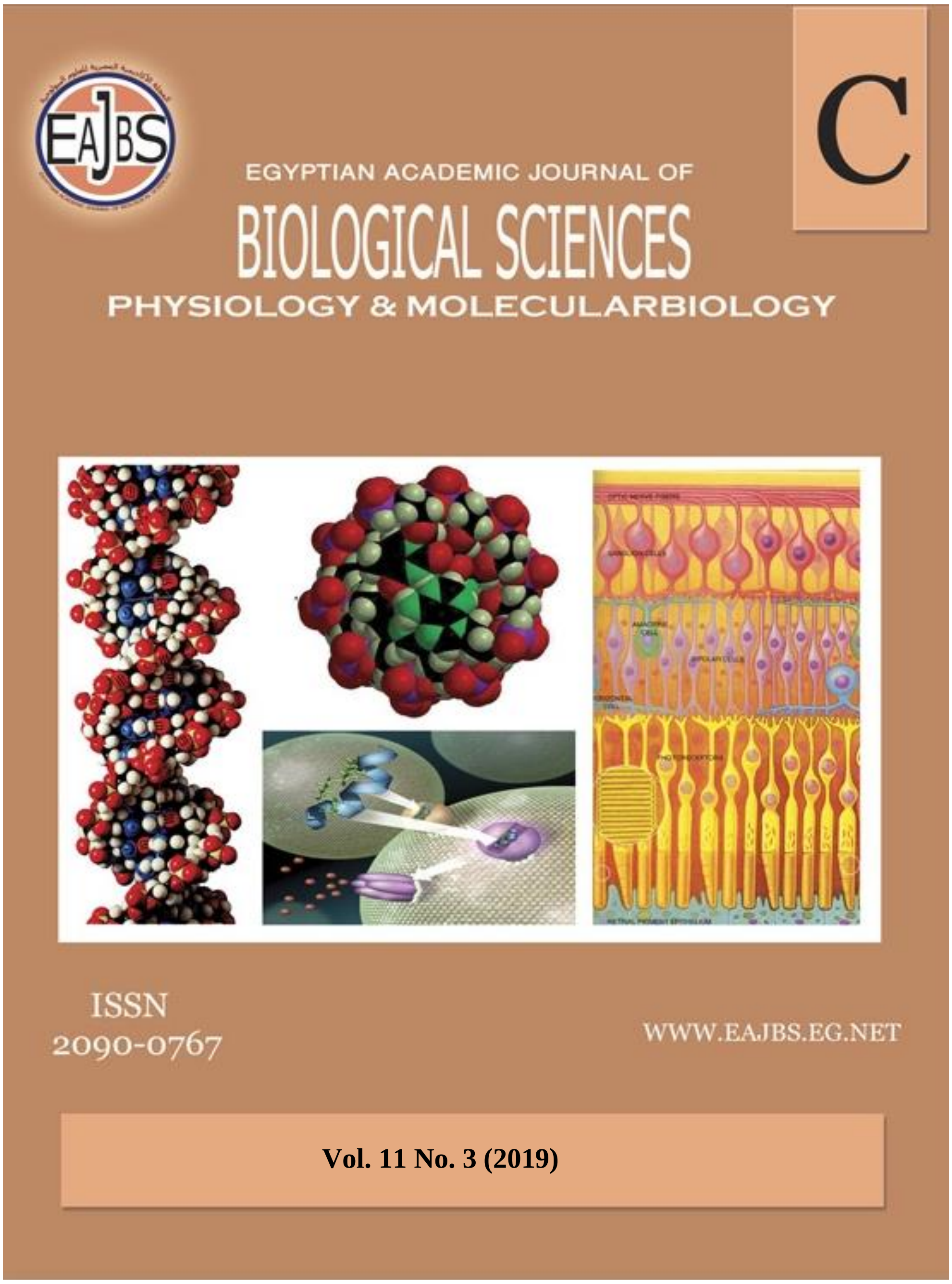

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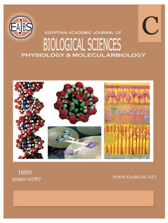

Physiological Responses Influenced by Certain Heavy Metals at the Mullet Fish, *Mugil cephalus* Inhabiting Mediterranean Sea Coast at Damietta Governorate, Egypt.

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ABSTRACT

The present study aims to determine the concentrations of some heavy metals in the target organs of mullet fish, *Mugil cephalus* collected from the Coast of Mediterranean Sea, at Damietta Governorate, to compare concentrations of metals in the different organs and their effects on some physiological parameters in the edible organs of this species during winter and summer, 2018.

The present data indicated that the highest values of heavy metals in the different organs were observed during the hot season (summer) than the cold one (winter). It declared the highest value in the gonads for Iron concentration during summer and the lowest one was detected for Cadmium concentration during winter (38.74±4.60 and 1.46±0.33 µg/g wet wt, respectively). Kidneys appeared the same trend with high peak for Iron level followed by Zinc ions during summer; being 153.70±6.24 and 73.34±5.24 µg/g wet wt, respectively. It showed a depletion concentration (1.12±0.17 µg/g wet wt) during winter in Copper ion than the other metals. Due to its function, liver contains the high levels of heavy metals during summer (106.70 ± 16.73 µg/g wet wt) for Iron ion and the lowest values (1.84±0.30 and 1.86±0.37µg/g wet wt, respectively) were measured for cadmium and lead during winter. Data revealed that heavy metals concentration in the muscles of *M. cephalus* fluctuated between 1.35± 0.73 µg/g wet wt for Copper ion during winter and 51.37± 1.34 µg/g wet wt for Iron during summer. ANOVA ($p< 0.05$) showed highly significant differences in one way of heavy metals concentrations except between the different organs showed significant difference. Moreover, two ways of analysis exhibited a significant difference ($p<0.05$) at the interaction between seasons and metals plus between organs and metals.

The present study revealed that total proteins in the different organs of *M. cephalus* attained its highest value in the muscles during winter and reached its lowest value in the kidney during summer (201.76±13.90 and 84.25 ±4.46 mg/g wet wt, respectively). The maximum values of total lipids were detected in the samples collected during winter (33.28±6.82 mg/g wet wt in the muscles and 31.41±3.43 mg/g wet wt in the liver) while the minimum values were determined during summer in gonads and kidneys; being 12.66±3.83 mg/g wet wt in the former and 13.78±2.64 mg/g wet wt in the latter.

Results exhibited the higher activities in ASAT and ALAT enzymes during summer in the liver while the lower values occurred in the muscles during winter; being 504.46±9.87 and 296.14±24.75 U/g wet wt, respectively for the first enzyme and 363.25±19.73 and 204.62±16.76 U/g wet wt, respectively for the second one.

Concerning analysis of variance for biochemical parameters, there are highly significant differences between the different seasons and parameters of one way. Also, two ways of ANOVA exhibited a significant difference in the interaction between seasons and different parameters.

INTRODUCTION

Fish are often the top of the aquatic food chain and are an important source of protein for human who may absorb large amounts of metals such as Cadmium, Copper, Iron, Nickel, Lead and Zinc through epithelial or mucosal surface of the skin, gills and gastrointestinal tract. Heavy metal contamination may cause devastating effects on the ecological balance of the recipient environment and its diversity of aquatic organisms (Farombi *et al*., 2007 and Vinodhini & Narayanan, 2008).These metals accumulate differently in the fish organs (liver, kidney, muscles, gonads, and brain) and caused health problems for fish consumers (Wallaert and Bobin, 1994 and Gomaa *et al*., 1995). The natural water bodies may extensively be contaminated with various heavy metals released from industrial and mining effluents, discharge of sewage and sewage sludge, dumping of hospital and anthropogenic activities, etc. (Vinodhini & Narayanan, 2008; Malik *et al.,* 2010; Laxmi-Priya *et al*., 2011 and Mohamed, 2019).

Traces of heavy metals play a biochemical role in the life processes of some aquatic plants and animals while it becomes toxic when it is present at high concentrations (Ghanem, 2014 and Ghanem *et al*, 2015). Low concentrations of heavy metals may not kill individuals of the fish but affect their size, reproduction, and body weights, thus reducing their ability to compete for food and habitat. Metabolic and enzyme activities are correlated with metals levels and changes in the rate of protein synthesis (Jovanovic *et al*., 2011, Ghanem, 2014 and Ghanem *et al*., 2015).

Feeding behavior of the fish may influence the metabolic process i.e. Mugilidae is the large family within the order Perciforms. They are generally filter feeders, feeding on algae, diatoms, small crustaceans and decayed organic matters from the bottom (Shehata, 1997a & b; Shapiro, 1998 and Khalaf-Allah, 2001). Direct contact with sediment may cause organ dysfunction depending on the degree of sediment contamination (Alne-Na-Ei and Rady, 1998; Khalaf-Allah & Shehata, 2011 and Ghanem *et al*., 2015). Some heavy metals are the most uncertain environmental pollutants such as Cadmium which is toxic for living organisms. It is mostly used in manufacturing of batteries, pigments and also in plastic industries (ATSDR, 1997), thus its toxicity at low level causes poisoning in various tissues which induce kidney, liver, gills and heart malfunctioning. The trace metals are uptake more rapidly at high temperatures by marine organisms (Raymont and Shields, 1994). Muscles are one of the most organs which are varied in composition according to the species, sex, and maturity as well as seasons (Rubbi *et al*., 1985).

Biochemical and physiological biomarkers are frequently used for detecting or diagnosing the harmful effects in fish exposed to different toxic substances. Transaminase enzymes play a vital role in carbohydrate and protein metabolism in fish and other organism's tissues (Eze, 1983). Changes in enzyme activity and other biomarkers have been studied as possible tools for aquatic toxicological research (Abou El-Naga *et al*., 2001; Ghanem, 2006 and Ghanem *et al*., 2015). Therefore, in the present study attempts have been made to assess the heavy metals concentrations in the fishes caught from Damietta Coast and their effects on biochemical parameters in the different organs of the mullet fish as a very important commercial species.

MATERIALS AND METHODS

Specimens Collection:

A total of 98 specimens of mullet fish, *Mugil cephalus* (Fig., 1) were collected during winter and summer, 2018 for the present study. Gill net and encircling net were the main fishing methods used to collect the fish samples. After collection however possible, fishes were freshly examined or immediately preserved in an icebox and transferred to the laboratory for later examination. In the laboratory, standard and total length of each fish were measured to the nearest centimeter and recorded, while the body weight was determined to the nearest gram. Then, each fish was dissected and the internal organs and muscles were separated and treated as the following:

Heavy Metals Determination in the Tissues:

Equal amounts (15 ml) of concentrated nitric acid, hydrofluoric acid, and perchloric acid were added to 0.5 gm of each tissue into Teflon beaker. The latter was covered, set aside for several hours, and evaporated to a few drops. 5 ml of HCIO4 were added again and evaporated just to dryness. After addition of 10 ml of concentrated HCl, beaker was placed back on a hot plate until the solution becomes clear. Deionized distilled water was added and the digested material was filtered, then residue washed several times with deionized distilled water and complete to 100 ml volumetric flask.

Heavy metals were analyzed by atomic absorption model Perkin Elmer 3150. Concentrations were expressed into µg / gm tissue according to APHA (1992).

Physiological Studies:

After the dissection of the collected fishes, a known weight of the target organs (liver, kidney, gonads, and muscles) was homogenized by using the electric homogenizer for 2 min. The homogenated specimens were centrifuged at 4000 r.p.m. for 15 min. at 2 C^o in a refrigerator centrifuge. The supernatant solution was used directly or stored at 4 C^o until the use of the biochemical analysis.

The total protein content of the different organs was determined according to Doumas Method (1975), while total lipids were detected according to the method of Knight *et al.*, (1972) by using a kit of Bioadwic Company. Enzymes activities were measured according to the method of Reitman and Frankel (1957) by using a kit of Bioadwic Company.

Statistical analysis:

Results were expressed in tables as mean ±S.D. Data were analyzed by using analysis of variance (ANOVA) according to Bailey (1981).

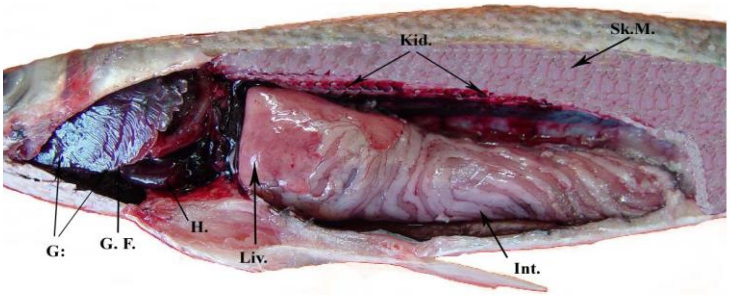

Fig. 1: Photograph of the grey mullet, *Mugil cephalus*, showing the general viscera; G., Gills; G.F., Gill filament; H., Heart; Int., Intestine; Kid., Kidney; Liv., Liver and Sk.M., Skeletal muscles.

RESULTS AND DISCUSSION

Heavy Metals Determinations:

The present study aimed to create awareness concerning the potential severe public health issues resulting from the toxic effects of heavy metals as pollutants from different sources. The toxic effects of heavy metals on fish involve hepatotoxicity, neurotoxicity, and nephrotoxicity (Valko *et al.*, 2005). Bioaccumulation of metals and consequent alterations in liver, kidney, and flesh of the mullet fish were examined. Results (Table, 1) indicated that, the highest values of heavy metals (Cadmium, Copper, Iron, Nickel, Lead and Zinc) in the **gonads** were observed during the hot season (summer) than the cold one (winter) with highest value (38.74±4.60 µg/g wet wt) for Iron concentration during summer and the lowest (1.46±0.33 µg/g wet wt) was detected for Cadmium concentration during winter.

The kidney is one of most important organs which can accumulate large quantities of metals than the other organs. Kidneys appeared the same trend with high peak for Iron level followed by Zinc ions during summer; being 153.70±6.24 µg/g wet wt in the first and 73.34±5.24 µg/g wet wt in the second. It showed a depletion concentration (1.12±0.17 µg/g wet wt) during winter in Copper ion than the other metals (Table, 1).

The liver plays an important role in detoxification and toxicant storage. Due to its function, liver contains the high levels of heavy metals. Results (Table, 1) exhibited that, the maximum value of different heavy metals in the liver of *M. cephalus* was recorded for Iron concentration during summer (106.70 ± 16.73 µg/g wet wt), while the lowest values (1.84±0.30 and 1.86±0.37µg/g wet wt, respectively) were measured for Cadmium and Lead during winter.

Muscle compositions are varied according to the species, sex, and maturity as well as seasons (Rubbi *et al.*, 1985). Data in Table (1) revealed that heavy metals concentration in the muscles of the studied fish fluctuated between 1.35± 0.73 µg/g wet wt for Copper ion during winter and 51.37± 1.34 µg/g wet wt for Iron concentration during summer.

Although some metals are essential elements at a low level for many organisms; it becomes very toxic at the higher concentrations (Clark and Keasling, 2002 and Faria *et al*. 2010). From the present results, it can be concluded an increasing level of heavy metals in the different organs of *M. cephalus* during summer than winter. This may be due to the increase of heavy metals in the drainage waters, decomposition of organic matter and discharge remnants of fertilizer factories and other chemicals lead to this fact, the uptake of metals is influenced by many factors including fish species, age, and type of fish organs, season and various environmental factors. This findings agree with Nagdi & Shaker (1998); Ptashynski & Klaverkamp (2002); El-Serafy *et al*. (2003a) and Ghanem (2006&2014) whom attributed the increase of metals during hot seasons to the effect of temperature and winds on the solubility and distribution of these metals and differ with Yacoub and Gad (2012) whom mentioned that, cold season exhibited the high level of these metals than the hot one. On the other hand, El-Serafy *et al*. (2003b) concluded that no markedly seasonal variations in the concentration of metals in *Patella Caerulea* lived in polluted areas of Alexandria Coast were detected.

Results indicated that heavy metals accumulate mainly in the metabolic organs such as liver which can store metals to be detoxified as its main function by production of metallothionein. Similar observations were in agreement with Ibrahim *et al*. (1999 a&b); Jovanovic *et al*. (2011); Ghanem (2014) and Mohamed (2019) whom reported that, the differences of heavy metals concentrations in the fish organ were related to their ability of absorption and accumulation of heavy metals through epithelial, mucosal surface, gastrointestinal tract, metabolic organs with relation to their mode of living and feeding behaviour.

The present study appeared that, the concentrations of heavy metals were increased during hot season (summer) than the cold (winter); this may be attributed to the low water level and the inefficient removal of trace metals by organisms or to the low degree of nutrient recycling and to the discharge of sewage, industrial wastes and paints into this location. This finding agrees with Abdel-Monem *et al*. (1994) who stated that the concentration of heavy metals may be associated with high trophic level predators, filter and bottom feeder with increased consumption of particulate matter along with absorbed metals.

The present results showed high concentration in some heavy metals than the other indicated to the lower values of one metal accompanied by a high concentration of others in the same season, this may be due to the fact that the presence of one metal deletes or reduce the accumulation of another metal. A similar observation was detected by Ghanem (2006 & 2014) and Mohamed (2019).

Analysis of variance (Table, 2) indicated that there are highly significant differences ($p<0.05$) at one way of heavy metals concentrations in the target organs except between the different organs, it showed a significant difference. Moreover, two ways of analysis for data exhibited significant difference ($p<0.05$) at the interaction between seasons and metals plus between organs and metals, however, it is a non-significant difference between different seasons and organs.

Table 1: Bioaccumulation of heavy metals (µg/g wet wt.) in the different organs of *M. cephalus*,collected from the Mediterranean Sea Coast; Damietta Governorate, Egypt.

Organs	Gonads		Kidney		Liver		Muscles	
Seasons / Metals	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Cd	1.46 ±0.33	1.93 ± 0.12	2.87 ±0.16	4.34 ± 0.45	1.84 ±0.30	2.41 ± 0.25	3.35 ± 0.27	5.20 ± 1.30
Cu	1.70 ±0.40	2.37 ± 0.14	1.12 ±0.17	1.84 ± 0.15	8.82 ± 0.43	13.93 ± 0.48	1.35 ± 0.73	2.28 ± 0.41
Fe	27.10 ±2.54	38.74 ± 4.60	123.09 ±5.72	153.70 ± 6.24	86.11 ± 2.50	106.70 ± 16.73	37.10 ± 7.14	51.37 ± 1.34
Ni	1.85 ±0.32	2.57 ± 0.25	3.67 ± 0.35	4.71 ±0.38	2.00 ± 0.11	2.54 ± 0.64	3.35 ± 0.52	5.09 ± 0.29
Pb	1.55 ±0.28	2.16 ±0.31	4.40 ± 0.18	5.18 ±0.61	1.86 ±0.37	2.81 ± 0.17	4.65 ±0.65	6.34 ± 0.38
Zn	16.25 ±2.28	29.18 ± 2.89	51.11 ± 4.35	73.34 ± 5.24	19.08 ± 2.28	29.10 ± 3.84	17.18 ± 2.29	23.43 ± 1.87

Table 2: Analysis of variance (ANOVA) on heavy metals concentrations of *M. cephalus*, collected from Mediterranean Sea Coast at Damietta Governorate during winter and summer, 2018.

Source of variance	F.V.
Seasons	2.34**
Organs	1.16 *
Metals	3.37**
Seasons* Organs	0.82 n.s.
Seasons* Metals	1.51*
Organs* Metals	1.31 *
Errors	--
Total	--

Biochemical Parameters:

The present study (Table, 3) revealed that total proteins in the different organs of *M. cephalus* collected from Mediterranean Sea Coast at Damietta Governorate attained its highest value (201.76±13.90 mg/g wet wt) in the muscles during winter. It decreased in the gonads and kidney during winter (114.76±30.40 and 109.53±3.98 mg/g wet wt, respectively) and reached its lowest one (86.43±10.54 mg/g wet wt) in the liver during summer.

Data revealed that the percentages of protein contents in the muscles of *Mugil cephalus* are usually affected by several factors including type of food, fish size, and stage of maturity. This finding was matching with Shakweer and Abbas (2005). Moreover, they found the major biochemical constituent of muscle including protein differs significantly from one fishing area to another. Such variations could be related to the biota and biotic conditions, which are prevailing in these areas. Protein depletion in tissues constitutes a physiological mechanism and may play an important role in compensatory mechanisms under propanil stress. Also, Abdel-Moati (1992) found that the increase of metal concentrations reduced the soluble protein in muscles which reflects both a reduction in synthesis and an increase in its utilization under metals stressed conditions.

The reduction of any tissues total proteins could be attributed to metabolic adaptation to food shortage in the environment and several pathological processes including plasma dissolution, renal damage elimination in the urine and decrease liver protein synthesis. This assumption suggested by Hilmy *et al*. (1987); Haggag *et al*. (1993) and Salah El-Deen *et al*. (2000). The exposure to metals may lead to high accumulation in gills that cause structural damage and a reduction in oxygen consumption causing sharp reduction in the metabolic rate of fish and consequently decrease protein contents in most tissues (Ghanem, 2014). A similar observation was reported by White *et al*. (1986) and Haggag *et al*. (1999) who stated that, during the period of inadequate food supply, energy required for metabolic maintenance may be provided from utilization of protein reserves which mainly accumulate in the muscle and metabolic tissues. From another angle, the decreasing level of protein may be attributed to the change in water characters as a result of the discharged effluents from different sources (Zaghloul, 2000 and Ghanem, 2014).

Total lipids in the mullet fish are slightly increased during winter compared with summer. Data in Table (3) declared that, the maximum values of total lipids were detected in the samples collected during winter (33.28±6.82 mg/g wet wt in the muscles and 31.41±3.43 mg/g wet wt in the liver) while the minimum values were determined during summer in gonads and kidneys; being 12.66±3.83 mg/g wet wt in the former and 13.78±2.64 mg/g wet wt in the latter. The decreasing level in total lipids in the muscles of *M. cephalus*, may be attributed to the toxic effects of pollutants dissolved in the higher amounts of polluted water and humic matter, despite in the presence of high concentrations of heavy metals. This may be attributed to the changes in water quality by the action of heavy metals, that may critically influence the growth rate and quality of fish (Hodson *et al*., 1984). Moreover, the drainage water is generally rich with nitrogen, phosphorous and organic matter that causes appropriate changes in the physical and chemical features of water (Khalil and Hussein, 1996). From another side of view, the depletion in total lipids in the different organs during summer than the winter may be due to the use of energy-rich lipids for energy production during toxic stress. Similar observations were recorded by Chandra *et al*. (2004); Blaner *et al*. (2005) and Ghanem (2014).

Aspartate aminotransferase (ASAT) activity in the mullet fish, *M. cephalus*, exhibited higher activity during summer in the liver and gonads; being 504.46±9.87 and 465.34±6.63 U/g wet wt, respectively. While, the lower value of ASAT (296.14±24.75 U/g wet wt) was determined in the muscles during winter (Table, 3). However, activity of alanine aminotransferase (ALAT) in the studied fish attained its higher peak during summer in the liver and kidney (363.25±19.73 and 332.62±17.94 U/g wet wt, respectively). While, its lower activity (204.62±16.76 U/g wet wt) was measured during winter in the muscle (Table, 3).

In the present study, the elevation of ASAT and ALAT activities in the gonads, kidney, liver, and muscles of *M. cephalus*, inhabiting the coast of the Mediterranean Sea at Damietta Governorate is relatively higher during summer than winter. Such elevation might reflect the early toxic effects of heavy metals on the hepatic enzyme activities. On the other hand, the opposite effects on hepatic ASAT and ALAT activities might be due to the liver necrosis induced by toxicants. The present results are in agreement with Rao (2006); Ghanem (2014) and Mohamed (2019). Also, Begum and Vijayaragharan (1995) reported that the hepatic ASAT and ALAT activities were increased significantly in the catfish, *Clarias batrachus*, toxicated with carbofuran and dimethoate.

Table 3: Biochemical analysis in the different organs of *M. cephalus* collected from the Mediterranean Sea Coast; Damietta Governorate, Egypt

Organs	Gonads		Kidney		Liver		Muscles	
Seasons / Parameters	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Total protein (mg/g wet wt.)	114.76 ±30.40	89.33 ±11.67	109.53 ±3.98	84.25 ±4.46	117.96 ±7.53	86.43 ±10.54	201.76 ±13.90	121.48 ±2.30
Total lipids (mg/g wet wt.)	23.45 ±7.73	12.66 ±3.83	18.81 ±3.41	13.78 ±2.64	31.41 ±3.43	26.63 ±8.21	33.28 ±6.82	17.25 ±5.50
ASAT (U/g wet wt.)	325.68 ±9.48	465.34 ±6.63	346.61 ±14.86	458.83 ±7.75	364.90 ±23.50	504.46 ±9.87	296.14 ±24.75	365.42 ±18.74
ALAT (U/g wet wt.)	297.11 ±21.52	327.32 ±12.36	301.24 ±15.82	332.62 ±17.94	314.85 ±21.74	363.25 ±19.73	204.62 ±16.76	267.74 ±22.41

Table 4: Analysis of variance (ANOVA) on physiological parameters of *M.cephalus*, collected from Mediterranean Sea Coast at Damietta Governorate during winter and summer, 2018.

Source of variance	F.V.
Seasons	3.45**
Organs	0.46 n.s.
Parameters	4.34**
Seasons* Organs	0.64 n.s.
Seasons* Parameters	1.46*
Organs* Parameters	0.28 n.s.
Errors	--
Total	--

Moreover, Shakoori *et al*. (1990) found that the hepatic ASAT and ALAT were increased in freshwater fish, *Cirrhinus marigala*, toxicated with Cd. Shalaby (2000) recorded the same observations in common carp, *Cyprinus carpio*, affected by Zn, Cu, and Cd. On the other hand, Gill *et al*. (1991) mentioned that the reduction of aminotransferases activities in various organs may have resulted from damaged tissues and consequently the reduction of enzyme turnover causally related to the presence of toxic metals. The decrease of ASAT and ALAT in the liver and muscles may be attributed to a number of reasons such as leakage from liver and muscles into the blood, actual liver and muscles enzymes inhibition by the effect of toxicant, disturbance in Kreb's cycle and damage of liver and kidney cells that affect the membranes permeability which in turn liberate the enzymes to extra-cellular fluid and blood (Abou El-Ella, 1996 and Salah El-Deen *et al*., 2000).

Concerning the biochemical parameters affected by metals concentrations in the target organs of studied fish, there are highly significant differences between the different seasons and parameters of one way. Also, two ways of ANOVA exhibited a significant increase between seasons and the different parameters (Table, 4).

Results recommended that the treatment of wastes water, sewage and other sources of metals must be conducted before discharge into any water body especially the study area. The advisable for public health that humans must be used only muscles of fish for food and that the internal organs must not be used as fishmeals for other purposes. Also, it is advisable for public health that humans can eat the fish during cold seasons which exhibited the little concentrations of heavy metals in different organs and avoid eating them at the summer which contains high concentrations. This is maybe due to that, the fish can regulate its biochemical properties at the less polluted seasons.

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ARABIC SUMMARY

الإستجابات الفسيولوجية المتأثرة بتركيزات بعض العناصر الثقيلة فى أسماك البورى الأصيل القاطن لسواحل البحر المتوسط , محافظة دمياط – مصر.

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تهدف هذه الدراسة إلى تقدير تركيزات بعض المعادن الثقيلة في الأعضاء المستهدفة من أسماك البورى الأصيل المجمعة من ساحل البحر المتوسط (محافظة دمياط) وذلك لمقارنة تركيزات تلك المعادن في الأعضاء المختلفة ممثلة فى المناسل، الكلى، الكبد، العضلات والتي تؤثر بدرجة كبيرة علي بعض المعايير الفسيولوجية من المحتوي الكلى للبروتينات، الدهون و كذلك النشاط الإنزيمى لإنزيمىASAT وALAT خلال فصلي الشتاء والصيف, 2018م, واللذان يلعبان دوراً كبيراً فى طعم و صلاحية هذه الأسماك للإستهلاك الآدمى و التي قد تؤدي إلي الفهم الصحيح لكثير من النواحي البيولوجية مثل معدلات النمو، السلوك الغذائي، و نسبة الوفيات.

أظهرت النتائج أن أعلى قيم للمعادن الثقيلة في مختلف أعضاء سمكة البورى الأصيل قد سجلت خلال فصل الصيف مقارنة بفصل الشتاء. كما بينت النتائج أن أعلى قيمة قد سجلت فى **مناسل** هذه النوعية من الأسماك لعنصر الحديد أثناء فصل الصيف وأقل قيمة قد سجلت لعنصر الكادميوم أثناء فصل الشتاء (38,74±4,60 و 1,46±0,33 ميكروجرام/ جرام وزن رطب, على التوالى). كما أظهرت كلى هذا النوع من الأسماك نفس الإتجاه, حيث كان عنصر الحديد الأعلى تركيزاً متبوعا بعنصر الزنك أثناء فصل الصيف (153,70±6,24 و 73,34±5,24 ميكروجرام/ جرام وزن رطب, على التوالى). بينما سجل أقل معدل (1,12±0,17 ميكروجرام/ جرام وزن رطب) لعنصر النحاس أثناء فصل الشتاء مقارنة بباقى العناصر. كما تحتوى أكباد الأسماك على أعلى مستوى لتركيز عنصر الحديد أثناء فصل الصيف (106,70±16,73 ميكروجرام/ جرام وزن رطب), بينما سجلت أقل التركيزات (1,84±0,30 و 1,86±0,37 ميكروجرام/ جرام وزن رطب, على التوالى) لعنصرى الكادميوم والرصاص أثناء فصل الشتاء. كما لوحظ أدنى تركيز لعنصر النحاس فى عضلات البورى الأصيل أثناء فصل الشتاء (1,35±0,73 ميكروجرام/ جرام وزن رطب) و أعلى معدل كان لعنصر الحديد أثناء فصل الصيف (51,37±1,34 ميكروجرام/ جرام وزن رطب). أوضحت التحاليل الإحصائية وجود فروق معنوية كبيرة فى حالة تحليل التباين أحادى الإتجاه. كما أظهر عدم وجود فروق معنوية فى حالة تداخل قيم المواسم المختلفة مع أعضاء أسماك الدراسة.

كما سجلت التحاليل البيوكيميائية أعلى قيم للبروتينات والدهون الكلية أثناء فصل الشتاء مقارنة بفصل الصيف, مع وجود زيادة ملحوظة فى مستوى هذه العوامل داخل العضلات (201,76±13,90 و 33,28±6,82 مليجرام/ جرام وزن رطب, على التوالى) مقارنة بباقى الأعضاء. كما أشارت النتائج إلى وجود آثار مدمرة بزيادة مستوى إنزيمى الأسبارتك والألانين ناقلى مجموعة الأمين, حيث سجلت عضلات الأسماك أقل نشاط لهما (296,14±24,75 و 204,62±16,76 وحدة دولية/ جرام وزن رطب, على التوالى). كما أوضحت نتائج التحاليل الإحصائية وجود إختلافات معنوية لمختلف القياسات البيوكيميائية أثناء فترة الدراسة داخل أجهزة الجسم المختلفة.