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Heavy metals concentrations and condition of some fish species at two hot spots, Mediterranean coast, Alexandria, Egypt

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Abstract

The present investigation aimed to determine concentrations of Zn, Cu, Fe and Cd in different organs and the extent that accumulation of these metals had affected condition of some commercial fish caught from two hot spots at Alexandria coast. The accumulation of these metals in fish muscles of El-Mex Bay ranged between 8.99-15.03, 0.99-7.96, 11.43-41.49 and 0.55-1.96, while, in fish muscles of Abu-Qir bay, they recorded 12.03, 18.69; 4.22, 4.68; 21.36, 37.05 and 0.45, 2.29 mg/kg wet weight for Zn, Cu, Fe and Cd, respectively. These ranges were found to be lesser than the recommended maximum permissible limits for human in muscles of fish from both studied areas. The abundance of these metals in fish organs was found to be muscles < gills < liver < gonads in most studied species. On the other hand, metals abundance has been found to follow the order Fe > Zn > Cu > Cd in muscles, gills, liver and gonads of fish at both studied areas. According to values of condition factor (K), fish condition still not affected yet by the recorded metals concentrations. Hepato-somatic index (H.S.I.) values display different fish response to metals in both studied areas. Results of statistical analyses revealed that concentrations of Zn, Cu, Fe and Cd in gills, liver and gonads may start to exert a stress effects on these organs.

Keywords: Mediterranean, El-Mex Bay, Abu-Qir Bay, heavy metals, condition factor, hepato-somatic index.

1. Introduction

Abu-Qir Bay, east of Alexandria coastal area, receives wastes belonging to different branches of industries e.g. chemical, textile, printing, engineering, pulp and paper, oil refineries and food industries. Many studies were carried out describing the physical and chemical conditions of water and distribution of metals in sediments of this area (Dowidar *et al.,* 1983; Tayel, 1992; Aboul-Naga *et al*., 2002).

On the other hand, El-Mex Bay, west of Alexandria coastal area, receives wastewaters from Chloro–alkali plant and mixed agricultural runoff from El-Umoum Drain and West-Nubaria canal. It receives also, air born particles from the fumes of adjacent industrial plants including petroleum, mercury, chlorine and chemical factories. This area exposed for many investigations studying the chemistry of seawater (Emara *et al.,* 1984), distribution and fluxes of metals in water (Emara and Shriadah 1991; Shriadah and Emara 1991 and El-Rayis and Abdallah, 2005) and distribution of heavy metals in sediments (El-Sammak and Abou El-Kassim 1999).

Nessim *et al.* (2005) studied the effect of the discharged effluents on the chemical composition of the seawater of Abu-Qir and El-Mex Bays. Sayed Ahmed *et al.* (2009) studied the effect of wastewaters of both El-Umoum Drain and West-Nubaria canal (west of Alexandria) on growth performance of *Mugil capito* fingerlings. Shakweer *et al.* (2008) investigated the prevailed environmental conditions where fish fry were collected along the Mediterranean.

The present investigation has two main goals: 1- Study the accumulation of some trace metals in organs of some commercial fish species in two hot spots (El-Mex and Abu-Qir Bays) at the west and east of Alexandria coastal area and identify any potential public health risks. 2- Explore to what extent accumulation of these heavy metals had affected fish condition.

2. Materials and methods

This work was carried out through the project: “Fisheries and fishing tools at Alexandria coastal area between Agamy and Abu-Qir Bay”. It was financed by NIOF during the period from 2003 – 2005.

Fish samples were regularly collected from the areas of study (Figure 1), during the period of the project. Fish collected from the coastal areas of El-Mex (21 species) and Abu-Qir Bays (11 species) were identified and their total length (cm), total weight (g) and gutted weight (g) were measured. Fulton's condition factor (K) for fish was calculated according to the equation:

K = [gutted weight (gm) / total length^3 (cm)] X 100 (Fulton, 1904; Bolger and Connolly, 1989). The hepato-somatic index (H.S.I.) was calculated according to the equation:

H.S.I. = [liver weight (gm) / gutted weight (gm)] x 100. (Goede and Barton, 1990; Facey *et al.,* 2005).

Tissue samples were taken from muscles, gills, liver and gonads (5 replicates) of 7 fish species from El-Mex Bay and 2 species from Abu-Qir Bay and were kept frozen in plastic bags for metals analyses. The sampled tissues were weighed (as wet weight) before treatment with 65% concentrated HNO_3 at 120°C according to Bernhard (1976). The concentrations of metals in fish tissues were determined, using Atomic Absorption Spectrophotometer (Perkin Elmer model 2380). For control quality, the standard reference material MA-A-2/TM (National Research Council, Canada) was used. The recovery percent of all metals ranged between 95.85 and 103.37 (Table 1).

Table 1. Certified and experimental values of standard reference material: MA-A-2/TM.

Element	Certified value	Experimental value	Recovery%
Zn	33.0	31.686±0.158	96.08
Cu	4.0	3.834±0.023	95.85
Fe	54.00	55.824±0.0242	103.37
Cd	0.07	0.067±0.002	95.71

Metal type, fish species and fish organs dependant variability of metals accumulation in fish organs were examined using two-tailed analysis of variance (ANOVA) and least significant difference test (LSD). Dependence of metals accumulation in fish organs on condition factor (K), hepato-somatic index (H.S.I.), total length T.L. and gutted weight (Gut. Wt.) values were examined using Spearman's rank correlation test. All statistical analyses were carried out using SPSS-10 for windows.

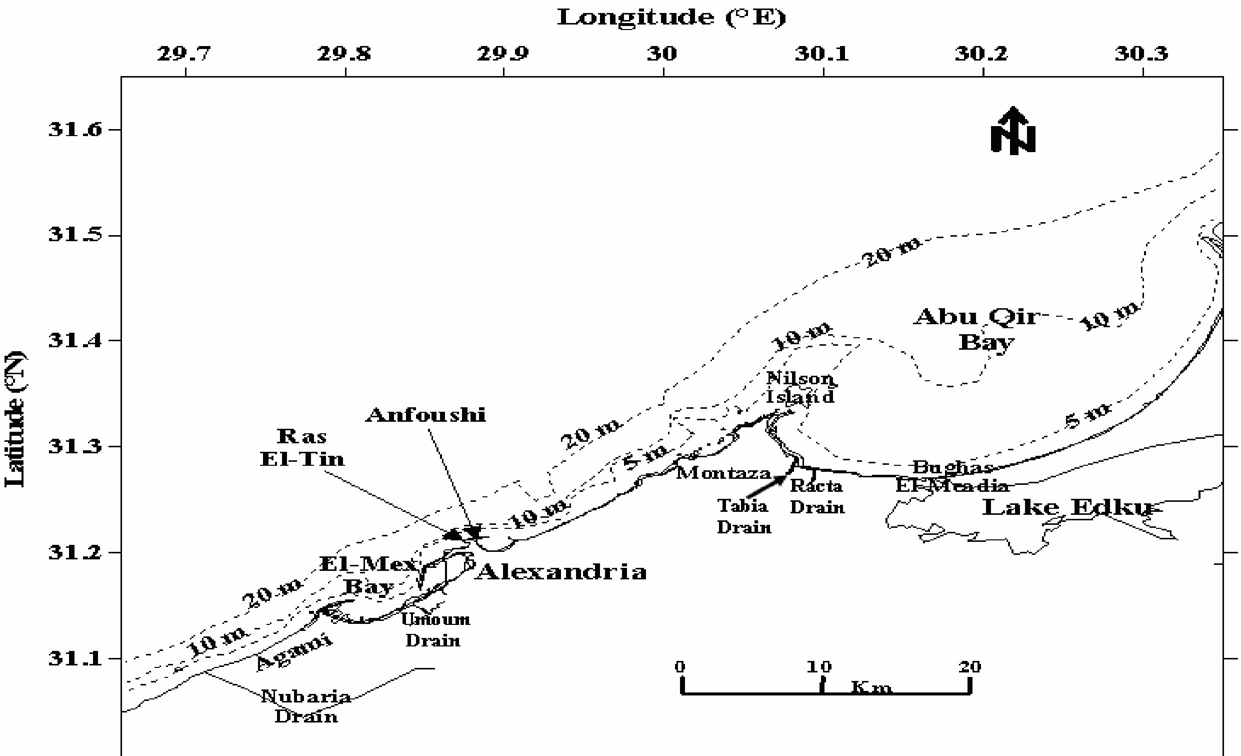

Figure 1. Sampling stations at Abu-Qir and El-Mex Bays along Alexandria coast.

3. Results and Discussion

3.1. Concentrations of heavy metals in fish

The seriousness of heavy metals leads the marine environmental pollution to be recognized as a serious matter to human health concern. Industrial and agricultural activities were reported to be the principal potential source of the accumulation of pollutants in the aquatic environment including the sea (Barlas, 1999; Akif *et al.,* 2002; Jordao *et al.,* 2002). The deleterious wastes in the sea are potentially accumulated in the sediments and marine organisms including fish which, consequently, transfer to human being through food chain. The inconsistency of metals concentrations in different fish organs within the same species or in different species may be attributed to the ecological factors such as season, place of development, nutrient availability, temperature and salinity of the water (Tuzen, 2003; Irwandi and Farida, 2009).

3.1.1. Concentrations of heavy metals in fish muscles

In present investigation, it is noteworthy that muscles tissues accumulated lower concentrations of metals in all sampled fish species if compared with other organs. The average concentrations of Zn, Cu, Fe and Cd ranged between 8.99, 15.93; 0.99, 7.96; 11.43, 41.49 and 0.55, 1.96, in muscles of fish caught from El-Mex Bay (Table 2), while they recorded 12.03, 18.69; 4.22, 4.68; 21.36, 37.05 and 0.45, 2.29 mg/kg wet weight in muscles of those caught from Abu-Qir Bay, respectively (Table 3). These results agree with other reports (Plaskette and Potter, 1979; Gibbs and Miskiewicz, 1995; Hamza-Chaffai, *et al.,* 1996; Yi-Chun Chen and Meng-Hsien Chen, 2001; Zheng Zhang, *et al.,* 2007). Bryan (1964 and 1980) pointed out that the essential metals like zinc and copper are better regulated in fish muscles than the non-essential metals such as mercury and cadmium. Eisler and LoRoche (1972) showed that higher marine organisms can regulate zinc concentration in their tissues.

Comparing to the maximum acceptable concentrations of Zn: 40 mg/kg (FDA, 2001), Cu: 30 mg/kg (FAO, 1983) and Cd: 2.0 mg/kg (NHMRC, 1974; FAO, 1992; FDA, 2001), it appears that the concentrations of these metals in the muscles tissues of fish collected from both areas of study were below the allowable limits. For the permissible concentration of Fe in fish flesh, Marks, *et al.* (1980) pointed out that there was no specified maximum for Fe concentration in fish flesh.

Table 2. Concentrations (average ± s.d.) of Zn, Cu, Fe and Cd in different organs of fish (N = 5) caught from El-Mex Bay, west of Alexandria coastal area.

Metal	Species	Concentration mg/Kg wet weight			
		Muscles	Gills	Liver	Gonads
Zn	1. *Sparus auratus*	11.45±2.55	36.37±7.64	64.66±23.85	104.16±26.05
	2. *Alpes djedata*	11.72 ± 2.79	33.01 ± 5.06	32.50 ± 11.05	208.75 ± 146.42
	3. *Scombermourus spp.*	15.93 ± 2.74	50.55 ± 16.82	57.72 ± 28.03	--
	4. *Mullus surmulatus*	12.31 ± 2.42	21.40 ± 26.21	127.82 ± 71.30	91.2 ± 0.45
	5. *Spicara flexusa*	13.29 ± 1.50	52.19 ± 13.64	167.14 ± 133.52	61.12 ± 16.39
	6. *Diplodus surgus*	15.03 ± 6.24	38.18 ± 8.28	178.49 ± 192.80	117.32 ± 89.58
	7. *Pagellus erythrinus*	8.99 ± 3.39	34.44 ± 10.93	61.06 ± 21.89	83.51 ± 80.90
Cu	1. *Sparus auratus*	1.90±1.41	1.91±0.42	13.76±13.93	19.47±16.18
	2. *Alpes djedata*	2.58 ± 0.55	7.42 ± 7.40	3.61 ± 1.36	--
	3. *Scombermourus spp.*	2.87 ± 1.42	6.50 ± 4.02	7.40 ± 2.39	58.30
	4. *Mullus surmulatus*	0.99 ± 0.05	1.77 ± 0.40	10.28	4.40
	5. *Spicara flexusa*	2.10 ± 0.72	6.19 ± 2.89	22.56 ± 12.55	21.54 ± 9.64
	6. *Diplodus surgus*	7.96 ± 4.18	4.49 ± 1.56	57.14 ± 65.03	--
	7. *Pagellus erythrinus*	2.57 ± 1.44	3.26 ± 1.57	14.69 ± 6.93	9.04 ± 5.48
Fe	1. *Sparus auratus*	41.49 ± 45.72	74.68 ± 19.22	269.12 ± 173.62	210.80 ± 211.50
	2. *Alpes djedata*	13.11 ± 6.55	61.52 ± 59.99	87.23 ± 61.59	126.88 ± 64.30
	3. *Scombermourus spp.*	18.62 ± 6.19	60.03 ± 26.01	116.94 ± 76.05	17.54
	4. *Mullus surmulatus*	11.43 ± 4.71	83.26 ± 18.97	151.85 ± 165.39	25.78 ± 11.25
	5. *Spicara flexusa*	16.23 ± 1.85	136.59 ± 30.02	306.11 ± 189.17	93.43 ± 25.66
	6. *Diplodus surgus*	13.44 ± 3.24	75.08 ± 8.67	624.88 ± 913.20	149.56 ± 109.81
	7. *Pagellus erythrinus*	11.66 ± 9.19	92.90 ± 24.53	92.47 ± 67.06	38.22 ± 34.32
Cd	1. *Sparus auratus*	0.55 ± 0.25	1.07 ± 0.68	3.72 ± 4.14	3.38 ± 2.18
	2. *Alpes djedata*	0.74 ± 0.50	1.67 ± 0.06	1.46 ± 0.53	7.34 ± 6.75
	3. *Scombermourus spp.*	0.72 ± 0.26	2.47 ± 3.26	1.12 ± 0.28	19.48
	4. *Mullus surmulatus*	0.84 ± 0.31	1.59 ± 0.54	3.03 ± 3.34	0.65 ± 0.17
	5. *Spicara flexusa*	1.96 ± 0.62	5.25 ± 2.70	27.66 ± 16.92	9.14 ± 9.08
	6. *Diplodus surgus*	1.62 ± 0.52	1.38 ± 0.78	3.81 ± 3.46	5.45 ± 3.73
	7. *Pagellus erythrinus*	0.97 ± 0.29	2.43 ± 0.83	6.38 ± 5.73	6.09 ± 4.08

3.1.2. Concentrations of heavy metals in fish gills

In this work, the concentrations of Zn, Cu, Fe and Cd in fish gills ranged between 21.4, 52.19; 1.77, 7.42; 60.03, 136.59 and 1.07, 5.25 in El-Mex Bay (Table 2) and recorded 26.05, 37.25; 5.44, 6.3; 76.48, 88.26 and 0.98, 1.81 mg/kg wet weight in Abu-Qir Bay (Table 3). Bahnasawy *et al.* (2009) reported seasonal variations of Zn, Cu, Cd and Pb between 48.18 - 141.98; 12.78 - 17.57; 3.14 - 6.26 and 8.21 - 12.67 in gills of *Mugil Cephalus* and between 46.9 - 138.30; 8.13 - 19.97; 1.63 - 5.92 and 5.36 - 11.52 µg/g dry weight in gills of *Liza Ramada* from Lake Manzala, Egypt. The increased concentrations of heavy metals in fish gills may lead to some toxic effects. Saleh *et al.* (1983) pointed out that the accumulation of heavy metals in gills may be considered as the main reason of fish death in Lake Mariut at Alexandria, Egypt. In this concern, Burton *et al.* (1972) indicated that the acute toxicity of Zn to rainbow trout supports the hypothesis that modifications of the gases exchange process in the gills may be created and causing hypoxia. Ellis (1973) described the toxic process of Cu in fish gills that such process starts when this element attacks the gill filaments, precipitates in the spaces between gill lamellae and so the circulation of blood is affected.

On the other hand, some fish species concentrated zinc with high percent in their organs, especially, gills and liver. Salanaki *et al.* (1982) found that the values of zinc concentration factors in the gills of ***Stizonstedion lucioperca*** in Lake Balton (Hungary) were 1.6 x 10^3. Silker (1961) pointed out that concentration factor of particulate zinc in marine organisms can be as high as 10000. Positive correlation between cadmium concentration in the seawater and its uptake by the whole soft body of ***Mytilus edulis*** was established by Scholz (1980) who indicated that cadmium uptake significantly increased with increasing of its concentration in the surrounding medium until 100 µg Cd/l.

3.1.3. Concentrations of heavy metals in fish liver

The average concentrations of Zn, Cu, Fe and Cd in fish liver were in the range of 32.5, 178.49; 3.61, 57.14; 87.23, 624.88 and 1.12, 27.66 mg/kg in El-Mex Bay (Table 2) and recorded 67.67, 77.92; 7.76, 11.91; 130.21, 210.87 and 2.29, 4.11 mg/kg wet weight in Abu-Qir Bay, respectively (Table 3). The higher concentrations of heavy metals in fish liver have been attributed by Saleh *et al.* (1983) to the fatness of the liver, as well as due to the fact that the fish liver is the responsible organ for getting rid of toxicants. Papadopoulou *et al.* (1984) pointed out that the tendency of Zn accumulation was, mainly, in the liver of fish species caught from the Greece water. Buckley *et al.* (1982) pointed out that the liver of fish is the selective storage organ for copper. Excessive intake of copper may lead to liver cirrhosis, dermatitis and neurological disorders. Salanaki *et al.* (1982) found that the values of zinc concentration factors in liver of ***Stizonstedion lucioperca*** in Lake Balton (Hungary) were 1.5 x 10^3.

3.1.4. Concentrations of heavy metals in fish gonads

The gonads of fish investigated in the present study, obviously, accumulated Zn, Cu, Fe and Cd, in most species, with highest concentrations in comparison with the other fish organs. These concentrations ranged between 61.12, 208.75; 4.4, 58.3; 17.54, 210.8 and 0.65, 19.48 mg/kg at El-Mex Bay (Table2) and recorded 282.62; 18.4; 128.44 and 4.04 mg/kg wet weight respectively at Abu-Qir Bay (Table 3). This agrees with the data given by many authors. Windom *et al.* (1973) found elevated levels of Zn accumulated in gonads of 35 fish species from the North Atlantic in comparison with the other body organs. This may be attributed to the distribution of this element from liver in case of accumulation with high concentrations. Lauren and McDonalds (1987) stated that further Cu uptake over a maximum concentration in the liver is distributed to other internal organs and may favor the existence with high concentrations in gonads.

In present work, the distribution of metals in different fish organs has been found to follow the order: muscles < gills < liver < gonads in most studied species, but in some ones the metals accumulation in liver exceeds that in gonads. These results are more or less comparable with Shakweer (1999) who determined accumulation order: flesh < gills < gonads < Liver in fish taken from the Egyptian Mediterranean water. On the other hand, metals abundance has been found to follow the order Fe > Zn > Cu > Cd in fish muscles, gills, liver and gonads of fish at both areas of study. These results agree with Abdallah (2008), who found order of metals abundance Zn > Cr > Cu > Pb >Cd in muscles of fish collected from El-Mex Bay and Eastern Harbor at Alexandria coast. The differences of metals concentrations which reported in different species or within the same species may be attributed to the fact that their concentrations depend on species, sex and biological cycle and on the type of the fish tissue to be analyzed (Tuzen, 2003; Irwandi and Farida, 2009).

3.1.5. Metal type, fish species and fish organs dependent variations of metals levels

Two-tailed ANOVA was used for testing the significance of accumulation of different metals in fish muscles and organs. In fish muscles, the analysis revealed, dependence on metal type, significant accumulation ($F = 22.88$, $P = 0.000$) and, dependence on fish species, insignificant accumulation of Zn, Cu, Fe and Cd ($F = 1.32$, $P = 0.280$) at the level 0.05. In fish organs the analysis revealed, dependence on organs, significant accumulation of Zn ($F = 6.02$, $P = 0.003$) and Fe ($F = 51.83$, $P = 0.000$) and insignificant accumulation of Cu ($F = 2.50$, $P = 0.084$) and Cd ($F = 2.69$, $P = 0.069$) at the level 0.05 in different fish species. Meanwhile, dependence on species, analysis revealed, only, significant accumulation of Fe ($F = 6.87$, $P = 0.000$) and insignificant accumulation of Zn ($F = 0.838$, $P = 0.579$); Cu ($F = 0.78$, $P = 0.627$) and Cd ($F = 1.59$, $P = 0.180$) at the level 0.05 in different fish organs (Table 6).

Applying LSD test on metals accumulation revealed significant mean differences between accumulations of approximately almost metals in muscles and organs at the level 0.05 (Tables 7A-7E). The results of ANOVA and LSD test show that although the recorded metals concentrations in fish muscles are below the recommended acceptable limits, they attained levels in gills, liver and gonads tissues that may start to exert stress effects on these organs.

3.2. Biological characters of fish

Fulton's condition factor (K) for fish is considered a popular metric that has been applied to many fish species (Fulton 1904; Bolger and Connolly 1989). It is computed as body mass divided by the cube of body length assuming isometric growth because length is raised to the third power. The assumption of isometric growth is a fair approximation for many species (Jones *et al.,* 1999; Kimmerer *et al.,* 2005).

This index allows for more objective comparison between fish plump on either geographic, time or species basis and reflects the suitability of the environmental and feeding conditions for fish. Lambert and Dutil (1997 a, b) stated that, Atlantic cod with a low condition index presumably resulting from adverse environmental status, poor feeding conditions or parasitic infections. They demonstrated (K) to be a measure of the energy reserves of fish. Tesch (1968) stated that (K) is used for comparing the condition, fatness and well-being of fish, based on the assumption that heavier fish of a given length are in better conditions.

The values of this index, in this work, ranged between 0.58 (***Scombermourus* sp.**) and 1.59 (***Diplodus surgus* and *Diplodus vulgaris***) for fish caught from El-Mex Bay (Table 4). Meanwhile, its values ranged between 0.7 (***Sardinella maderensis***) and 1.42 (***Crenidens crenidens***) for fish caught from Abu-Qir Bay (Table 5). Comparing the values of K for same species caught from both investigated areas, ***Pagellus erythrinus*:** 1.23, 1.20; ***Sparisoma cretense*:** 1.42, 1.29; ***Pagellus mormyrus*:** 1.20, 1.15 and ***Siganus rivulatus*:** 1.15, 1.09 (Tables 4 and 5), it is obvious that its values were more or less comparable. This may indicate that the food availability and adverse environmental conditions resulting from discharge of different wastes are more or less identical and led to growth without significant variations in the two investigated areas (Lambert and Dutil, 1997 a+b and Tesch, 1968).

Hepato-somatic index (H.S.I.) is another metric that has been used in fishery biology as a useful tool for assessing the fish condition. Exposure to contaminants can lead to an increase in liver size as a result of increase in hepatocytes size (hypertrophy) or number (hyperplasia) (Hilmy *et al.,* 1983; Hinton and Lauren, 1990). Studies evaluating the relative liver size of fishes from contaminated and reference sites often utilize the H.S.I. (Heath, 1990; Facey *et al.,* 1999). Goede and Barton (1990) have used H.S.I. as a biomarker of contaminant exposure. Facey *et al.* (2005) stated that H.S.I. as a biomarker is often correlated with exposure to various contaminants (e.g., polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and some heavy metals).

In present work, the calculated values of H.S.I. for fish collected from El-Mex Bay ranged between 0.62 (***Spicara flexusa***) and 5.62 (***Sparisoma cretense***) (Table 4) and ranged between 0.78 (***Pagellus mormyrus***) and 2.26 (***Terapon puta***) for fish caught from Abu-Qir Bay (Table 5). It can be indicated from the given data that this index differs from one species to another living in the same area. On the other hand, valuable differences existed among individuals of the same species lived in both studied areas: ***Pagellus erythrinus*:** 0.77, 0.92; ***Sparisoma cretense*:** 5.62, 1.27; ***Pagellus mormyrus*:** 1.26, 0.78 and ***Siganus rivulatus*:** 3.15, 1.97. This may be attributed by the difference of response of every species to the pollutants in the inhabitant water and refers to increase in liver size of fish whose elevated H.S.I. index as a result of exposure to different wastes (Hilmy, *et al.,* 1983; Hinton and Lauren, 1990),. On the other hand, this confirms that H.S.I. is a useful biomarker often correlated with exposure to diverse contaminants (Goede and Barton, 1990; Facey *et al.,* 2005).

3.2.1. Correlation analysis

The results of Spearman's rank correlation analyses revealed insignificant dependence of metals accumulation on K, H.S.I., T.L. and Gut. Wt. except for Cd accumulation in gills ($r = -0.778$, $p < 0.05$) on K (Table 8A), Cu accumulation in gonads ($r = -0.678$, $p < 0.05$) on H.S.I. (Table 8B), Fe accumulation in gills ($r = -0.899$, $p < 0.01$) on T.L. (Table 8C), Cd accumulation in liver ($r = -0.714$, $p < 0.05$) on T.L. (Table 8D) and Fe accumulation in gills ($r = -0.817$, $p < 0.01$) on Gut. Wt. (Table 8E). Correlation between accumulation of metals in different fish organs revealed insignificant correlation except for accumulation of Cd in both muscles and liver ($p < 0.05$) and both gills and gonads ($p < 0.01$) (Tables 8A and 8D). Correlation results between K, H.S.I., T.L. and Gut. Wt. and concentrations of metals in different fish organs mean that the concentrations of Zn, Cu, Fe and Cd, may indicate that fish condition at both studied areas still not distorted.

Table 3. Concentrations (average ± s.d.) of Zn, Cu, Fe and Cd in different organs of fish (N = 5) caught from Abu-Qir Bay, east of Alexandria coastal area.

Metal	Species	Concentration mg/Kg wet weight			
		Muscles	Gills	Liver	Gonads
Zn	1. *Pagellus erythrinus*	12.03 ± 4.97	37.25 ± 13.80	77.92 ± 32.87	282.62 ± 222.06
	2. *Sparisoma cretense*	18.69 ± 3.46	26.05 ± 6.57	67.67 ± 31.27	--
Cu	1. *Pagellus erythrinus*	4.68 ± 1.92	5.44 ± 2.75	11.91 ± 4.42	18.40 ± 17.35
	2. *Sparisoma cretense*	4.22 ± 3.79	6.30 ± 5.01	7.76 ± 6.85	--
Fe	1. *Pagellus erythrinus*	21.36 ± 22.79	76.48 ± 7.34	210.87 ± 83.69	128.44 ± 84.65
	2. *Sparisoma cretense*	37.05 ± 26.33	88.26 ± 35.96	130.21 ± 27.25	--
Cd	1. *Pagellus erythrinus*	0.45 ± 0.35	1.81 ± 1.53	2.29 ± 2.27	4.04 ± 6.07
	2. *Sparisoma cretense*	2.29 ± 1.72	0.98 ± 0.42	4.11 ± 5.42	--

Table 4. Some biological characters for fish caught from Mex Bay, west of Alexandria coastal area.

Species	Length range (cm)	Average total length. (cm)	Average total weight. (g)	Average gutted weight. (g)	Condition factor (K)	Hepato-somatic index (H.S.I.)
1. *Sparus auratus*	16.3–23.7	19.9 ± 1.78	107.7 ± 30.53	100.9 ± 28.02	1.26 ± 0.10	0.88 ± 0.34
2. *Alpes djedata*	13.8–21.9	19.7 ± 2.34	105.6± 29.26	94.5 ± 26.98	1.20 ± 0.24	2.71 ± 0.69
3. *Scombermourus spp.*	30.4–57.0	43.6 ± 10.22	555.1±343.68	533.2 ± 334.83	0.58 ± 0.04	1.15 ± 0.62
4. *Mullus surmulatus*	14.1–21.0	17.4 ± 2.63	65.6± 36.81	58.9 ± 31.78	1.02 ± 0.09	0.96 ± 0.61
5. *Spicara flexusa*	10.4–12.4	11.4 ± 0.93	14.4± 4.53	13.7 ± 4.42	0.90 ± 0.08	0.62 ± 0.32
6. *Diplodus surgus*	12.0–26.5	17.4 ± 4.48	111.1± 90.90	103.9 ± 83.90	1.59 ± 0.24	1.48 ± 0.56
7. *Pagellus erythrinus**	13.8–19.5	15.2± 2.03	49.2± 23.16	46.2± 22.32	1.23± 0.15	0.77± 0.46
8. *Sparisoma cretense**	13.8–20.0	16.6 ± 2.23	80.9± 38.55	69.4 ± 31.17	1.42 ± 0.06	5.62 ± 1.51
9. *Pagellus mormyrus**	12.4–19.0	15.9 ± 1.90	51.2± 12.72	48.4 ± 12.57	1.20 ± 0.15	1.26 ± 0.68
10. *Siganus rivulatus**	13.5–18.2	15.6 ± 1.83	56.0± 17.47	44.2 ± 13.54	1.15 ± 0.11	3.15 ± 1.26
11. *Diplodus vulgaris*	13.8–16.2	14.7 ± 1.11	52.7± 3.87	49.3 ± 3.90	1.59 ± 0.24	0.91 ± 0.19
12. *Crenidens crenidens*	11.9–14.8	13.3 ± 0.96	38.6± 7.64	32.7 ± 6.77	1.37 ± 0.10	1.37 ± 0.10
13. *Sardinella aurita*	12.0–17.3	15.5 ± 1.34	34.0± 6.94	30.2 ± 6.65	0.80 ± 0.11	0.97 ± 0.75
14. *Sardinella maderensis*	10.0 –15.0	13.0± 1.83	18.3± 2.95	16.7± 2.64	0.75± 0.14	--
15. *Serranus hepatus.*	7.5 –8.9	8.5 ± 0.76	10.1± 3.15	9.4 ± 3.31	1.55± 0.20	1.18 ± 0.47
16. *Mugil cephalus*	18.4–29.9	24.1± 4.70	141.8± 93.10	127.5± 82.28	0.80± 0.14	1.20 ± 1.09
17. *Trachinotus ovatus*	15.8 –21.7	19.6± 2.60	78.8+ 41.74	71.9± 36.61	0.89± 0.19	3.84 ± 4.14
18. *Lepidotrigla cavillone*	8.5–23.6	16.6 ± 5.18	62.8± 42.44	55.9 ± 35.41	1.19 ± 0.54	--
19. *Saurida undsqaumis*	17.4 –27.2	21.5± 3.18	71.2± 36.28	62.5± 27.60	0.60± 0.03	1.72 ± 0.82
20. *Spicara smaris*	12.0–18.0	14.0± 2.79	25.3± 17.03	23.4± 15.24	0.79± 0.05	--
21. *Mullus barbatus*	14.1–15.5	14.9± 0.74	38.3± 5.89	35.5± 5.74	1.06± 0.04	--

* Species collected from both studied areas.

Table 5: Some biological characters of fish caught from Abu-Qir Bay, east of Alexandria coastal area.

Species	Length range (cm)	Average total length. (cm)	Average total weight (g)	Average gutted weight (g)	Condition factor (K)	Hepato-somatic index (H.S.I.)
1. *Pagellus erythrinus**	12.4 -17.8	15.20±1.96	46.7±16.68	43.9± 15.44	1.20±0.08	0.92± 0.30
2. *Sparisoma cretense**	14.5 – 18.6	16.5 ± 1.51	65.6±17.89	59.5 ± 17.27	1.29 ± 0.17	1.27± 0.47
3. *Pagellus mormyrus**	12.8 – 14.3	13.6 ± 0.59	31.3± 3.32	28.8 ± 3.06	1.15 ± 0.04	0.78 ± 0.24
4. *Siganus rivulatus**	12.2 – 19.7	15.50 ± 3.07	52.7±29.77	43.7 ± 23.81	1.09 ± 0.12	1.97 ± 0.72
5. *Pagellus acarne*	14.3 – 14.6	14.5± 0.15	44.8± 5.50	42.2± 4.93	1.39±0.14	1.02± 0.21
6. *Boops boops*	14.5 – 17.5	16.0 ± 1.16	47.0± 6.28	43.2 ± 9.04	1.04 ± 0.05	0.94 ± 0.46
7. *Crenidens crenidens*	13.1 – 14.6	14.0 ± 0.65	43.0± 6.44	39.2 ± 5.80	1.42 ± 0.05	1.76 ± 0.58
8. *Terapon puta*	11.7 – 13.4	12.7 ± 0.67	26.3± 5.18	22.5 ± 4.13	1.10 ± 0.10	2.26 ± 1.05
9. *Umbrina cirrosa*	12.7 – 15.3	13.9 ± 1.18	29.8± 7.78	28.3 ± 7.11	1.05 ± 0.13	0.98 ± 0.35
10. *Sardinella maderensis*	14.5 – 17.2	15.2 ± 1.11	27.2± 4.35	24.9 ± 4.50	0.70 ± 0.06	--
11. *Mugil cephalus*	16.5 – 18.8	17.5± 0.97	44.3±13.05	40.6± 11.20	0.75± 0.08	0.81 ± 0.33

* Species collected from both studied areas.

Table 6. Two-tailed ANOVA results for accumulation of metals in muscles and organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

. Two-tailed ANOVA	Source	Sum of Squares	df	Mean Square	F
Accumulation of metals in muscles	Species	337.271	8	42.159	1.323
	Metals	2187.380	3	729.127	**22.881***
Accumulation of Zn in organs	Species	19559.455	8	2444.932	.838
	Organs	52666.819	3	17555.606	**6.018***
Accumulation of Cu in organs	Species	1012.229	8	126.529	.777
	Organs	1219.711	3	406.570	2.495
Accumulation of Fe in organs	Species	9381.289	8	1172.661	**6.866***
	Organs	26555.021	3	8851.674	**51.827***
Accumulation of Cd in organs	Species	289.494	8	36.187	1.591
	Organs	183.672	3	61.224	2.691

* Significant at P < 0.05 level.

Table 7A. Mean differences of metals concentrations in muscles of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Muscles			Mean Difference (I-J)	Std. Error	P	95% Confidence Interval	
	(I) treat	(J) treat				Lower Bound	Upper Bound
LSD	Zn	Cu	9.9522	2.7664	**.001***	4.3172	15.5873
		Fe	-7.2067	2.7664	**.014***	-12.8417	-1.5716
		Cd	12.1444	2.7664	**.000***	6.5094	17.7795
	Cu	Zn	-9.9522	2.7664	**.001***	-15.5873	-4.3172
		Fe	-17.1589	2.7664	**.000***	-22.7940	-11.5238
		Cd	2.1922	2.7664	.434	-3.4428	7.8273
	Fe	Zn	7.2067	2.7664	**.014***	1.5716	12.8417
		Cu	17.1589	2.7664	**.000***	11.5238	22.7940
		Cd	19.3511	2.7664	**.000***	13.7160	24.9862
	Cd	Zn	-12.1444	2.7664	**.000***	-17.7795	-6.5094
		Cu	-2.1922	2.7664	.434	-7.8273	3.4428
		Fe	-19.3511	2.7664	**.000***	-24.9862	-13.7160

* The mean difference is significant at 0.05 level.

Table 7B: Mean differences of Zn concentration in organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Zn			Mean Difference (I-J)	Std. Error	P	95% Confidence Interval	
	(I) treat	(J) treat				Lower Bound	Upper Bound
LSD	muscles	gills	-23.3333	24.9397	.356	-74.1338	27.4671
		liver	-79.5044	24.9397	**.003***	-130.3049	-28.7040
		gonads	-92.1489	24.9397	**.001***	-142.9494	-41.3484
	gills	muscles	23.3333	24.9397	.356	-27.4671	74.1338
		liver	-56.1711	24.9397	**.031***	-106.9716	-5.3706
		gonads	-68.8156	24.9397	**.010***	-119.6160	-18.0151
	liver	muscles	79.5044	24.9397	**.003***	28.7040	130.3049
		gills	56.1711	24.9397	**.031***	5.3706	106.9716
		gonads	-12.6444	24.9397	.616	-63.4449	38.1560
	gonads	muscles	92.1489	24.9397	**.001***	41.3484	142.9494
		gills	68.8156	24.9397	**.010***	18.0151	119.6160
		liver	12.6444	24.9397	.616	-38.1560	63.4449

* The mean difference is significant at 0.05 level.

Table 7C. Mean differences of Cu concentration in organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Cu			Mean Difference (I-J)	Std. Error	P	95% Confidence Interval	
	(I) treat	(J) treat				Lower Bound	Upper Bound
LSD	muscles	gills	-1.4900	5.8467	.800	-13.3994	10.4194
		liver	-13.2489	5.8467	**.030***	-25.1583	-1.3395
		gonads	-11.2567	5.8467	.063	-23.1661	.6527
	gills	muscles	1.4900	5.8467	.800	-10.4194	13.3994
		liver	-11.7589	5.8467	.053	-23.6683	.1505
		gonads	-9.7667	5.8467	.105	-21.6761	2.1427
	liver	muscles	13.2489	5.8467	**.030***	1.3395	25.1583
		gills	11.7589	5.8467	.053	-.1505	23.6683
		gonads	1.9922	5.8467	.736	-9.9172	13.9016
	gonads	muscles	11.2567	5.8467	.063	-.6527	23.1661
		gills	9.7667	5.8467	.105	-2.1427	21.6761
		liver	-1.9922	5.8467	.736	-13.9016	9.9172

* The mean difference is significant at 0.05 level.

Table 7D. Mean differences of Fe concentration in organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Fe			Mean Difference (I-J)	Std. Error	P	95% Confidence Interval	
	(I) treat	(J) treat				Lower Bound	Upper Bound
LSD	muscles	gills	-62.7222	9.6754	**.000***	-82.4304	-43.0141
		liver	-62.7222	9.6754	**.000***	-82.4304	-43.0141
		gonads	-62.7222	9.6754	**.000***	-82.4304	-43.0141
	gills	muscles	62.7222	9.6754	**.000***	43.0141	82.4304
		liver	.0000	9.6754	1.000	-19.7081	19.7081
		gonads	.0000	9.6754	1.000	-19.7081	19.7081
	liver	muscles	62.7222	9.6754	**.000***	43.0141	82.4304
		gills	.0000	9.6754	1.000	-19.7081	19.7081
		gonads	.0000	9.6754	1.000	-19.7081	19.7081
	gonads	muscles	62.7222	9.6754	**.000***	43.0141	82.4304
		gills	.0000	9.6754	1.000	-19.7081	19.7081
		liver	.0000	9.6754	1.000	-19.7081	19.7081

* The mean difference is significant at 0.05 level.

Table 7E. Mean differences of Cd concentration in organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Cd			Mean Difference (I-J)	Std. Error	P	95% Confidence Interval	
	(I) treat	(J) treat				Lower Bound	Upper Bound
LSD	muscles	gills	-.9456	2.4087	.697	-5.8520	3.9609
		liver	-4.8267	2.4087	.054	-9.7331	7.978E-02
		gonads	-5.0489	2.4087	**.044***	-9.9553	-.1424
	gills	muscles	.9456	2.4087	.697	-3.9609	5.8520
		liver	-3.8811	2.4087	.117	-8.7876	1.0253
		gonads	-4.1033	2.4087	.098	-9.0098	.8031
	liver	muscles	4.8267	2.4087	.054	-7.9778E-02	9.7331
		gills	3.8811	2.4087	.117	-1.0253	8.7876
		gonads	-.2222	2.4087	.927	-5.1287	4.6842
	gonads	muscles	5.0489	2.4087	**.044***	.1424	9.9553
		gills	4.1033	2.4087	.098	-.8031	9.0098
		liver	.2222	2.4087	.927	-4.6842	5.1287

* The mean difference is significant at 0.05 level.

Table 8A. Spearman's rank correlation between condition factor (K) and accumulation of Cd in organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Spearman's rho		K-Cd	Muscles	Gills	Liver	Gonads
K-Cd	Correlation coefficient	1.000	.276	**-.778***	.360	-.577
	Sig. (2-tailed)	.	.472	**.014**	.342	.104
Muscles	Correlation coefficient	.276	1.000	-.117	**.733***	-.100
	Sig. (2-tailed)	.472	.	.765	**.025**	.798
Gills	Correlation coefficient	**-.778***	-.117	1.000	-.017	**.833****
	Sig. (2-tailed)	**.014**	.765	.	.966	**.005**
Liver	Correlation coefficient	.360	**.733***	-.017	1.000	-.167
	Sig. (2-tailed)	.342	**.025**	.966	.	.668
Gonads	Correlation coefficient	-.577	-.100	**.833****	-.167	1.000
	Sig. (2-tailed)	.104	.798	**.005**	.668	.

* Significant at 0.05 level, ** Significant at 0.01 level.

Table 8B. Spearman's rank correlation between hepato-somatic index (H.S.I.) and accumulation of Cu in organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Spearman's rho		HSI-Cu	Muscles	Gills	Liver	Gonads
HSI-Cu	Correlation coefficient	1.000	.517	.467	-.517	**-.678***
	Sig. (2-tailed)	.	.154	.205	.154	**.045**
Muscles	Correlation coefficient	.517	1.000	.467	.033	-.322
	Sig. (2-tailed)	.154	.	.205	.932	.398
Gills	Correlation coefficient	.467	.467	1.000	-.550	-.034
	Sig. (2-tailed)	.205	.205	.	.125	.931
Liver	Correlation coefficient	-.517	.033	-.550	1.000	.102
	Sig. (2-tailed)	.154	.932	.125	.	.795
Gonads	Correlation coefficient	**-.678***	-.322	-.034	.102	1.000
	Sig. (2-tailed)	**.045**	.398	.931	.795	.

* Significant at 0.05 level, ** Significant at 0.01 level.

Table 8C. Spearman's rank correlation between total length (T.L.) and accumulation of Fe in organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Spearman's rho		TL-Fe	Muscles	Gills	Liver	Gonads
TL-Fe	Correlation coefficient	1.000	.151	**-.899****	-.235	.067
	Sig. (2-tailed)	.	.698	**.001**	.542	.864
Muscles	Correlation coefficient	.151	1.000	-.200	.300	.183
	Sig. (2-tailed)	.698	.	.606	.433	.637
Gills	Correlation coefficient	**-.899****	-.200	1.000	.217	-.250
	Sig. (2-tailed)	**.001**	.606	.	.576	.516
Liver	Correlation coefficient	-.235	.300	.217	1.000	.517
	Sig. (2-tailed)	.542	.433	.576	.	.154
Gonads	Correlation coefficient	.067	.183	-.250	.517	1.000
	Sig. (2-tailed)	.864	.637	.516	.154	.

* Significant at 0.05 level, ** Significant at 0.01 level.

Table 8D. Spearman's rank correlation between total length (T.L.) and accumulation of Cd in organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Spearman's rho		TL-Cd	Muscles	Gills	Liver	Gonads
TL-Cd	Correlation coefficient	1.000	-.445	-.303	**-.714***	.076
	Sig. (2-tailed)	.	.230	.429	**.031**	.847
Muscles	Correlation coefficient	-.445	1.000	-.117	**.733***	-.100
	Sig. (2-tailed)	.230	.	.765	**.025**	.798
Gills	Correlation coefficient	-.303	-.117	1.000	-.017	**.833****
	Sig. (2-tailed)	.429	.765	.	.966	**.005**
Liver	Correlation coefficient	**-.714***	**.733***	-.017	1.000	-.167
	Sig. (2-tailed)	**.031**	**.025**	.966	.	.668
Gonads	Correlation coefficient	.076	-.100	**.833****	-.167	1.000
	Sig. (2-tailed)	.847	.798	**.005**	.668	.

* Significant at 0.05 level, ** Significant at 0.01 level.

Table 8E. Spearman's rank correlation between gutted weight (Gut. Wt.) and accumulation of Fe in organs of fish (N = 9) caught from El-Mex and Abu-Qir Bays.

Spearman's rho		Gut.wt.-Fe	Muscles	Gills	Liver	Gonads
Gut.wt.-Fe	Correlation coefficient	1.000	.183	**-.817****	-.083	.067
	Sig. (2-tailed)	.	.637	**.007**	.831	.865
Muscled	Correlation coefficient	.183	1.000	-.200	.300	.183
	Sig. (2-tailed)	.637	.	.606	.433	.637
Gills	Correlation coefficient	**-.817****	-.200	1.000	.217	-.250
	Sig. (2-tailed)	**.007**	.606	.	.576	.516
Liver	Correlation coefficient	-.083	.300	.217	1.000	.517
	Sig. (2-tailed)	.831	.433	.576	.	.154
Gonads	Correlation coefficient	.067	.183	-.250	.517	1.000
	Sig. (2-tailed)	.865	.637	.516	.154	.

* Significant at 0.05 level, ** Significant at 0.01 level.

4. Conclusion

Accumulation of Zn, Cu, Fe, and Cd still below the recommended maximum permissible limits in muscles tissues although they attained higher values of accumulation in gills, liver and gonads of fish at both studied areas. The observed variations in metals concentrations between fish species at both studied areas can be attributed mainly to the variations in nutrition behavior. Fish condition, according to condition factor (K) and hepato-somatic index (H.S.I.) values showed similar growth rate, but at the same time, different response of fish to metals in both studied areas. The results of statistical analyses indicate that the accumulation of Zn, Cu, Fe and Cd in gills, liver and gonads may start to exert a stress effects on these organs. At the same time, rate of metals accumulation in muscles and organs still not attained levels that may affect fish condition in both studied areas.

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تركيزات بعض المعادن الثقيلة و حالة بعض الأسماك فى منطقتين ملوثتين بشاطئ الإسكندرية ـ مصر

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يهدف هذا البحث إلى دراسة تركيزات معادن الزنك ، النحاس ، الحديد و الكادميوم فى العضلات ، الخياشيم ، الكبد و المناسل لبعض أنواع الأسماك من خليجي أبو قير و المكس بشاطئ الإسكندرية . و قد وجد أن تركيزات هذه المعادن فى عضلات هذه الأسماك يتراوح بين 8.99 – 15.03 ؛ 0.99 – 7.96 ؛ 11.43 – 41.49 ؛ 0.55 – 1.96 فى أسماك خليج المكس ، أما فى عضلات أسماك خليج أبو قير فقد سجلت 12.03 , 18.69 ؛ 4.22 , 4.68 ؛ 21.36 , 37.05 ؛ 0.45 , 2.29 مللى جرام / كيلو جرام (أنسجة رطبة) من الزنك ، النحاس ، الحديد و الكادميوم . بمقارنة هذه التركيزات بمعدلات التركيزات المسموح بها عالميا لهذه المعادن ، وجد أن هذه التركيزات هى فى الحدود المقبولة عالميا . كما وجد أن تركيزات هذه المعادن فى كل من العضلات ، الخياشيم ، الكبد ، المناسل تتبع الترتيب الحديد > الزنك > النحاس > الكادميوم . كما وجد أن غزارة تركيزاتها فى الأعضاء المختلفة يتبع الترتيب العضلات < الخياشيم < الكبد < المناسل . و قد وجد أيضا ، أن قيم معامل الحالة (K) تتراوح بين 0.58 – 1.59 و معامل الكبد (H.S.I.) تتراوح بين 0.77 – 5.62 لأسماك خليج المكس و قيم معامل الحالة تتراوح بين 1.04 – 1.42 و معامل الكبد بين 0.78 – 2.26 لأسماك خليج أبو قير .

إحصائيا وجد أن تركيزات هذه المعادن فى العضلات معنويا ($F = 22.88, P < 0.05$) بالنسبة لأنواع المعادن ، غير معنويا ($F = 1.32, P > 0.05$) بالنسبة لأنواع الأسماك ، كما وجد أن تركيزات الزنك ($F = 6.01, P < 0.05$) و الحديد ($F = 51.83, P < 0.05$) معنويا فى الخياشيم و الكبد و المناسل ، أما تركيزات النحاس و الكادميوم فى هذه الأعضاء فقد وجد غير معنويا.

من نتائج معاملى الحالة و الكبد و التحليل الاحصائى يتضح أن الأسماك فى كل من منطقتى الدراسة تتعرض لمعدلات تلوث متقاربة ، كما يتضح تقارب معدلات نمو (حالة) الأسماك مع اختلاف تأثرها بتراكم هذه المعادن فى أنسجتها .