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Levels of heavy metals (Zn, Pb, Cu, Cd, Ni) in tissues of *Sarpa salpa* from Honaine bay in the Western part of the Algerian Coast

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ABSTRACT

This study aims to determine the bioaccumulation of heavy metals in various organs (gonads, muscle, liver and gill) of Saupe *Sarpa salpa* (SS) from Honaine bay in the western part of the Algerian coast. Elements such as Zn, Pb, Cu, Cd and Ni were assayed using Atomic Absorption Spectrophotometry. Accumulation of heavy metals gradually increases in liver. Mean concentrations in gonads, livers and gills of SS followed the sequence Cu > Ni > Zn > Cd > Pb and in muscles Cu > Zn > Ni > Cd > Pb, respectively. Ni and Cu concentrations were above the prescribed levels (IAEA-407). The results of a linear regression analysis showed that, except in some few cases, significant negative relationships between metal concentrations and fish size exist. Highly significant ($p < 0.001$) negative relationships were found between fish length, and concentrations of zinc, lead and copper in liver and gill, and cadmium in liver of SS principal component analysis was applied, with the metal concentrations and fish sizes as variables. It totaled 54.6% of the total information (40.3% for factor 1 and 14.3% for factor 2) of the metal concentration.

Keywords: Heavy metals; *Sarpa salpa*; ACP; Honaine bay; Algeria

1. Introduction

Heavy metals are introduced into the environment by means of a wide spectrum of natural sources. Some of these are metals, such as lead, nickel, cadmium, mercury, which are toxic to living organisms, even at quite low concentrations; while others such as copper, iron, zinc and manganese are biologically essential and are natural constituents of the aquatic ecosystems but can become toxic only at very high concentrations. Fish constitutes an important and cheap source of animal protein to human beings and a large number of people depend on fish and fishing activities for their livelihood [1]. Increasing human influences through heavy metal pollution have however led to the depletion of our fish resources and substantial reduction in the nutritive values [2]. The danger of these heavy metals is their persistent nature, as they remain in the

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biota for long periods of time when they are released into the environment [3]. They can cause reductions on marine species' diversity and damage their ecosystem. A wide range of metals and metallic compounds found in the marine environment pose risks to human health through the consumption of seafood where the contaminant content and exposure are significant [4–6]. The *Sarpa salpa* (SS) (Linnaeus, 1758) is a fish found along rocky coasts covered with algae. It is a protogynous hermaphrodite which sexually matures at approximately 20 cm long, and spawns at the beginning of fall and in winter [7]. Under natural living conditions, it is mostly an herbivore, changing its food habits by the age and flesh chemistry at the same time [8–10]. SS could be hallucinogenic by ingestion of algae or phytoplankton. Honaine bay is located in the north-west of Algeria, at 60 km to the west of Tlemcen, on the western Mediterranean coast. Its area is approximately 200 km^2, and it is about 20 km long and 10 km wide (Fig. 1). In summer, sea temperature increases up to 30˚C and decreases down to 12˚C in winter, with a respective maximum salinity of 36 and 38 $g\,l^{-1}$. No industrial effluents are poured into Honaine bay. Domestic discharges and pesticides used in agriculture are the main sources of pollution [11]. In 2009, this area became a desalinisation plant. Fishing is the main activity of the region. SS form 20% of the total catch in the bay [11]. The present study is thus to assess the levels of Zn, Pb, Cu, Cd, and Ni in the tissues (gonads, muscle, liver and gill) of SS of Honaine bay. It is semi pelagic [12,13]. The present study's objective is to understand whether the concentration level of these metals constitute health hazards to consumers, and investigate the relationship between fish size (length and weight) and metal concentrations in the tissues.

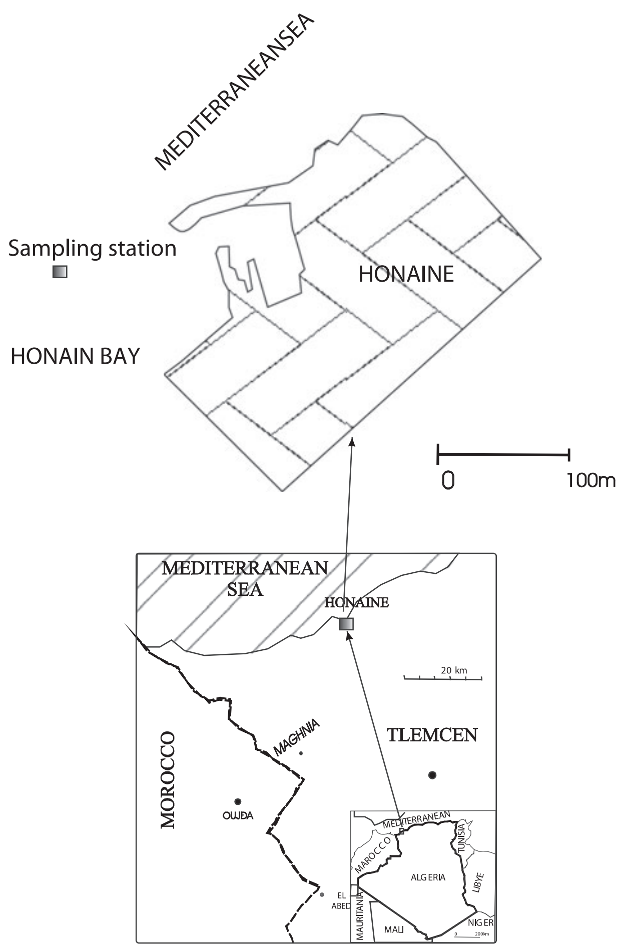

Fig. 1. Map of the studied area, showing the Honaine bay where samples were collected.

2. Materials and methods

Fish sampling was done at one station, by the traditional fishermen at Honaine bay between April and June 2010 (Fig. 1). The samples were immediately kept in precleaned polythene bags, which were sealed and kept in an ice box and transported to the laboratory. Total lengths and weights were measured for each fish. Next, gonads, muscles, livers and gills were removed using a plastic knife and then weighed. After dissection, all the samples were labelled. The protocol of mineralization used in our investigation was proposed in literature [14]. The tissues were separately dried in the laboratory oven at 110˚C for 3 h. Each sample was removed and treated with 1 ml nitric acid and put back on again in the muffle furnace at 350˚C, for 90 min. Then, the samples were placed into 25 ml flasks and double-distilled water was added. The resulting solutions were filtered with a 0.45 μm filter (natural absorbing membrane, Gelman in polyethersulfone, 25 mm diameter), and acidified with 50 μl of HNO_3. High quality chemical products from Merck were used. Concentrations of metals were determined using an atomic absorption spectrophotometer (Rayleigh WFX-130). The following absorption lines were found: zinc = 213.9 nm, lead = 283.3 nm, copper = 324.8 nm, and cadmium = 228.8 nm. The mean metal concentrations were calculated together with their standard deviations. As far as the pooled samples are concerned, the standard deviations show the variation of different measurements. In the case of fish, it is the variation of metal concentrations between individuals. The heavy metal contents found in the gonads, muscles, liver and gill of SS were evaluated statistically using a variance analysis (ANOVA). In order to make correlations between the size and heavy metal concentrations, we used MINITAB (statistical

Table 1
Size range, mean standard deviation and relationships between weight (W) and total length (L) of SS

Fish	n	(Min–Max) L. ranges	(Min–Max) W. ranges	Equation[a]	R value
SS	32	15–23 18.79 ± 2.58	41–195 114.55 ± 47.62	$Y = 12.64 + 0.054X$	0.99

[a] Y is the total fish length (cm) and X is the total fish weight (g).

Table 2
Mean concentrations (mg kg^{-1} DW^{-1}) of metals and standard deviations in the tissues of SS caught in the Northwestern Mediterranean Sea (Honaine)

Tissue	Zinc	Lead	Copper	Cadmium	Nickel
Gonads	0.139 ± 0.057	0.037 ± 0.021	12.651 ± 4.195	0.072 ± 0.084	6.088 ± 3.758
Muscle	0.856 ± 0.244	0.005 ± 0.001	1.723 ± 0.149	0.019 ± 0.006	0.776 ± 0.528
Liver	0.495 ± 0.181	0.015 ± 0.007	4.714 ± 2.141	0.047 ± 0.021	1.173 ± 1.270
Gill	0.845 ± 0.471	0.015 ± 0.007	3.461 ± 1.478	0.045 ± 0.031	1.291 ± 0.838

software). To identify the differences in metal concentrations between organs, the principal component analysis (PCA) on metal concentrations (XlStat 2007) was performed.

3. Results and discussion

Table 1 shows the number of fish sampled, mean standard deviation, length and weight range and their relationships. Table 2 indicates the mean metal concentrations of Zn, Pb, Cu, Cd and Ni (mg kg^{-1} DW^{-1}.) and the standard deviations in tissues (gonads, muscle, liver and gill of SS. The Mean concentrations followed the sequences Cu > Ni > Zn > Cd > Pb in gonads, liver and gill, and Cu > Zn > Ni > Cd > Pb in muscles, respectively.

Different tissues showed different capacities for accumulation of heavy metals. The highest Ni concentrations were recorded in gonads, and Zn in gill of SS, ranging from 1.499 to 20.228 (mg kg^{-1} DW^{-1}) and from 0.375 to 1.911 (mg kg^{-1} DW^{-1}), respectively. Ni concentrations varied significantly ($p < 0.05$) in gonads; and Zinc, lead, copper and cadmium concentrations varied significantly ($p < 0.05$) in liver of *Sarpa salpa*. Zinc, lead and nickel concentrations varied importantly in gill ($p < 0.05$, $p < 0.001$, $p < 0.01$). The mean values obtained for Zn in this study in all organs were below 67.1 (mg kg^{-1} DW^{-1}), recommended value (IAEA-407) [15], thus indicating that the fishes examined were free from Zn related toxicity. The mean concentration of Pb varied from a minimum of 0.005 ± 0.001 (mg kg^{-1} $DW^{-1)}$) in muscles to a maximum of 0.037 ± 0.021 (mg kg^{-1} DW^{-1}) in gonads. The values obtained for Pb in the present investigation were below 0.12 (mg kg^{-1} DW^{-1}), recommended value (IAEA-407) [15] for Pb in food fish. A high mean concentration of Cu was also observed in gonads, liver and gill of all the fishes studied, and the mean concentration varied from a minimum of 1.723 ± 0.149 (mg kg^{-1} DW^{-1}) in muscles to a maximum value of 12.651 ± 4.195 (mg kg^{-1} DW^{-1}) in gonads. The values obtained for Cu in gonads, liver, and gill were above 3.28 (mg kg^{-1} DW^{-1}), recommended value (IAEA-407) [15], indicating that these fishes could pose health problem to consumers. Copper is available in surface water and ground water due to the extensive use of pesticide sprays containing copper compounds for agricultural purposes. The mean concentration of Cd varied from a minimum of 0.019 ± 0.006 mg kg^{-1} DW^{-1} in muscles, to a maximum of 0.072 ± 0.084 mg kg^{-1} DW^{-1} in gonads. The mean values obtained for Cd in this study, in all organs, were below 0.189 mg kg^{-1} DW^{-1}, recommended value (IAEA-407) [15]. The mean concentration of Ni in the studied fishes varied from a minimum of 0.776 ± 0.528 (mg kg^{-1} DW^{-1}) in muscles to a maximum value of 6.088 ± 3.758 (mg kg^{-1} DW^{-1}) in gonads (Table 2). Nickel concentrations were higher in all fishes studied. The values obtained for Ni in all fishes in the present investigation were above 0.6 (mg kg^{-1} DW^{-1}), recommended value (IAEA-407) [15], thus indicating that these fishes may pose Ni related health hazard, such as cancer of lungs and kidneys of consumers. From other researches, it is clear that the target organs have a tendency to accumulate heavy metals (copper, cadmium, lead, nickel and zinc) in high concentrations, as shown in many species of fish in different areas [16,17]. Table 3 shows the relationships between metal concentrations and fish size. The relationship between metal levels

Table 3
The relationships between heavy metal concentrations and total fish lengths and weights in the tissues of SS

Tissue	Data	Zinc	Lead	Copper	Cadmium	Nickel
Gonads	Equation	$Y = 0.0004X + 0.133$	$Y = -0.0037X + 0.107$	$Y = -0.694X + 19.59$	$Y = -0.0054Y + 0.173$	$Y = 0.281X + 0.814$
	R value	0.02	−0.05	−0.23	−0.16	0.19
	P value	NS	*	NS	NS	NS
Muscle	Equation	$Y = -0.0063X + 0.974$	$Y = -3E-05X + 0.0054$	$Y = -0.0073X + 1.86$	$Y = -0.0004X + 0.026$	$Y = -0.0004X + 0.0257$
	R value	−0.07	−0.15	−0.13	−0.15	−0.15
	P value	NS	NS	NS	NS	NS
Liver	Equation	$Y = 0.054X - 0.519$	$Y = -0.0023X + 0.0579$	$Y = -0.641X + 16.78$	$Y = -0.0048X + 0.137$	$Y = -0.202X + 4.96$
	R value	0.77	−0.79	−0.77	−0.59	−0.41
	P value	***	***	***	***(**)	*
Gill	Equation	$Y = 0.126X - 1.52$	$Y = -0.0022X + 0.0568$	$Y = -0.48X + 12.49$	$Y = -0.0063X + 0.164$	$Y = -0.232X + 5.64$
	R value	0.69	−0.83	−0.84	−0.52	−0.71
	P value	***	***	***	**	**

[a]In the equations, Y is the metal concentration ($mg\,kg^{-1}\,DW^{-1}$) and X is the total fish length. *Indicate significant results. [b]NS, not significant, $p > 0.05$.
*$p < 0.05$.
**$p < 0.001$.
***$p < 0.001$.

and weight were also investigated and the significance of data was exactly the same except for a few cases which are indicated in the Table 3.

Negative correlations were found between fish size (weight) and metal concentrations in organs (lead and copper) in the liver ($p < 0.001$), lead in the gonads ($p < 0.05$), cadmium in the liver and gills ($p < 0.001$), Ni in the liver and gills ($p < 0.01$) (Table 3). Also there were positive relationships between zinc levels in the liver and gill and fish lengths ($p < 0.001$). The average metal concentrations in all organs of the studied fishes showed some differences. Statistical comparisons revealed that the metal concentrations were significantly different in tissues of different fishes [18]. The difference in metal concentrations in fish tissues might be the result of their capacity to induce metal-binding proteins such as metallothioneins. Liang et al. [19] studied metal (Zn, Cu, Cd, Cr, Pb, Ni) concentrations in various polycultured fished species and found that metals in fish viscera were generally negatively correlated. It has been suggested that metal metabolism in fish played an important role in metal accumulation in fish viscera. Results showed that there were negative relationships between fish sizes and metal levels in most cases of *Sarpa salpa*. The data showed that positive relationships were found only between zinc levels in liver and gill. Comparisons of metal concentrations and size parameters showed the same trend in all fishes except in a few cases (Table 3). The negative relationships between heavy metal levels in tissues and fish sizes were generally supported in the literature [20]. Authors showed that accumulation of metals (Cr, Mn, Ni and Pb) decreased with an increase in the length of fish *labeo umbratus*. Al-Yousuf et al. [21] found that the average metal concentrations in tissues of female fish were higher than those in male fish, indicating the differences in metabolic activities of the two sexes. It is also known that the metabolic activity of a young individual is normally higher than that of an older one [22]. One explanation for negative relationships between metal concentration and fish size found in this study may be the difference in metabolic activity between younger and older fish. High metal concentrations in water can also retard fish development, causing possible alternations in fish size [23]. Metal accumulation could reach a steady state after a certain age [24]. The decrease in metal concentrations in tissues, due to growth or metabolic activity in adult individuals, can be considered only if the metal concentrations in water are high compared to their accumulation capacities. In This case, a continuous accumulation of metals may occur and positive relationships may be seen between animal size and metal concentrations in tissues. PCA

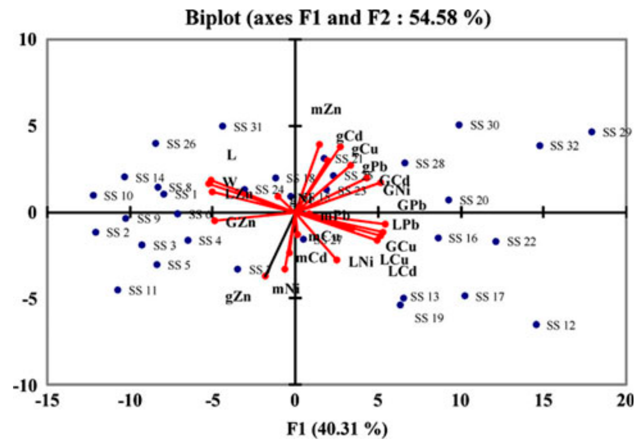

Fig. 2. Biplots for the first and second axis of the ACP based on values of length (L), weight (W) and metal concentrations (Zn, Pb, Cu, Cd, and Ni) in tissues of SS (g: Gonad; m: Muscle; L: Liver; G: Gill).

totaled 54.6% of the total information (40.3% for factor 1 and 14.3% for factor 2) of the metal concentration (Fig. 2). These herbivorous organisms take up metals from all environmental compartments, either from the aqueous medium or through ingestion from food and inorganic particulate material. It can be supposed that metal levels in their tissues are substantially influenced by metals accumulated in the algae on which they graze.

This investigation was concerned with a detailed analysis of the concentrations of Zn, Pb, Cu, Cd, and Ni in tissues of SS, in the bay of Honaine on the western Algerian coast, and the relationships between heavy metal concentrations in tissues, and fish lengths and weights. This study showed that while the concentrations of Zn, Pb, and Cd were below the prescribed values (IAEA-407) for fish species, Ni and Cu were above. These metals could pass to humans through the food chain and predispose the consumers to possible health hazards. Periodic monitoring of these and other heavy metals in fishes to ensure continuous safety of people in the area is recommended. Safe disposal of domestic wastes should be practiced, and recycling must be done to prevent these metals and other contaminants from going into the environment. Further studies on heavy metal concentrations in other fish tissues (brain, kidney, intestine and heart) are recommended.

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