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Accumulation of Hg, Pb, Cr, and Fe in muscle and head of four fish species: Diplodus annularis, Zosterisessor ophiocephalus, Liza aurata and Caranx rhonchus

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ABSTRACT

Because heavy metal pollution was recently reported in the Gulf of Gabes (Tunisia), the concentration of selected elements (Hg, Pb, Cr and Fe) in the muscles and heads for fish species, *Diplodus annularis*, *Zosterisessor ophiocephalus*, *Liza aurata* and *Caranx rhonchus*, were determined using atomic absorption spectrometry. The element contents were identified to have the following decreasing sequence: Fe > Pb, Cr > Hg in both muscles and heads. However, levels of these elements were higher in heads but in trace in muscles. This indicates that, heads were contaminated but muscles were safe for the species caught from Gabes gulf area.

Keywords

Heavy metals, bioaccumulation, fish muscle, head

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INTRODUCTION

The fishery sector plays an important socioeconomic role in coastal countries. The world production of fishes and invertebrates is approximately 100 million tons annually. The average human consumption of fish is about 12 kg/person annually. In Tunisia, the fish production was estimated to about 100.451 tons and the coastal catch was about 22.662 tons [1]. This high consumption of seafood products is due to their significant amounts of different beneficial nutrients such as nutritional and digestible proteins, lipid-soluble vitamins, essential minerals and highly unsaturated fatty acids [2,3]. Most of these constituents have been shown to play important roles in human diet. As the fish stock tends to decrease, this natural food reserve should be preserved from contamination by toxic products as well as industrial waste. The effects of anthropogenic pollution on seawater become increasingly serious. One of the major pollution problems that pose serious health risk and environmental concern is the presence of heavy metals because of their toxicity, long persistence, bioaccumulation and biomagnifications in the food chain [4,5]. Fish samples can be considered as one of the most significant indicators in seawater systems for the estimation of metal pollution level [6,7,8]. In recent years, much attention has been directed to the concentrations of some inorganic elements in seawater fish [9,10,11]. The non-essential metals such as Hg, Cr and Fe have no known physiological function in fish, but can also be acquired from the diet. Both types of metals can originate from a variety of sources (domestic, agricultural and industrial sources) [12,13,14].

Generally, marine organisms absorb minerals from their diet and the surrounding water and deposit them in their skeletal tissues and organs. Various elements are widely known to be present in enzyme active centers that are responsible for the development of important functions in all animals; thus, marine-derived foods can serve as a good source of essential elements [15,16]. Additionally, fish and shellfish are good bioindicators of trace element contamination in the marine environment because they occupy different trophic levels and can exhibit large bioaccumulation factors. By studying fish and shellfish, the harmful effects of certain metals and metalloids to marine environment and to human health have been recognized [17,18]. For both the essential and toxic groups, elements corresponding to the transition and electronegative groups of the periodic table have been reported to be strongly bound to other constituents, whereas elements corresponding to electropositive groups, generally, remain dissolved in the ionic state in the cell medium [19]. Preliminary studies have indicated that the concentration of essential and toxic minerals in fish is influenced by a number of factors such as seasonal and biological differences (species, size, muscle, age, sex and sexual maturity), food source and environment (water chemistry, salinity, temperature and contaminants) [16,18].

The commercial and edible species have been widely investigated in order to check for those hazardous to protect human health. Hence, the aim of this study was to determine the seasonal variations of Hg, Pb, Cr and Fe in muscle and head of *Diplodus annularis, Zosterissor ophiocephalus, Liza aurata and Caranx rhonchus* species caught from Gabes gulf area (Tunisia).

MATERIALS AND METHODS

Fish material

Diplodus annularis, Zosterisessor ophiocephalus, Liza aurata and Caranx rhonchus species were caught from Gabes gulf area (Tunisia). Fishes were rapidly transported on ice to the laboratory for preparation to elemental analysis. The total length (12-14; 14-17; 20-30 and 16-21 cm, respctively) and weight (30-50, 30-60, 80-200 and 50-100 g, respectively) were mesured. Weight of samples was determined by using a precision scale 10^{-4} g (Sauter). Heads and muscles were dissected.

Mineral analysis

Each sample was dried at 105°C for 48 h to constant weight. 1 g of dried tissues were weighed and digested with concentrated HNO_3 at 120°C. When fumes were white and the solution was completely clear, the samples were cooled to room temperature and the tubes were filled to 5 ml with ultra pure water [20]. Sea water samples were stabilized at pH 2 with 1 mol/l HNO_3 prior to direct determination of total metal concentrations .The filtrates were analyzed by atomic absorption spectrophotometry (Perkin Elmer AAnalyst 200) [21].

Statistical analysis

Statistical analysis were performed by using SPSS software® version 11.0 (Statistical Package for Social Sciences). Values are expressed as mean ± error deviation. Variance analysis was performed for Hg, Pb, Cr and Fe concentrations in both muscle and the head according to the factors sex, size of the fish species to determine the pertinent factors increasing the toxic element in muscle or head of fish ($p < 0.05$). Correlation matrixes were established between the measured variables (Hg, Pb, Cr and Fe). Honestly, significant difference (HSD) with ANOVA one factor was performed. Every factor presenting a p-value (p) inferior to 0.05 was considered significant.

RESULTS

Results of the seasonal variations of Hg, Pb, Cr and Fe in head and muscle of *D. annularis* were given in Table 1. The rough content orders of heavy metals in the head decreased in the sequence: Fe > Pb >Cr > Hg in head and in the sequence of Fe > Cr =Pb= Hg in the muscle. The Highest iron concentrations were found in the head of *D. annularis*, while the lowest levels were found in fish muscle. Fe was found to be the most abundant element in muscle. The higher values were obtained in autumn (3.28 and 3.19 mg / 1kg of fresh fish muscle for males and females respectively). Whereas, Hg, Cr and Pb were present at very low levels (inferior to 0.2 mg / kg of fresh fish muscle). Besides, the head of

D. annularis contained high levels of iron, the maximum values varied between 664.96 mg / kg (in spring) and 1815.93 mg / kg (in summer) for males; and between 843.04 mg / kg (in summer) and 1531.31 mg / kg (in autumn) for females. The maximum lead concentrations in the head were obtained in spring (286.34 mg / kg for males and 160.30 mg / kg for females). The head contained a higher level of Cr in summer (1815.93 mg / kg) for males and in autumn for females (1531.31 mg / kg). For Hg, values varied from 2.29 and 0.89 mg / kg (in summer) to 2.56 and 1.22 mg / kg (in winter) for male and female heads, respectively.

Table 1. Seasonal variation of Hg, Pb, Cr and Fe in head and muscle of *D. annularis* (mg / Kg of fresh fish).

		Winter	Spring	Summer	Autumn
***Diplodus annularis* head**					
Hg	Male	2.56±0.12a	2.77±0.20a	2.29±0.20a	2.50±0.08a
	Female	1.22±0.10a	1.44±0.12a	0.83±0.16a	1.14±0.05a
Pb	Male	198.67±31.98a	286.34±24.89a	126.79±23.24a	54.67±8.82a
	Female	147.03±21.65a	160.30±12.94a	46.13±17.27a	72.33±8.27a
Cr	Male	73.90±2.72a	29.63±10.76a	114.73 ±10.11b	76.37±2.08a
	Female	35.29±1.02a	62.29±3.53a	33.43 ± 7.31ab	62.62±7.81b
Fe	Male	1712.17±207.23a	1664.96±251.22a	1815.93±163.38a	1728.15±51.20a
	Female	1076.36 ±144.13 a	1141.78±179.83a	843.04±127.59a	1531.31±108.89a
***Diplodus annularis* muscle**					
Hg	Male	0.02±0.10b	0.02±0.00b	0.03±0.00a	0.20±0.00b
	Female	0.02±0.00ab	0.01±0.00a	0.03±0.00b	0.19±0.00c
Pb	Male	0.17± 0.00d	0.11±0.00c	0.11±0.00b	0.10 ± 0.00a
	Female	0.16±0.00c	0.11±0.00b	0.11±0.00b	0.04 ± 0.00a
Cr	Male	0.20±0.00b	0.07±0.00a	0.20±0.00b	0.20±0.00b
	Female	0.20±0.00b	0.09±0.00a	0.20±0.00b	0.20±0.00b
Fe	Male	1.12±0.01b	0.92±0.00a	1.17±0.00c	3.28±0.00d
	Female	1.10±0.07a	110±0.02a	1.07±0.04a	3.19±0.04b

In the case of, *Z. ophiocephalus,* head and muscle presented the same rough content orders (in comparison to *D.annularis* (Table 2). In heads, the Hg element varied between 1.63 (in winter) and 2.20 mg / kg (in autumn) for males and from 0.76 (in summer) to 1.03 mg / kg (in winter) for females. The Cr values were higher in autumn (130.79 and 41.12 mg / 100 g for males and females head, respectively). For lead, the concentrations were high in winter (228.04 mg / kg for males and 104.24 mg / kg for females). Moreover, *Z. ophiocephalus* heads presented high iron concentration with values ranged between 1724.33 (in winter) and 2352.96 mg / kg (in summer) for males and between 653.32 (in summer) and 1393.12 mg / kg (in autumn) for females. In addition to that, the muscle of *Z. ophiocephalus* showed lower values of Hg, Cr and Pb (inferior to 0.2 mg/ kg). Fe was found to be the most abundant element in muscle with maximum values in winter (4.80 and 4.60 mg/ kg for males and females, respectively).

Table 2. Seasonal variation of Hg. Pb. Cr and Fe in head and muscle of *Z. ophiocephalus* (mg / Kg of fresh fish)

		Winter	Spring	Summer	Autumn
***Z. ophiocephalus* head**					
Hg	Male	1.63±0.36a	2.15±0.28b	2.12±0.38ab	2.20 ±0.31ab
	Female	1.03±0.15ab	0.91±0.20b	0.76 ±0.20a	1.00 ±0.06a
Pb	Male	228.04±46.17ab	237.75 ±40.96b	118.74 ±24.85ab	117.80± 3.77a
	Female	104.24±24.85ab	7.990 ±14.39b	49.53±5.08a	79.26 ±10.70a
Cr	Male	63.24±12.97a	59.56±0.32ab	93.38± 20.91c	130.79 ±18.19bc
	Female	33.36±01.59a	20.33±5.86a	34.02 ±10.69a	41.12±1.92a
Fe	Male	1724.33±375.57a	1793.32±171.54ab	2352.96±126.47b	1994.58±407.10ab

	Female	814.89±130.06a	718.34±162.49a	65.332±10.486a	139.312±23.71a
***Z. ophiocephalus* muscle**					
Hg	Male	0.20 ± 0.00c	0.02±00.00a	0.05±0.00b	0.20±0.00c
	Female	0.20 ± 0.00c	0.03±00.00a	0.04±0.00b	0.30±0.00d
Pb	Male	0.22 ± 0.00d	0.12±00.00b	0.17±0.00c	0.07±0.00a
	Female	0.08 ± 0.00a	0.22±00.01c	0.13±0.00b	0.15±0.00b
Cr	Male	0.20 ± 0.00c	0.06±00.00a	0.10±0.01b	0.20±0.00c
	Female	0.20 ± 0.00b	0.10±00.00a	0.10±0.00a	0.30±0.00c
Fe	Male	4.80 ± 0.01d	0.64±00.04a	2.17±0.03b	2.42±0.01c
	Female	4.60 ± 0.20d	1.40±00.09b	1.02±0.06a	3.84±0.04c

Similarly to *D.annularis* and *Z.ophiocephalus*, the seasonal variation of Hg, Pb, Cr and Fe in head and muscle of *L. aurata showed* the same rough content orders (Table 3). For *L. aurata* heads, Hg varied between 1.11 (in winter) and 1.97 mg / kg (in spring) for males and from 0.78 (in autumn) to 0.98 mg / kg (in summer) for females, respectively. Also, Cr varied between 32.18 (in winter) and 71.17 mg / kg (in summer) for males and from 21.91 (in spring) to 58.05 mg / kg (in autumn) for females. However, the maximum lead concentration was observed in spring (17.674 and 8.443 mg / kg for males and females, respectively. In addition, the highest iron values were showed in summer (652.23 and 923.85 mg / kg for males and females, respectively). In muscle, Hg, Cr and Pb were low (inferior to 0.2 mg/ kg). Only in winter, the lead presented 0.49 mg /kg in muscle; however Fe was found to be the most abundant element with maximum values in winter (2.07 and 1.99 mg / kg for males and females, respectively).

Table 3. Seasonal variation of Hg. Pb. Cr and Fe in head and muscle of *L. aurata* (mg / Kg of fresh fish).

		Winter	Spring	Summer	Autumn
***L. aurata* head**					
Hg	Male	1.11±0.31a	1.97±0.15a	1.66±0.25a	1.74±0.25a
	Female	0.89±0.20 a	0.94±0.24a	0.98±0.21a	0.78±0.22a
Pb	Male	113.28±28.75a	176.74±16.72a	83.52±7.64a	52.99±6.70a
	Female	63.76±16.50a	84.43±15.19a	49.51±17.05a	66.51±16.09a
Cr	Male	32.18±7.66a	50.65±7.38a	71.17±5.56a	55.59±3.38b
	Female	33.90±4.32ab	21.91±7.54a	35.24±7.15ab	58.05±7.56b
Fe	Male	304.95±81.57a	569.87±120.56a	652.23±39.75a	406.95±73.30a
	Female	531.39±80.81a	406.14±0.67a	923.85±103.51a	882.70±111.47b
***L. aurata* muscle**					
Hg	Male	0.07±0.00b	0.01±0.00a	0.01±0.00a	0.13±0.00c
	Female	0.10±0.00c	$0.05\ 10^{-1}$±0.00a	0.01±0.00b	0.10±0.00c
Pb	Male	0.03±0.00a	0.07±0.00d	0.05±0.00b	0.05±0.00c
	Female	0.49±0.00c	0.03±0.00a	0.04±0.00b	0.04±0.00b
Cr	Male	0.10±0.00c	0.03±0.00a	0.09±0.00b	0.10±0.00c
	Female	0.10±0.00b	0.02±0.00a	0.10±0.00b	0.10±0.00b
Fe	Male	2.07±0.01d	0.92±0.02b	0.62±0.02a	1.91±0.00c
	Female	1.99±0.00d	0.30±0.00a	0.55±0.02b	1.74 ±0.02c

Results related to *C. rhronchus* are presented in Table 4. Generally, both head and muscle of *C. rhronchus* presented the same rough content orders (Fe > Pb >Cr> Hg). In heads, the Hg element varied between 1.18 (in autumn) and 2.41 mg / kg (in spring) for males and from 0.65 (in spring) to 0.87 mg / kg (in autumn) for females. For Cr (in heads), values varied between 47.71 (in winter) and 105.15 mg / kg (in summer) for males and from 25.47 (in spring) to 39.44 mg / kg (in autumn) for females. For lead (in heads), values varied between 95.94% (in summer) and 286.04 (in spring) for males and from 40.35 mg / kg (in summer) to 113.87 (in winter) for females. Maximum iron values were presented in winter (1027.61

and 861.03 mg / kg for males and females head, respectively). For *C. rhonchus* muscle, Hg, Cr and Pb elements were low (inferior to 0.3 mg/ 100 g). Fe was found to be the most abundant in muscles with maximum values obtained in winter (3.10 and 2.69 mg / kg for males and females, respectively). The elements levels were high in head compared with muscles.

Generally, Hg values in head of all fish species do not exceed 2.77 mg / kg. This value is recorded in spring for *D. annularis* males (Hg values ranged between 0.83 and 2.77 mg / kg). Cr reached 130.79 mg / kg in the case of *Z. ophiocephalus* (in autumn). However, Pb is moderately high for the four species with values ranging between 46.13 (in summer) and 286.34 mg / kg (in spring) for *D. annularis* females. The Fe contents were high and varied between 304.95 (*L. aurata* males in winter) to 2352.96 mg / kg (*Z. ophiocephalus* males in summer). The variation of Hg, Pb, Cr in muscle of all fish species was low (inferior to 0.3 mg/ 100 g). But, the Fe level varies between 0.30 mg / kg for *L. aurata* femelles (in spring) and 4.80 mg / kg for *Z.ophiocephalus males.*

Table 4. Seasonal variation of Hg. Pb. Cr and Fe in head and muscle of *C. rhonchus* (mg / kg of fresh fish).

		Winter	Spring	Summer	Autumn
***C. rhonchus* head**					
Hg	Male	1.77±0.36a	2.41±0.11a	1.44±0.18a	1.18±0.31a
	Female	0.76±0.21 a	0.65±0.05a	0.84±0.20a	0.87±0.22a
Pb	Male	192.99±33.98 a	286.04±1.95a	95.94±23.56a	120.24±34.19a
	Female	113.87±26.85 a	57.45±8.92a	40.35±5.40a	60.05±22.44 a
Cr	Male	47.71±2.97ab	52.75±0.75a	105.15±17.85ab	71.33±1.46b
	Female	28.29±11.17 a	25.47±6.76a	38.42±15.31a	39.44±4.26a
Fe	Male	1027.61±204.87a	853.75±146.24a	738.96±68.16 a	738.33±132.34 a
	Female	861.03±114.06a	740.45±123.21a	1012.37±113.47 a	634.76±59.95 a
***C. rhonchus* muscle**					
Hg	Male	0.10 ±0.01b	0.00a	0.01±0.00a	0.10±0.00b
	Female	0.10 ±0.00b	0.00a	0.01±0.00a	0.10±0.00b
Pb	Male	0.01±0.00a	0.04± 0.00b	0.05±0.00c	0.05±0.00c
	Female	0.04±0.00b	0.05± 0.00c	0.05±0.00c	0.00a
Cr	Male	0.30±0.00c	0.02± 0.00a	0.10±0.00b	0.10±0.00b
	Female	0.20±0.00c	0.04± 0.00a	0.10±0.00b	0.20±0.00c
Fe	Male	3.10±0.00d	0.44± 0.03a	0.63±0.03b	1.62±0.01c
	Female	2.69±0.04c	0.52± 0.01a	0.62±0.02a	2.22±0.05b

As indicated in table 5, the variation of heavy metals (Hg, Pb, Cr and Fe) in muscle was significant as a function of species, season, sexes and the interactions species×season, species×sex, sex × season and species × season × Sex ($p<10^{-3}$). Only the sex factors, it is not significant in iron variation ($P< 0.05$).

Table 5. Effect of sex and species of fish and season factors on the variation of heavy metals contained in the heads and muscles of of *D. annularis*. Z. *ophiocephalus*. *L. aurata* and *C. rhonchus*

		Head		Muscle	
Factors	**Content**	**F (Fisher number)**	**p (p-value)**	**F (Fisher number)**	**p (p-value)**
Species	Hg	52.75	$<10^{-3}$	1734.05	$<10^{-3}$
	Pb	15.99	$<10^{-3}$	1480.39	$<10^{-3}$
	Cr	56.71	$<10^{-3}$	1581.26	$<10^{-3}$
	Fe	95.78	0.03	2243.15	$<10^{-3}$
Season	Hg	2.31	0.08	5395.86	$<10^{-3}$
	Pb	16.79	$<10^{-3}$	886.78	$<10^{-3}$
	Cr	20.82	$<10^{-3}$	3680.27	$<10^{-3}$

	Fe	2.48	0.07	6208.83	$<10^{-3}$
Sex	Hg	4.67	0.03	361.78	$<10^{-3}$
	Pb	1.13	0.29	235.60	$<10^{-3}$
	Cr	0.57	0.45	126.06	$<10^{-3}$
	Fe	4.42	0.03	0.84	0.36
Species × Season	Hg	1.13	0.35	394.19	$<10^{-3}$
	Pb	2.23	0.03	472.62	$<10^{-3}$
	Cr	3.29	$<10^{-3}$	438.89	$<10^{-3}$
	Fe	3.38	$<10^{-3}$	920.15	$<10^{-3}$
Species × Sex	Hg	1.85	0.14	809.54	$<10^{-3}$
	Pb	2.90	0.04	498.75	$<10^{-3}$
	Cr	3.20	0.03	63.81	$<10^{-3}$
	Fe	5.68	$<10^{-3}$	56.35	$<10^{-3}$
Sex × Season	Hg	0.06	0.96	238.91	$<10^{-3}$
	Pb	0.87	0.46	344.92	$<10^{-3}$
	Cr	0.47	0.70	243.31	$<10^{-3}$
	Fe	0.34	0.79	183.97	$<10^{-3}$
Species × Season × Sex	Hg	1.27	0.27	257.83	$<10^{-3}$
	Pb	0.74	0.67	881.94	$<10^{-3}$
	Cr	3.14	$<10^{-3}$	109.12	$<10^{-3}$
	Fe	1.33	0.23	140.08	$<10^{-3}$

In heads, Pb and Cr varied significantly as a function of species, season and the interaction species×season and species×sex factors. Also, the variation of Cr was significant with the interaction Species×Season×Sex ($P< 0.05$). However, Hg variation is significant as a function of species and sex factors ($P< 0.05$). The factors species, sex and the interaction species×season and species×sex have significant effect on the variation of Fe ($P< 0.05$) (Table 5).

DISCUSSION

In the present work only fish muscles and heads were evaluated for the elemental concentrations. Iron, lead, mercury and chrome were selected from the viewpoint of the industry type near the golf of Gabes and the metal pollution anticipated. Although many researchers have presented the elemental contents in various tissues, such as liver, kidneys, gills, gonads and muscles of fish [11,22]. Among the analyzed elements, Fe was found to be the most abundant, whereas Hg, Cr and Pb were presented at very low levels in muscles. Fe, Hg, Pb and Cr found in the fish muscles are at acceptable levels (below the threshold) [23]. These results are consistent with those of other studies [24,25] concerning fish muscles from the lagoon Tuzla. These authors reported significant seasonal variations.

Higher heavy metal values were observed in heads compared with muscles. The elemental head values were superior to the threshold [23]. The ranges of international standards for fish are (in mg/ 100 g): 0.0055 ± 0.0006 for Hg; 0.003 ± 0.0015 for Pb; 0.018 ± 0.0055 % for Cr and 3.65 ± 0.35 for Fe. The rough content orders were: iron > lead>chromium> mercury. These sequences were the same as those obtained in Malibu Lagoon, California and Dhanmondi Lake in Bangladesh [26,27]. Data related Fe, Pb, Cr and Hg contents found in the present study are in agreement with mean values reported for muscles of most fish species [16,17,19]. It is well known that muscle is not an active tissue in accumulating heavy metals [28]. The greater presence of heavy metals in the gills than in muscle is probably due to the direct exposure of this organ to the water and thus to toxic compounds [29]. The least abundant metals in muscle were Hg, Cr and Pb. These values are similar to those reported by [30] in four fish species caught adjacent to Raine Island in northern Britain. Iron is quantitatively the most important in the muscle regardless of fish species and season. It is involved in the base metabolism [31]. Iron contents have exposed fluctuations depending on the species, the sex of fish and season. Fe serves as a carrier of oxygen to the muscle from the lungs by red blood cell haemoglobin, as a transport medium for electrons within cells and as an integrated part of important enzyme systems in different tissues [32,33]. The average intake of Fe is too low, although many people receive more than 18 mg per day, which is the recommended dietary allowance (RDA) [34]. However, lead showed no physiological role in fish [35], but it can be absorbed by the gastrointestinal tract [36,37,38]. It showed high values in head for all species. Chromium is essential for normal carbohydrate and lipid metabolism. The role of chromium in glucose metabolism has been reported for poults and mammals. It is considered to be a cofactor for insulin activity and part of an organic tolerance factor |39,40]. Also, it was reported the influence of dietary chromium on glucose metabolism of fish [41]. Hence, chromium salts improved glucose utilization and inhibited gluconeogenesis, probably by modulating the endogenous insulin activity. Supplemental dietary chromium increased the weight gain, energy deposition and liver glycogen content in tilapia fed glucose diets [42]. The biological availability of this element depends on its characteristic ability to form coordination compounds and chelates. It occurs in food as part of a biologically active molecule and as inorganic trivalent chromium. The contamination by heavy metals is in direct relation with the diet. *D. annularis* feeds on worms, crustaceans, molluscs, echinoderms, hydrozoans and algae that absorb high levels of heavy metals. *L. aurata* feeds on small plants, invertebrates and various detritus dig into the bottom sediments and filter through their gill rakers. However, *Z. ophiocephalus* feeds on small fish and crustaceans [43,44]. It is well-known that a number of factors such as sex, age, season, spawning period, variability of food habitats, pollutant exposure and phylogenetical differences in regulatory mechanisms, may influence the uptake, retention and bioaccumulation of trace contaminants in fish tissues. In the case of *Z. ophiocephalus*, a near-bottom feeder, sediments may also play an important role as a source of contaminated food [45]. *C. rhonchus* feeds on small fish and invertebrates [43,44]. In comparison with other species, *C. rhonchus* is less contaminated by heavy metals and their diet is responsible for the lower contamination.

CONCLUSION

The study of the seasonal variation of the heavy metals, from the Gabes Gulf (Tunisia) is important and useful to study the effect of pollution on the consumable fish. The significant seasonal differences observed in the mineral elements are mainly related to diet and environmental factors. Based on the present study, it is recommended to do not eat fish heads.

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