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COMPARATIVE STUDY BETWEEN DESERT CULTIVATED AND NATURAL FISHERIES OF MULLET FISH IN EGYPT: I- CONCERNING HEAVY METALS

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ABSTRACT

Cultivated mullet fish were compared with the wild mullet fish from four locations during summer and winter 2005/2006. This work was evaluated via chemical analysis of feed, water, sediments and fish besides their contents of three heavy metals (Cd, Fe & Pb). From the results obtained, it could be concluded that there is a pollution with heavy metals (particularly with iron and lead) in all fish feeds, rearing water and sediments of the tested locations (mainly in summer season). Also, there is no difference between fish of natural resources and those of aquaculture concerning metals pollution. So, it is a must to take considerations from the responsible authorities for treating all kinds of waste waters before reaching water bodies to protect aquatic life and consumers.
Keywords: Mullet – Heavy metals.

INTRODUCTION

Fish had long been regarded as a nutritious and highly desirable food due to their contribution of high quality animal protein, richness in calcium and phosphorus and generous supply of vitamins. Heavy metals in soil and water may enter the food chain through the biological cycle, which includes bio-concentration by plants and animals. The presence of such metals at significant concentrations in the environment is considered a potential health hazard to human and animals. The pollution of the aquatic environment with heavy metals has become a serious health concern during recent years. Untreated municipal and industrial wastes, are the major sources of metal pollution, especially in areas in close vicinity to industrial and agricultural activities. Industrial and agricultural discharges are considered the primary source of metal poisoning of fish (Abdelhamid *et al.*, 2000). Many of these metals such as lead and cadmium have no nutritional importance, and their presence in relatively high concentration in body tissues can result in health problems in human as well as in animals (Goldfrank *et al.*, 2001). The objective of the present work was to study fish body measurements, chemical analysis of water and flesh from mullet fish, and determination of heavy metals (Cd, Pb and Fe) concentration in mullet flesh, water, sediments and feed stuffs of fish collected during summer and winter seasons from four locations in Egypt (Marsa Matroh – Alexendria – El-Bardaweel and Port Said).

MATERIALS AND METHODS

Sampling Locations:

1) Marsa Matroh(natural source), at the coastal region of Egypt, El-Hammam canal extension, 10 Km distance from Km 60 to Km 70 west

Alexandria. 2)Alexandria farm, located at the Alexandria desert road, about 12 feddan divided into ten ponds, source of water from Almahmodia canal, fish culture system is polyculture (mullets and tilapia), artificial fish diet (25% protein). 3) Port Saied farm, located at the Port Saied desert road, Kilo 21 Port Saied – Domietta road, aquaculture system is polyculture (mullet and tilapia), water sources are the Mediterranean sea and Manzala lake, artificial fish diet (25% protein), water is saline. 4) El-Bardaweel lake(natural source), located at the far north of Sinai, water salinity range from 37 to 65 part per thousand, mullet annual production 30%. One hundred and sixty samples of *Mugil cephalus* fish were collected from these four locations, forty samples per location, 20 samples were collected in summer season (from March 2005 to June 2005) while the other 20 were collected in winter season (from November 2005 to January 2006). The collected samples were packed in a sterile polyethylene bags, sealed and cooled in an insulated box contained crushed ice, then immediately transferred to the laboratory for examination. At the laboratory, fish weight, length, depth and sex were recorded individually. Each fish sample was wrapped separately in polyethylene bag, given an identification number and the collection site and date of collection were recorded on it. The fish were kept in ice box until the samples were prepared for analysis. Physical characteristics of fish examined are shown in Table (1). Eight water samples were collected (four samples for each season) from the same locations where the fish were collected. The water samples were collected in clean 1 liter polyethylene bottles from a depth of 50 cm. Each sample was preserved by adding 3 ml of pure concentrated nitric acid (99.9%-Merck) per liter of water. Samples were kept for analysis in a refrigerator at + 4°C. Eight samples of sediments were collected from the same locations (four samples / season). A dredge was used for collecting these superficial sediment samples which were transported in polyethylene bags into the laboratory. They were kept at room temperature for analysis. Fish feed samples were collected from Port Said and Alexandria locations (one sample for each season) for the chemical examinations.

Table (1): Fish body measurements (means* ± SE) as affected by location, season and sex of *M. cephalus*.

Variables	Weight, g	Length, cm	Depth, cm
Location (L.)			
1- Marsa Matroh	$153.9^{a} \pm 1.321$	$21.2^{a} \pm 0.189$	$4.4^{a} \pm 0.070$
2- Alexandria	$129.3^{c} \pm 3.70$	$18.8^{c} \pm 0.290$	$3.4^{c} \pm 0.070$
3- Port Saied	$141.1^{b} \pm 0.55$	$19.8^{b} \pm 0.238$	$4.1^{b} \pm 0.060$
4- El-Bardaweel lake	$151.6^{a} \pm 2.28$	$20.3^{b} \pm 0.495$	$4.2^{b} \pm 0.087$
Season (S)			
1- Summer	$153.8^{a} \pm 1.296$	$20.9^{a} \pm 0.264$	$4.1^{a} \pm 0.071$
2- Winter	$134.1^{b} \pm 1.860$	$19.2^{b} \pm 0.187$	$3.9^{b} \pm 0.057$
Sex			
1- Male	$142.8^{b} \pm 2.08$	$19.9^{a} \pm 0.258$	$3.9^{a} \pm 0.067$
2- Female	$145.0^{a} \pm 1.818$	$20.2^{a} \pm 0.239$	$4.1^{a} \pm 0.064$

* Means (within the same variable and column) superscripted with different letters differ significantly ($P \leq 0.05$).

Heavy Metals Analysis:

The head and external skeleton of each sample (one fish) were removed. The internal muscles were transferred to a clean, dry container and then minced to obtain a fine mince representing the whole flesh. The samples of fish were prepared for heavy metals determination according to Greig *et al.* (1982). The same procedures were used for detection of heavy metals in feed stuffs of fish. Water samples were prepared for heavy metals determination according to Polprasert (1982). For preparing the sediment samples, the procedure outlined by Medina *et al.* (1986) was performed. Perkin Elmer atomic absorption spectrophotometer (AAS) model 2380 equipped with MHS-10 hydride generation system (Deseret Recherch Center) was used for the quantitative determination of the studied elements according to Medina *et al.* (1986) and Abdallah *et al.* (1993). The bioaccumulation factor (BAF%) was calculated as a percent of fish heavy metal level from the heavy metal level in the rearing water.

Physicochemical Parameters:

Values of pH of the collected water samples were recorded using a pH meter, concentrations of total dissolved solids (TDS) were measured using OAKLON, TDS/conductivity meter. Alkalinity, hardness, calcium ion and magnesium ion levels were determined by titrimetric methods. Dissolved oxygen was measured by the modified Winkelr's method. Water temperature and salinity were determined by portable thermometer and salinometer. Nitrate and nitrite were estimated using a spectrophotometer at wavelengths 534 and 540 nm, respectively. Finally, CO_2 concentration was determined by titration against NaOH N/44. All these parameters were measured as described in APHA (1992).

Proximate Analysis:

Proximate analysis of feed and fish samples was carried out using the standard methods of analysis (AOAC, 2000).

Statistical Analysis:

Using S.A.S. (2001) and Duncan (1955), numerical data collected were statistically analyzed for analysis of variance and least significant difference. T-test and correlation were calculated too when required.

RESULTS AND DISCUSSION

Water quality criteria:

The pH values were slightly higher in winter (7.1 – 7.8) than in summer (7.1 – 7.2), regardless to the sampling locations; yet, it was higher in both seasons in Port Saied (location No. 3) than the other 3 locations. Water temperature was, naturally, higher in summer (18 – 24.5°C) than in winter (13 – 18°C), but was also higher in Port Saied in either seasons, than in the other locations. Consequently, the dissolved oxygen (DO) concentration was higher (6.4 – 10.4 mg/l) in winter than in summer (4.2 – 6.8 mg/l), in general. Anyhow, carbon dioxide (CO_2) concentrations varied from location to another and from season to another, without a fixed trend. Generally, it ranged from 3.9 – 10 mg/l in winter to 5.8 – 10.1 mg/l in summer. Toxic ammonia (NH_3) levels were lower in summer (0.04 – 0.12 mg/l) than in winter (0.04 – 0.20

mg/l) without clear trend of location effect. But, the nitrite (NO_2) concentrations were wider in summer (0.002 – 0.056 mg/l) than in winter (0.012 – 0.025 mg/l) without specific effect of sampling location. The same trend was recorded for the nitrate (NO_3) levels, being 0.20 – 0.36 vs. 0.18 – 0.22 mg/l during summer and winter, respectively. The alkalinity and hardness levels reflected the opposite trend, since they were lower in summer (156 – 308 and 4100 – 3100 mg/l, respectively) than in winter (400 – 800 and 3000 – 3900 mg/l, respectively) with the highest levels of both criteria for the location No. 1 (Marsa Matroh). Consequently, the concentrations of magnesium (Mg) and total dissolved solids (T.D.S.) were wider in winter (480 – 8160 and 2884 – 42218 mg/l, respectively) than in summer (624 – 6120 and 9512 – 42025 mg/l, respectively). Calcium (Ca) levels in summer (600 – 2200 mg/l) were higher than in winter (400 – 2000 mg/l). Marsa Matroh reflected the highest Ca and Mg levels in both seasons, but El-Bardaweel (4^{th} sampling location) has the highest T.D.S. and salinity levels in both seasons.

The high salinity in location No. 4, relatively to the other three location, is due to the nature of fish rearing water, i.e. its source. Since El-Bardaweel lake has salinity range of 37 – 65 ppt (‰), whereas the other locations' water were brackish. Saleh *et al.* (1988) found that the increase in salinity may be attributed to evaporation and/or leaching of salts from soil as water moves deep into the desert. In this respect, Abdelhamid (2003) cited that DO levels are influenced negatively by elevating water temperatures and salinity. He added that, pH value of the surface areas in the open seas are constant (being 8.1 – 8.3). He cited also that the suitable alkalinity and hardness for fish growth ranged between 50 – 200 and 50 – 300 mg/l, respectively, since the hard water contains more ions than the soft one. However, the hardness is correlated with the pH and alkalinity. The same author said that, the toxic level of NH_3 for fish is 0.6 – 2.0 mg/l. This means that all tested criteria of water quality from all sampling locations were within the normal ranges, which are suitable for normal fish growth. Additionally, Abdelhakeem *et al.* (2002) mentioned also that NH_3 level is influenced by pH and temperature of water. They added that, hardness and alkalinity of water are related to each other. They mentioned some water parameters for aquaculture as > 20 ppm alkalinity, 0.005 ppm Cd, 1.5 ppm CO_2, > 5 ppm DO, < 0.1 ppm Fe, < 0.02 ppm Pb, < 1 ppm NO_3, 6.7 – 8.6 pH, and > 400 ppm TDS.

Fish body measurements:

Sampling locations and seasons affected significantly ($P \leq 0.05$) each of the fish body measurements, but the fish sex affected significantly ($P \leq 0.05$) only fish weight but not ($P \geq 0.05$) the fish length and depth. The fish of Marsa Matroh (location No. 1) reflected the heaviest, longest and deepest ($P \leq 0.05$) fish among all sampling locations. Also, summer fish were more better ($P \leq 0.05$) than winter fish, concerning the three measured parameters. Yet, the female fish were heavier ($P \leq 0.05$) than the male ones (Table 1). The only significant interaction was location x season for all these parameters. Summer season is the feeding season, where the suitable temperature for fish growth. Therefore, the growth parameters were significantly higher for the summer fish than for the winter fish. Since elevating water temperature within the normal range specific for a fish species leads to improving the growth of this species (Abdelhamid, 2003). The superiority of the tested body measurements for Marsa Matroh fish (Table 1) may be related to the highest concentrations of Ca, Mg, alkalinity and hardness.

Heavy metals:

The fish diets offered in Alexandria farm contained high levels in winter (0.574, 7.551 and 0.056 ppm) than in summer (0.253, 4.939 and 0.040 ppm) for Pb, Fe and Cd, respectively. The opposite was true for the diets offered in Port Saied farm, being 0.217, 5.779 and 0.072 ppm in winter and 0.494, 8.551 and 0.117 ppm in summer for Pb, Fe and Cd, respectively. Generally, these heavy metal's concentrations in the diets, regardless to the sampling location or season, took the descending order, i.e. Fe > Pb > Cd. Also, the fish rearing water contained higher Pb levels in all tested locations in summer (0.353 – 3.164 ppm) than in winter (0.001 – 0.060 ppm), but the opposite was true for Fe, since it was lower in summer (0.376 – 0.549) than in winter (0.815 – 1.553 ppm) for all locations. Cd had different trends in both seasons and different locations, its ranges in summer and winter were 0.083-0.300 and 0.045-0.226 ppm, respectively. However, Marsa Matroh water was the highest in Pb contents (in both seasons) among the different sampling locations. The other two elements had variable trends from location to another. In summer season, Pb was > Fe > Cd; but in winter, Fe was > Cd > Pb. However, sediments from the same sampling locations reflected higher concentrations in winter (0.049-0.284 and 5.879-500.0 ppm) than in summer (0.030-0.047 and 24.85-28.60 ppm) for Cd and Fe, respectively (except the 2nd location in Fe) but the opposite was true for Pb (0.841-2.780 and 0.064-0.739 ppm in summer and winter, respectively) in all locations. Generally, the sediment samples from the four locations contained concentrations of Fe > Pb > Cd. There was no specific trend for these elements level in the sediments as affected by the sampling locations.

Heavy metals content in the fish flesh is presented in Table (2). The highest ($P \leq 0.05$) levels of the tested heavy metals were found in fish collected from Marsa Matroh (0.851 ppm Pb), Port Saied (2.40 ppm Fe) and El-Bardaweel (0.081 ppm Cd). This may be related to the high content of Pb in water and sediments collected from location No. 1 during both seasons. Also, Fe levels of the summer diet and winter sediments from Port Said were the highest. Cd level in El-Bardaweel sediment collected in summer was also the highest. The Fe concentrations range (1.3 – 2.4 ppm) of fish tested was higher than that of Pb (0.172 – 0.851 ppm) than Cd (0.016 – 0.081 ppm), regardless to the sampling locations. The same order was previously mentioned in heavy metals of the fish diets and sediments. Pb in fish was the only significantly ($P \leq 0.05$) affected by sampling season, being higher in summer than in winter, but not ($P \geq 0.05$) either of Fe or Cd. This is correlated too with the very high contents of Pb in water and sediments of all locations during summer than in winter. However, there was no significant ($P \geq 0.05$)

effect of fish sex on the tested heavy metals content in the fish flesh. The heavy metals content in the fish diet (high Pb content in winter) and rearing water (high Fe content in both seasons) may be responsible for the lowest ($P \leq 0.05$) values of body measurements (Table 1) of Alexandria (location No. 2) fish. Also, the highest values of body measurements of Marsa Matroh (location No. 1) may be attributed to the lowest Fe and Cd level in summer water as well as lowest Cd level in summer sediments.

Heavy metals pollution of the Egyptian aquatic media was reviewed by Abdelhamid (2006). However, Pb content was significantly higher in feedstuffs, water and blood in winter than in summer (Abdelhamid and El-Ayouty,1989).Lead causes hemorrhages and congestion of the gastrointestinal tract and kidneys of fish (Abdelhamid and El-Ayouty, 1991). Moreover, iron content of the Egyptian feeds is unusually high (Abdelhamid *et al.*, 1992). Abdelhamid *et al.* (1997) found that there were significant effects on water Fe due to sampling seasons and locations. Also, there were variations in the levels of the studied elements due to sampling locations, seasons, and fish species. They added that the elements' concentrations in the sediments and fishes were much higher than the corresponding values in the water, particularly for iron. However, lead and cadmium levels in fish muscles were concentrated more in fish, while iron was highest in sediments followed by fish tissues. They found that *Mugil cephalus* samples were more frequently contaminated than *Liza ramada* and *Sparus aurata*.

Table (2): Heavy metals content (means*± SE) in the tested *M. cephalus*.

Variables	Pb	Fe	Cd
Locations			
Marsa Matroh	$0.851^{a} \pm 0.119$	$1.70^{b} \pm 0.225$	$0.016^{c} \pm 0.006$
Alexandria	$0.172^{c} \pm 0.027$	$1.30^{b} \pm 0.166$	$0.067^{ab} \pm 0.015$
Port Saied	$0.780^{a} \pm 0.117$	$2.40^{a} \pm 0.182$	$0.041^{bc} \pm 0.008$
El-Bardaweel Lake	$0.572^{b} \pm 0.082$	$1.60^{b} \pm 0.113$	$0.081^{a} \pm 0.020$
Seasons			
Summer season	$1.10^{a} \pm 0.12$	$1.90^{a} \pm 0.09$	$0.04^{a} \pm 0.012$
Winter season	$0.08^{b} \pm 0.007$	$1.50^{b} \pm 0.157$	$0.06^{a} \pm 0.013$
Sex			
Male	$0.59^{a} \pm 0.068$	$1.78^{a} \pm 0.150$	$0.06^{a} \pm 0.012$
Female	$0.59^{a} \pm 0.068$	$1.71^{a} \pm 0.110$	$0.04^{a} \pm 0.004$

***Means (within the same variable and column) superscripted with different letters differ significantly ($P \leq 0.05$).**

Anyhow, Cd is known to be human carcinogen (Mandel *et al.*, 1995), Bahr El-Bakar drain water contained 0.910 and 0.0242 mg/l Pb and Cd, respectively, whereas its *M. cephalus* fish flesh contained 0.9376 and 0.0324 mg/Kg Pb and Cd, respectively (Galhoom *et al.*, 2000). Cd reduced fish growth, feed efficiency and mitotic index and led to abnormal chromosomal behavior (Magouz *et al.*, 1996). Additionally, Salem (2003) found that Cd and Pb caused significant reduction in fish performance, survival, and muscular area. Cd and Pb ions are able to induce metallothionein gene expression in fish tissues, e.g liver and gills (Cheung *et al.*, 2004). Cd residues in fish flesh increased by dose increase. The protein banding patterns fluctuated in numbers and intensities by Cd concentrations. Cd residues affected the DNA nucleotide sequences (El-Fadly *et al.*, 2006).

The no effect level of Cd, Pb and Fe in water for growing aquatic life are 0.03, 0.10 and 1.00 ppm, respectively (Yokokawa, 2000). However, the commission regulation setting maximum Pb level for muscle meat of fish, released from the European communities, as 0.2 mg/Kg wet weight. Yet, the Egyptians' standards are 0.1 ppm Pb and Cd in food fish (ES, 1993). Comparing these standards with the levels obtained herein, it would be indicated that there is a water pollution with heavy metals in all tested locations, particularly with Pb in summer, Fe in winter (locations No. 2 and 4) and Cd in both seasons and all locations. Abdelhakeem *et al.* (2002) cited the tolerance limits of Pb, Fe and Cd in fish water as 0.10, 0.35 and 0.10 ppm, respectively and in fish body as 2, 30 and 0.5 ppm, respectively. Heavy metal concentrations in fish varied significantly depending on the type of the tissue, fish species and sampling location. Generally, *Mugil cephalus* L. showed higher levels of Fe and Pb concentrations than *Sparus aurata* L. (Yilmaz, 2005). Yet, there was no significant seasonal variation in marine water metal (Cd and Pb) concentrations (Kucuksezgin *et al.*, 2006). However, heavy metals contamination of water is one of the environmental stressors affecting significantly and negatively lysozyme activity of fish serum, intestinal scrapping and skin mucus as well as serum hemolytic activity, leukocytic count, packed cell volume, hemoglobin concentration, plasma protein and glucose concentrations (Abdelhamid *et al.*, 2006-b).

The bioaccumulation factors (BAF, of different heavy metals tested) in the *M. cephalus* studied from four sampling locations during two seasons are presented in Table (3). The significantly ($P \leq 0.05$) highest BAF was in fish from locations No. 2 (Alexandria), No. 3 (Port Saied) and No. 4 (El-Bardaweel) for Pb, Fe and Cd, respectively. This is correlated with the lowest ($P \leq 0.05$) fish body measurement of Alexandria fish samples, and to some extend also low body measurements of Port Saied and El-Bardaweel fish samples in comparison with those of Marsa Matroh fish samples. Winter Pb–BAF and summer Fe–BAF were significantly ($P \leq 0.05$) higher than those of the other season; yet, Cd – BAC was not influenced ($P \geq 0.05$) by sampling seasons. The high Pb – BAF in winter was correlated with the lower ($P \leq 0.05$) fish body measurements in this season. However, fish sex did not affect BAF of all tested heavy metals in the tested *M. cephalus*. The high ($P \leq 0.05$) Pb – BAF of Alexandria fish samples during winter is also correlated with high Pb content of the winter diet offered to Alexandria fish. Also, the high ($P \leq 0.05$) Fe – BAF of Port Saied fish samples during the summer season is related to high Fe level in summer diet given to these location's fish. These BAFs of heavy metals in fish were not influenced by the level of these metals in the fish rearing waters, but were correlated with the level of Pb and Fe in winter sediment sampled from Port Saied and Cd level in summer sediment sampled from El-Bardaweel.

Table (3): Bioaccumulation factors (B.A.F.%, means* ± SE) of heavy metals in the fish (*M. cephalus*) flesh.

Variables	B.A.F. – Pb	B.A.F. - Fe	B.A.F. – Cd
Locations			
Marsa Matroh	147.92[b] ± 44.17	306.36[b] ± 35.66	11.18[b] ± 1.91
Alexandria	1664.26[a] ± 383.15	219.03[c] ± 33.75	51.73[ab] ± 11.36
Port Saied	174.78[b] ± 21.45	528.43[a] ± 38.89	102.28[a] ± 12.41
El-Bardaweel Lake	140.53[b] ± 20.27	226.54[bc] ± 29.59	122.92[a] ± 59.14
Seasons			
Summer season	60.63[b] ± 3.08	442.56[a] ± 21.57	77.44[a] ± 30.69
Winter season	1003.12[a] ± 205.25	197.62[b] ± 27.12	66.62[a] ± 6.29
Sex			
Male	594.25[a] ± 174.88	319.17[a] ± 31.03	85.70[a] ± 31.57
Female	476.84[a] ± 135.73	320.90[a] ± 25.50	59.96[a] ± 9.53

* Means (within the same variable and column) superscripted with different letters differ significantly ($P \leq 0.05$).

The highest ($P \leq 0.05$) BAF of Fe in Port Saied fish samples was related also to the highest ($P \leq 0.05$) Fe contents in fish of this location. The same relation was confirmed for Cd in El-Bardaweel fish samples, but not for Pb. This may be due to the store tissue of each metal in (on) the fish, i.e. Pb is an external pollutant (Rashed and Awadallah, 1994), whereas Fe and Cd are internal pollutants. Therefore, Fe and Cd contents of fish affected positively their BAFs, but Pb was not. The same note is available for the effect of season, since BAF of Pb was not influenced by its level in (on) the fish, whereas BAF of Fe was correlated with its level in fish, being the highest in summer season. However, all tested metals level and their BAFs were not affected significantly ($P \geq 0.05$) by fish sex. Also, there were remarkable effects on microelements of fish muscles as well as their bioaccumulation factors due to sampling seasons and locations and fish species (Abdelhamid and El-Zareef, 1996). To interpret the collective death of fish in Domietta region, it was proved that the water of the studied area (El-Bostan village – Kafr El-Batiekh) has suffered from increase of iron concentrations. This picture is very harmful to fish life and production. Pollution of water was reflected in the form of heavy metal accumulation in different fish tissues. The lowest bioaccumulation factors were calculated in fish muscles, therefore muscles only are suitable for human consumption. The bioconcentration of iron was higher than that of lead in fish muscles (Abdelhamid *et al.*, 2000).

Table 4 presents significant positive correlations between fish weight, on one side, and Pb, Fe, Fe-BAF, length and depth of fish on the other side, but negative correlations between fish weight and Pb – BAF, Cd, and Cd – BAF. The fish depth correlated positively with Pb, Fe, Fe – BAF and length of fish, but negatively with Pb – BAF, and Cd level in fish. Fish length correlated, too, with Pb, Fe and Fe – BAF positively, but with Pb – BAC and Cd level negatively. Also, Cd – BAF correlated positively with Cd level ($P \leq 0.01$). Cd correlated ($P \leq 0.05$) negatively with Pb level in fish. Fe – BAF correlated ($P \leq 0.01$) positively with Pb and Fe levels in fish, but negatively with Pb – BAF. Fe level in fish correlated positively with Pb level and negatively with Pb – BAF. Lastly, Pb – BAF correlated ($P \leq 0.01$) negatively with Pb level in fish.

Table (4):Correlation coefficients between different variables measured for *M. cephalus*.

Items		Pb	BAF-Pb	Fe	BAF-Fe	Cd	BAF-Cd	Length	Depth	Weight
Pb	Pearson Correlat.	1								
	Sig. (2-tailed)									
	N	160								
BAF-Pb	Pearson Correlat.	-.273**	1							
	Sig. (2-tailed)	.000								
	N	160	160							
Fe	Pearson Correlat.	.196*	-.295**	1						
	Sig. (2-tailed)	.013	.000							
	N	160	160	160						
BAF-Fe	Pearson Correlat.	.496**	-.332**	.886**	1					
	Sig. (2-tailed)	.000	.000	.000						
	N	160	160	160	160					
Cd	Pearson Correlat.	-.184*	.071	-.042	-.118	1				
	Sig. (2-tailed)	.020	.371	.599	.137					
	N	160	160	160	160	160				
BAF-Cd	Pearson Correlat.	.026	-.017	.021	.043	.851**	1			
	Sig. (2-tailed)	.741	.837	.792	.591	.000				
	N	160	160	160	160	160	160			
Length	Pearson Correlat.	.330**	-.352**	.266**	.337**	-.209**	-.057	1		
	Sig. (2-tailed)	.000	.000	.001	.000	.008	.476			
	N	160	160	160	160	160	160	160		
Depth	Pearson Correlat.	.327**	-.445**	.263**	.282**	-.168*	-.064	.709**	1	
	Sig. (2-tailed)	.000	.000	.001	.000	.033	.423	.000		
	N	160	160	160	160	160	160	160	160	
Weight	Pearson Correlat.	.470**	-.642**	.308**	.377**	-.178*	-.045	.803**	.719**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.024	.574	.000	.000	
	N	160	160	160	160	160	160	160	160	160

***Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).**

Cd in water negatively affected fish growth and feed and vitamin C utilization. Fe also is toxic for fish, since it damages fish gills and their function. Pb reduces hemoglobin content and red blood cells count of fish (Abdelhamid, 2003). However, any degree of poisoning will weaken the fish, making it vulnerable towards disease. Heavy metals can create problems and be concentrated in waterway organisms up to 9100 times more than the surrounding environment's levels, so may lead to acute or chronic effects (WRC, 2005). Hovanec (1998) mentioned that metals are involved in many aspects of fish keeping and aquarium water metals are acutely toxic while others are necessary for the life of the fish nitrifying bacteria. Still others are responsible for such basic water hardness. For a metal to be toxic, it almost has ionized or free form. Water hardness can have a drastic effect on metal toxicity. Since the toxicity and biological activity of many metals and metalloids is profoundly influenced by their chemical form. The metabolism of ingested metals could significantly modify their toxicity. The micro-organisms in lakes, rivers and soil could biotransform metallic compounds (Rowland, 1981). Zyadah (1997) reported significant effects on water mineral contents (containing Cd and Pb) due to different locations and seasons. Also, he found high levels of heavy metals in the sediment and fish, exceeded the allowable limit. Yet, Aboul-Naga (2000) confirmed that sediment samples from Abu-Qir Bay and infront of El-Maadiya channel indicate a non-polluted environment with trace elements including Cd, Fe and Pb. However, he reported high trace metal concentrations in front of El-Tabia Pumping Station.Iron was the dominant metal in all humic acids and sediments examined. He added that humic acids are trace metals holder in the sediments, therefore humic acids play a major role in the geochemical cycling of the elements in the aquatic environment.

Moreover, Radwan (2000) reported average values of dissolved heavy metals (Cd, Fe and Pb) in Lake Burullos water as 1.93, 2.46 and 2.67 µg/l, respectively. He added that, levels of heavy metals are correlated with salinity changes due to the discharge of water. Hussein and Mekkawy (2001) revealed that fish reflect further mechanisms to avoid lead impacts such as the secretion of intestinal mucus that bind lead. Also, it is a fact that body adaptive balance mechanisms for lead impacts were evident in different organ tissues of fish. Yet, Mzimela *et al.* (2002) reported that lead negatively affected the blood hematology and acid-base balance of the groovy mullet, *Liza dumerili*. Usero *et al.* (2004) reported that heavy metal concentrations in the water, sediment and fish were variable from site to another. Significant correlations were obtained for the levels of numerous metals in water, sediment and fish. The results of Xie and Klerks (2004) suggest that reduced uptake and accumulation of Cd accounted for approximately two-third of the increased resistance in the Cd-adapted lines of fish. However, Cd has been found to accumulate in reproductive organs of fish and disrupt important endocrine processes. Moreover, responses along the hypothalamus – pituitary – gonadal axis were more sensitive to Cd exposure (Tilton *et al.*, 2003).

Metal concentrations in the sediment at each site depended more on the general characteristics of the sediment, such as the percentage of fine grained sediments and Fe content, than on whether or not there was replanted (Paulson *et al.*, 2001). Siam (2001) found high level of accumulation of Cd, Fe and Pb in the different organs (gills, liver, stomach and brain) of Alexandria coast fish, with respect to their corresponding in the muscle tissues. He added that the accumulation factors for these metals were higher in the herbivorous fish (*Siganus rivulatus*) than in the carnivorous ones (*Mugil capito*). Fe was the more pronounced one reflecting increase the trophic level of the fish. Cd level was generally lower than that of Pb in various organs while brain gained the highest values. Pb concentration ranged from 1.2 to 3.5 mg/kg in the stomach and brain while it ranged from 0.4 to 0.9 mg/kg in fish muscles. Most of the fish generally showed levels of Cd in the organs, which are close to that of the recommended standard (2.0 mg/kg) of the National Health and Medical Council in Australia. However, none of them contained Cd concentrations above 0.5 mg/kg in their muscle tissues. Total length, body weight and age are mostly correlated biometric parameters with metallothionein and soluble metal concentrations in striped red mullet and golden grey mullet (Filipovic and Raspor, 2003). Cadmium and lead were higher in muscular tissue from mullet (*Mugil spp.*) than snook (*Centropomus spp.*) and higher in summer than in winter (Joyeux *et al.*, 2004).

Kirby *et al.* (2001) mentioned that mullet are directly exposed to trace metal concentrations as a result of feeding and the ingestion of contaminated sediment and detritus. Lower metal concentrations found in mullet tissues are attributed to the burial of highly contaminated sediment with material containing lower trace metal concentrations. Little of the variations in trace metal concentrations between mullet was explained by mass, gender, or age. Geochemical controls of metal assimilation from contaminated sediment are relatively apparent for Cd. The influences of metal speciation on metal bioavailability can be confounded by the degree to which sediments are contaminated with metals (Fan *et al.*, 2002). Heavy metals (Cd, Fe, and Pb) strongly inhibit the enzyme activity and the hexobarbital metabolism (Medline Repository, 2001). They alter the immune system and lead to increased susceptibility to autoimmune diseases and allergic manifestations (Bernier *et al.*, 2005). Suciu *et al.* (2005) reported that Cd-bioaccumulation factor was increased by age. Cd and Pb were accumulated more in males than females sturgeon. However, liver microsomal 7-ethoxyresorufin O-deethylase (EROD) activity of leaping mullet inhibits the toxicity of divalent metal ions through the inhibitory effect of the glutathione (GSH) on Cd inhibition of EROD activity indicating the protective action of GSH (Bozcaarmutlu and Arinc, 2004). Staniskiene *et al.* (2005) found high concentrations of Fe in 15 fish species as a direct result of water contamination with heavy metals. Metal concentrations were found to be influenced by fish type. Cadmium – binding protein level in the cells of the intestine was increased after exposure to Cd, so it appears that this protein is synthesized as a response to Cd exposure. This is a mechanism of the regulation of Cd levels (Demuynck *et al.*, 2004).

Proximate analysis:

Table 5 presents data of chemical analysis of mullet flesh. There were significant effects of sampling locations and seasons on all components tested. Port Said and Marsa Matroh fish reflected higher ($P \leq 0.05$) protein than Alexandria and El-Bardaweel fish. Yet, the fat and ash contents differed also but not in a clear trend. However, winter fish contained more protein and less fat percentages ($P \leq 0.05$) than those of summer. This means that aquaculture or artificial feeding did not affect chemical composition of the fish. Also, better protein content in fish flesh from Port Saied and Marsa Matroh may be attributed to the lower total bacterial count in sediments from these both locations than the others (Abdelhamid *et al.*, 2006-a) . Elevated protein content in winter may be due to the lower ($P \leq 0.05$) heavy metals content (Pb and Fe) in fish flesh during this season than in summer as well as to the significantly ($P \leq 0.05$) lower total bacterial count of the fish (Abdelhamid *et al.* , *2006-a*). The negative correlation between protein and fat percentages was proved too by El-Ebiary and Zaki (2003) and Abdelhamid *et al.* (2004 and 2005-a & b).

Table (5): Chemical analysis of the experimented fish flesh as affected by sampling location and season (means ± SE) as % dry matter basis.

Location/season	Protein	Fat	Ash
Alexandria	58.29[b] ± 0.933	28.00[c] ± 0.357	11.50[a] ± 0.549
El-Bardaweel	58.88[b] ± 0.744	32.59[a] ± 0.173	6.948[c] ± 0.797
Port Saied	61.23[a] ± 0.853	25.71[d] ± 0.659	11.91[a] ± 0.302
Marsa Matroh	60.75[a] ± 0.630	29.67[b] ± 0.540	7.968[b] ± 1.132
Summer	58.23[b] ± 0.463	29.11[a] ± 0.561	11.06[a] ± 0.504
Winter	61.34[a] ± 0.450	28.77[b] ± 0.981	8.103[b] ± 0.849

a – c: Means in the same column within the same category superscripted with different letters differ significantly ($P \le 0.05$).

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دراسة مقارنة بين أسماك البورى المستزرعة والتى من المصايد الطبيعية فى مصر – من حيث العناصر الثقيلة

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تمت مقارنة أسماك البورى المستزرعة مع تلك من مصادرها الطبيعية فى أربعة مواقع خلال فصلى الصيف والشتاء ٢٠٠٥/٢٠٠٦م، وذلك من حيث تحاليل المياه والأعلاف والرسوبيات والأسماك كيماويا، ومن حيث محتواها من ٣ عناصر معدنية ثقيلة. ويستخلص من هذه الدراسة التأكيد على وجود تلوث بالعناصر الثقيلة (خاصة بالحديد والرصاص) فى كل من الأعلاف الصناعية للأسماك ومياه تربيتها ورسوبيات المواقع المدروسة (خاصة فى الصيف)، وأنه لا فرق بين أسماك المصايد الطبيعية والمزارع السمكية من حيث التلوث المعدنى ، مما يستوجب التنبيه على الجهات المسئولة بمعالجة كل أنواع الصرف قبل صبه فى الأجسام المائية حماية للكائنات المائية والمستهلك.