4^{b}	33.3 ± 4.6^{b}
		Female (♀)	17.5 ± 1.6^{a}	25.4 ± 7.6^{b}	14.9 ± 0.7^{a}	42.4 ± 5.5^{c}
Fe	Gill	Male (♂)	186 ± 24^{a}	371 ± 45^{c}	272 ± 50^{b}	232 ± 33^{ab}
		Female (♀)	235 ± 11^{a}	270 ± 38^{b}	231 ± 72^{a}	240 ± 52^{a}
	Hepatopancreas	Male (♂)	213 ± 2.4^{a}	284 ± 12^{b}	251 ± 19^{a}	291 ± 47^{b}
		Female (♀)	237 ± 5.5^{a}	261 ± 30^{ab}	285 ± 14^{b}	287 ± 20^{b}
	Gonad	Male (♂)	47.5 ± 12^{b}	18.4 ± 6.8^{a}	38.2 ± 13.1^{b}	48.1 ± 6.8^{b}
		Female (♀)	14.5 ± 3.1^{a}	18.7 ± 4.1^{b}	15.6 ± 1.9^{a}	19.1 ± 12.3^{b}
	Muscle	Male (♂)	5.9 ± 1.8^{a}	10.7 ± 7.1^{a}	21.5 ± 4.0^{b}	33.1 ± 13.8^{c}
		Female (♀)	6.8 ± 1.8^{a}	12.5 ± 8.9^{ab}	24.7 ± 9.3^{b}	22.8 ± 5.9^{b}
Zn	Gill	Male (♂)	167 ± 33^{a}	241 ± 15^{b}	196 ± 19^{ab}	185 ± 22^{a}
		Female (♀)	142 ± 0.1^{a}	181 ± 16^{b}	159 ± 9^{ab}	160 ± 4^{b}
	Hepatopancreas	Male (♂)	236 ± 2^{a}	266 ± 9^{b}	255 ± 9^{b}	234 ± 5^{a}
		Female (♀)	284 ± 40^{b}	232 ± 25^{b}	185 ± 16^{a}	261 ± 30^{b}
	Gonad	Male (♂)	85.3 ± 8^{b}	82.3 ± 7^{b}	51.1 ± 13^{a}	110 ± 6^{c}
		Female (♀)	80.1 ± 6^{b}	78.3 ± 11^{b}	41.8 ± 5^{a}	116 ± 17^{c}
	Muscle	Male (♂)	6.1 ± 2^{a}	6.0 ± 2.6^{a}	6.1 ± 1.3^{a}	10.2 ± 1.9^{b}
		Female (♀)	4.8 ± 1.8^{a}	4.3 ± 2.2^{a}	6.1 ± 1.6^{a}	10.3 ± 2.9^{b}

* (Mean ± SD) Mean concentrations (μg metal g^{-1} w.w.) and associated standard deviations.
** N.d. = Not detected.
*** Means in the same line with different superscripts were significantly different ($P < 0.05$) between the seasons.

Mean nickel concentrations were much higher in the gill of female and gonads of the male shrimps than the other studied tissues (Table 2). The highest nickel concentrations were measured in January for both male (27.3) and female (10.8) gonads tissues. There were significant differences between seasons ($P < 0.05$).

Lead concentrations in the muscle tissue of male shrimps ranged from 0.3 to 0.6 μg g^{-1} w.w., while concentrations of female shrimps were in the range of 0.2–0.6 μg g^{-1} w.w. (Table 2). Lead concentrations did not vary significantly ($P > 0.05$) in muscles of both sexes, except in July. Higher concentrations of lead were observed in hepatopancreas and gonads of male samples while lower ones in the gonads of female shrimps.

Variations in copper concentrations occurred in hepatopancreas, gonads and muscle tissues of shrimps (Table 2) ($P < 0.05$). While significant differences were found in the copper levels in the hepatopancreas of male shrimps for different seasons, there were no statistical differences in the seasonal data of the hepatopancreas of female shrimp samples. Concentrations of copper in the gill, hepatopancreas, gonads and muscle tissues of male shrimps ranged between 32.1 and 44.3, 24.2 and 101, 55.9 and 115, and 17.2 and 41.0 μg g^{-1} w.w., respectively.

Higher concentrations of iron were observed in the gill and hepatopancreas of all male shrimps than in the muscle and gonads whereas lower concentrations of this metal were noted in the muscle (Table 2). Iron concentrations varied significantly ($P < 0.05$) in the tissues of all male shrimp samples for various seasons. Significant differences in iron concentrations in the gill were found in female samples between April and July, while there were no statistical differences in April, October and January. Iron concentrations in the gill of male and female shrimps were observed to vary between 186 and 371 μg g^{-1} w.w., and between 231 and 270 μg g^{-1} w.w., respectively.

There were no considerable differences in the zinc levels of the samples of different sexes. Zinc concentrations varied significantly between seasons in the studied tissues of all shrimp samples (Table 2) ($P < 0.05$). The highest zinc concentrations were found in hepatopancreas. Higher concentrations of zinc were observed in the gills while lower ones in the muscle of the shrimps. Zinc concentrations in the hepatopancreas of the shrimps ranged from 185 to 284 μg g^{-1} w.wt., while the same in muscles were in the range of 4.3–10.3 μg g^{-1} w.wt. (Table 2).

There have been several studies on accumulation of heavy metals in shrimp species (Canli et al., 2001; Darmono & Denton, 1990; Mendez, Acosta, Palacois, & Magallon, 1997; Pourang & Amini, 2001; Pourang et al., 2004), yet few studies have taken into account the effect of seasonal changes (Kargın et al., 2001.) and sexual differences of *P. semisulcatus* with respect to the metal accumulation and distribution among tissues. Shrimps from Iskenderun bay showed high metal concentrations in their tissues, especially in the gill and hepatopancreas in all seasons. In addition, there were significant differences according to seasons.

Kumlu, Başusta, Avşar, and Eroldoğan (1999) found that *P. semisulcatus* mainly spawns between the spring and the summer months (May–July) at 24–28 °C in north-eastern Mediterranean coast of Turkey. They reported that the temperature of the bay ranged from 25.3 to 28.2 °C in summer, 24 to 27 °C in autumn, and 15.2 to 17.5 °C in winter. The information on the differences between the metal content of sexes is more limited than for the other factors so far considered. The faster-growing sex (usually the female) can be expected to contain lower concentrations of metals, but not necessarily a smaller total body burden (Pourang et al., 2004). In this study, the levels of heavy metals of male shrimps were rather high in all seasons except for a few cases (Table 2). The relationship between metal accumulation and sex found in this study may be due to the difference in metabolic activities between the males and the females.

All four non-essential elements (Ag, Cr, Ni and Pb) differ in accumulation in tissues and sex significantly. With regard to the results given in Table 2, the patterns of metal occurrence in the selected tissues can be written as follows in descending order:

Silver	(♂)	Gill > Gonads > Hepatopancreas > Muscle
	(♀)	Gill > Hepatopancreas > Gonads > Muscle
Chromium	(♂)	Gill > Gonads > Hepatopancreas > Muscle
	(♀)	Gill > Hepatopancreas > Gonads > Muscle

Patterns of metal accumulations were quite similar for the same sex. Pourang and Amini (2001) reported that the general relationships in Cd, Cr and Ni concentrations among their studied tissues were carapace > exoskeleton > abdominal muscle, exoskeleton > carapace > abdominal muscle and carapace > exoskeleton > abdominal muscle, respectively. They suggested that high concentrations of these metals in carapace could be explained by considering the fact that carapace examined in that study contained hepatopancreas. Some other researchers also reported that in crustaceans abdominal muscle generally contained the lowest amounts of these metals (Paez-Osuna & Tron-Mayen, 1996). The present study shows different accumulations in the concentrations of silver, chromium and nickel in the selected tissues. Gills of male shrimps were shown to be the main tissue in which Ag, Cr and Ni accumulated, followed by gonads, hepatopancreas and muscle, while gill accumulations of female samples were followed by hepatopancreas, gonads and muscle.

Mean value of the Lead level in gonads of males (♂) was (Gonads > Hepatopancreas > Gill > Muscle) considerably higher. This may be due to higher potential of the testis for bioaccumulation of this element when compared with the ovary. But the gills of the females (♀) accumulated higher levels of lead (Gill > Hepatopancreas > Gonads > Muscle) than those of the males. Canli and Furness (1993) found that 70% of lead in internal tissues was located in the gill of Norway Lobster *Nephrops norvegicus*.

Cu, Fe and Zn accumulations of essential elements in the muscles were notably higher than those of non-essential metals. Copper, iron and zinc content of both sexes in the selected tissues were different (Hepatopancreas > Gills > Gonads > Muscle), except for copper accumulations of the males (Gonads > Hepatopancreas > Gills > Muscle), as those of lead. Frenet and Alliot (1985) reported that bioaccumulation factor of copper in the prawn *Palaemonetes varians* was greater in the males and the juveniles. Paez-Osuna and Tron-Mayen (1996) also reported the maximum concentration of Zn in hepatopancreas of *Penaeus vannamei.* As previously mentioned, the high concentration of Zn in the hepatopancreas appears to be the case common among crustaceans (Darmono & Denton, 1990; Paul & Gupta, 1995). Zinc has a much lower toxicity to crustaceans than copper (Canli & Furness, 1993). In this study highest concentrations of zinc were found in the hepatopancreas and gill tissue.

Seasonal variations observed in the heavy metal load of the bream attribute to changes in the feeding rate, as well as the lipid dynamics of tissues and the growth of fish (Farkas et al., 2003). Season may influence body burdens of heavy metals. This seasonal variability may result from either internal biological cycles of the organism or from changes in the availability of the metals in the environment of the organism. The seasonal spawning of gametes from many benthic invertebrates changes the relative proportion of the body tissue weight within different organ types (Pourang et al., 2004). Steenkamp, du Preeze, Schoonbee, and van Eden (1994) reported that significant differences were detected in various months for most tissues (except the gills) in crab, *Potamonautes warreni*, sampled from Natalspruit River (South Africa). Joseph and Srivastava (1992) showed that in prawn *Penaeus indicus*, heavy metals exhibited seasonality. Relatively high concentrations were observed in prawns collected during November. The present study shows a significant seasonal variation ($P < 0.05$) in the concentration of the studied metals in the selected tissues. Gametes generally contain heavy metals at a concentration level below the average for all of the organs of the individual and therefore spawning may substantially increase the mean value of the tissue metal concentration of the body as a whole (Phillips, 1980). In this study, higher concentrations were observed in male shrimps collected between July and October, which coincide with the peak temperature of the seawater in the studied region.

4. Conclusion

As we expected, significant differences were found in different tissues in view of accumulation of the selected metals. The results obtained from this study indicate that concentration rates of trace metals in shrimps vary significantly not only as a function of season and the pollution load of tissue, but it is also influenced to a remarkable degree by the sexual differences of organisms, a fact, that is essential to be considered in comparative biomonitoring studies.

Based on the samples analyzed, metal concentrations found in the muscles of shrimps proved to be below the tolerance levels for human consumption. Comparing the present data with guidelines and limits, it can be seen that the mean values of Cu in the muscle for both sexes were somewhat greater than the recommended levels of WHO, NHMRC and UK. As regards gill, hepatopancreas and gonads concentration, these exceed the limits; yet, these tissues are usually not used as food.

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