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HEAVY METALS AND MACRONUTRIENTS CONCENTRATION IN *OREOCHROMIS NILOTICUS* AND *TILAPIA ZILLII* FISH SPECIES INHABITING SOME EGYPTIAN LAKES AND EL-SALAM CANAL

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Key words: heavy metals, macronutrients, *Oreochromis niloticus*, *Tilapia zillii*, Lake Manzalah, Lake Qarun, El-Salam Canal

ABSTRACT

The present study was initiated to assess the levels of Fe, Mn, Zn, Cu, Ni, Co, Pb and Cd together with Na, K, Ca and Mg in liver and muscle of *Tilapia zillii* from three different aquatic ecosystems namely, Lake Manzalah (Brackish water), Lake Qarun (Saline water) and El-Salam Canal (fresh water) and *Oreochromis niloticus* from Lake Manzalah and El-Salam Canal throughout four seasons (1999-2000). The present results revealed that liver has higher tendency to accumulate Fe and Cu more than the other studied heavy metals for *O. niloticus* and *T. zillii* in different studied sites. Zn followed Fe in the accumulation abundance in muscle tissues of the two studied species and Cd was the lowest one. The fluctuation of metal concentrations in muscle tissues for *O. niloticus* and *T. zillii* exhibited the following descending order Fe>Zn>Mn=Cu=Ni=Co=Pb>Cd, while the abundance order of the same metals in liver tissues was: Fe>Cu>Zn>Mn>Ni>Co= Pb>Cd.

INTRODUCTION

In aquatic ecosystems, fish integrate and reflect the effects of numerous interacting biotic and abiotic factors (Eastwood and Couture, 2002). Although anthropogenic stresses such as metal contaminants adversely affect fish, these organisms are typically subjected to numerous stressors including unfavorable or fluctuating temperature, low dissolved oxygen, elevated sediment metal load, high water velocity, limited food availability and other types of episodic variables. All these factors, individually or together, can impose considerable stress on physicological systems of fish and impair their health or condition (Wedemeyer *et al.*, 1990).

Fish are able to uptake and retain heavy metals dissolved in water via active or passive processes (Ay *et al.* 1999). Toxic effects of metals occur after excretory, metabolic, storage and detoxification mechanisms are no longer able to match with uptake rates (Longston, 1990; Roesijadi and Robinson, 1994).

All heavy metals are potentially harmful to most organisms at some levels of exposure and absorption. Their presence in the environment has increased in some areas to levels which threaten the health of aquatic and terrestrial organisms, man included (Saeed, 1998). Stewart (1999) reported that metal toxicity in nature is determined to a great extent by the availability of individual metals for uptake by organisms.

The passage of different environmental pollutants to their aquatic systems demonstrates the need for a comprehensive study for their effects on living resources. Waste discharge never occurs singly but always as a mixture. Meanwhile, the resistance and sensitivity of organisms to pollutants are highly specific (Jana and Choudhuri, 1994).

Abdel-Satar and Shehata. (2000) concluded that the fish flesh *O. niloticus* and *T. zillii* is contaminated with both lead and cadmium for fish caught from sites more close to the sources of industrial, agricultural and domestic effluents in the River Nile and they added that the flesh of *T. zillii* has high affinity for its metal uptake than that for *O. niloticus*.

Lake Manzalah was subjected to excessive and progressive organic and inorganic pollution from different sources. The lake has become a sick pond after these serious changeable conditions of its environment. Ibrahim *et al.* (1999) stated that the fish in Lake Manzalah is characterized by slow growth rates, where the small illegal-sized caught fish contribute a remarkable portion (63-96%) of the lake fishery. This was attributed to eutrophication and pollution (Abdel-Baky & Bahnasawy, 1994 & El-Caryoni, 1994). Mohamed *et al.* (1999) stated that bioaccumulation of heavy metals in fish may critically influence the growth rate and the quality of fish. The southern sector of Lake Manzalah receives 75% of the total annual drainage water to the lake from Hadous, Ramsis and Bahr El-Bagar drains. These drains play an important role in increasing the eutrophication condition of the lake water (Abdel-Satar, 2001).

El-Salam Canal is carrying the Nile waters from Damietta branch upstream to Faraskour Barrage. The canal receives increasing amount of agricultural drainage water, which may exert considerable changes in the physical, chemical and biological properties. Sabae and Abdel-Satar (2001) suggested that the gradual increase in chemical character from up- to down stream and the irregular seasonal changes in the metal contents of the canal water might be related to the agricultural wastes discharged into the canal.

Lake Qarun receives the agricultural drainage water from surrounding cultivated lands. Most of the drainage water reaches the lake by two greatest drains, El-Batts (at the northeastern corner) and El-Wadi drains (near mid point of the southern shore). Ali (2002) determined some trace elements (Zn, Cr, Co, Ni, Pb, Cd and As) in different organs (liver, Kidney and muscle) in *T. zillii* and *Solea vulgaris* caught from Lake Qarun and reported that *Solea vulgaris* showed more accumulative tendencies than *T. zillii*. Also, the kidney showed more accumulation of the studied elements followed by liver and muscle.

The aim of this study is to compare between the concentrations of some heavy metals and macronutrients in the muscle and liver of the most common and commercial fish species, namely *O. niloticus* and *T. zillii* inhabiting three different aquatic ecosystems in Egypt.

MATERIALS AND METHODS

Fish specimens of *O. niloticus* and *T. zillii* were caught seasonally from three sites along the southern sector of Lake Manzalah (sites 1, 2 and 3) and two sites from El- Salam canal up to 63 Km.(sites 4 and 5) during the period from autumn 1999 to summer 2000. In addition to one site in Lake Qarun in the eastern region (infront of El-Batts drain) were chosen for *T. zillii* during the same period (site 6) (Fig. 1).

Samples pertaining to *O. niloticus* and *T. zillii* were obtained in a controlled weight range of 100-150 gm for *O. niloticus* and 30-50 gm for *T. zillii* from each site. After the dissection of fish samples, parts of liver and muscle individually of six specimens were mixed together. These composite samples were dried in an oven at 105 °C for 24 hour to constant weight. Fish samples of one gm (muscle) and 0.5 gm. (liver) dry weight were digested with 5 ml conc. HNO_3 and 5 ml conc. perchloric acids and finally, the samples were filtered (Ghazaly, 1992).

The metals (Fe, Mn, Zn, Cu, Pb, Cd, Ni and Co) concentrations were determined using atomic absorption spectrophotometer (Hitachi model 170-30) with Graphite Atomizer (GA-2) and comparing the readings with a standard curve. For macronutrients (Na, K, Ca and Mg), the samples were determined using atomic absorption spectrophotometer (Hitachi model 170-30).

RESULTS AND DISCUSSION

a. Heavy metals

The present investigation revealed that, bioaccumulation of the studied heavy metals in studied organs of fish species depends mainly on sampling sites. Moreover, seasonal variations showed higher residual values in hot than in cold seasons. The heavy metals concentrations of the studied species in different water bodies were presented in Tables (1-8).

The results indicated that, the iron concentrations in the *O. niloticus* were ranging between 0.036-0.064 and 0.301-0.710 mg/g dry wt. for muscle and liver, respectively, while the values for *T. zillii* were 0.034-0.132 and 0.315-0.905 mg/g dry wt. The accumulation rates of Fe in *O. niloticus* and *T. zillii* were higher in liver than muscle. Mohamed *et al.* (1999) reported that the liver is the first sensitive organ for metal accumulation. On the other hand, muscle included the lowest levels of the heavy metals concentration.

For *T. zillii* the muscle showed high values of iron for fish caught from Lake Qarun (site 6) than the sites in Lake Manzalah and El-Salam Canal during different seasons except summer, while the fish caught from Lake Qarun had the minimum rate of accumulation in liver for Fe and Mn metals during all seasons. This may be attributed to the difference in type and amount of wastes discharged to the water bodies. Carbonell *et al.* (1998) reported that any increase in total dissolved metal concentration would correspondingly increase the free metal ions concentration, and thereby lead to an increase in metal uptake rate. If the rate of excretion does not follow a parallel increase, a net accumulation of metal occurs within the body. Fe was found to be the most abundant metal present in the fish tissue and liver for the two studied species.

Manganese levels were in the range of 1.904-7.010 and 2.301-5.511µg/g for muscle of *O. niloticus* and *T. zillii*, respectively and for liver the ranges were 15.28-50.40 and 15.66-51.45 µg/g. There is an increase in the concentrations of Mn during summer in fishes of most sites. In this concern, Phillips (1980) reported that many factors affect the rate of accumulation of which seasonal variation in temperature was taken into consideration. Gomaa (1995) added that weakly bound metals in soft organ (liver) may be more easily influenced by seasonal changes than strongly bound metals in flesh

It is commonly accepted that zinc is an essential micronutrient required for normal growth and metabolic functions by terrestrial vertebrates as well as various fish species (Gatlin *et al.*, 1991 ; Lan *et al.*, 1995). The findings of the present study show that for *T. zillii*. Zn accumulated more in the muscle of fish from site 6 (Lake Qarun) than the sites of Lake Manzalah and El-Salam Canal. On the contrary, the liver showed the minimum rate of accumulation of Zn in fish from Lake Qarun.

It is conspicuous that, Zn followed Fe in the accumulation abundance in fish tissue of the two species and Cd was the lowest one. Similar findings were reported by Jaffar *et al.* (1988): Schuhmacher *et al.* (1992); Abdel-Moneim *et al.* (1994 b); Zyadah (1997) and Abdel-Baky *et al.* (1998).

Copper is an essential trace elements in fish metabolism (Lan *et al.* 1995). However, it is different from Zn in that its presence in the aquatic environmental with relatively lower concentration is known to be harmful (Lan and Chen, 1991). Cu levels in the investigated fish muscle ranged between 2.07-8.28 and 2.07-7.66 µg/g for *O. niloticus* and *T. zillii*. respectively. According to FAO. 1983, the studied fishes of different sites were not contaminated with Zn (40 µg/g dry wt.) and Cu (20-30 µg/g dry wt.)

Bioaccumulation of heavy metals does not only depend on the structure of the organ but also on the interaction between metals and the target organs (Sorensen 1991 : Mohamed *et al.*, 1999). For *O. niloticus* and *T. zillii*, the present results showed that liver has higher tendency to accumulate Fe and Cu than the other studied heavy metals in different sits. These results agree with those reported by Abdel-Baky and Zyadah (1998) for Lake Manzalah.

Contrary to Zn. Cu showed high rate of accumulation in liver for *T. zillii* fishes from Lake Qarun than the other water bodies during different seasons except summer. The liver of the two species showed high values during hot seasons for all studied sites. This may be attributed to the increase of load in drainage water containing high amount of Cu. Our data support the conclusion of Taylor *et al.*, (2000) that in fish tissue. Cu concentrations rise only after exposure to high levels of Cu sources.

The present results revealed that the accumulation pattern of lead in muscle (2.00-5.80 and 2.03-8.79 µg/g for *O. niloticus* and *T. zillii*, respectively) was lower than the values in liver (4.09-17.09 and 4.20-19.06 µg/g). El-Nabawi *et al.* (1987) stated that lead resides in muscle tissue are usually lower than these in other organs. Barak and Mason (1990) recorded that lead levels were several times higher in liver than flesh. Muscle of *T. zillii* in Lake Qarun (site 6) showed accumulation levels higher than that recorded in Lake Manzalah and El-Salam Canal sites during different seasons. On the contrary, the liver levels for Lake Manzalah and El-Salam Canal sites showed higher accumulation than Lake Qarun during hot seasons.

Cadmium is a non-essential element that has severe toxic effects on aquatic organisms (Sorensen, 1991; Hollis *et al.*, 1999). In fish, Cd can damage gills (Voyer *et al.*, 1975) result in skeletal deformities and disturb calcium balance (Wicklund-Glynn *et al.*, 1994). The levels of Cd in muscle were found to be 0.438-1.214 and 0.464-1.628 µg/g for *O. niloticus* and *T. zillii*, respectively.

The fish of studied. water bodies are considered heavily contaminated with Cd and Pb where their levels were more than the permissible limits of FAO, 1983 (0.5 µg/g dry wt. for Cd and Pb) and Australian NH&MRC, 1987 (0.2 µg/g dry wt. for Cd and 1.5 µg/g dry wt. for Pb). In general, the highest Cd concentrations were found in the liver (0.757-2.877 and 0.874-3.440 µg/g in *O. niloticus* and *T. zillii*, respectively). The enrichment of heavy metals in liver was reported in the studied sites. Ibrahim *et al.* (1999) stated that the high metal content in the liver may be attributed to its multifunctional role in detoxification and storage processes. For *T. zillii*, Lake Qarun showed the highest values of Cd in muscle and liver during different seasons except autumn for muscle at site 1 (1.513 µg/g). This is confirmed with that reported by Koli *et al.*(1978), who stated that salt water fish have more heavy metals concentrations (Fe, Zn, Mn, Cu and Cd) than the fresh water fish.

Nickel levels ranged between 2.063-7.020 and 2.376-5.940 µg/g for muscle of *O. niloticus* and *T. zillii*, respectively. Several variations in liver Ni concentration were observed in the most studied sites (5.436-28.910 and 5.874-41.440 µg/g), with higher levels in the hot seasons.

During cold seasons, El-Salam Canal sites showed high accumulation of Ni level in liver of *O. niloticus* and *T. zillii*, while Lake Manzalah sites showed higher level during hot seasons for the two species. The dissimilarities in these results may be attributed substantially to the changeable ecological conditions in the studied aquatic systems as a result of fluctuation in the amounts of agricultural drainage water,, sewage effluents and industrial wastes. The accumulation of trace metals depends on the nature and the function of the tissue and ability of fish in regulating the level of the metals in their bodies during the uptake and elimination processes (Faris *et al.*, 1998).

The bioaccumulation rate of cobalt recorded the highest values in liver (4.19-19.69 and 4.31-19.39 µg/g for *O. niloticus* and *T. zillii*, respectively) than in muscle (2.50-6.10 and 2.70-5.23 µg/g) during different seasons. In cold seasons, the arrangement of the studied aquatic systems according to the ability of their liver tissue to accumulate Co metal was as follow: Lake Qarun> Lake Manzalah = El-Salam Canal, while the reverse was observed during hot seasons.

Ali (2002) studied the accumulated concentrations of Ni and Co in *T. zillii* collected from Lake Qarun. He found the nickel range was 5.0-6.7 and 6.7-11.0 µg/g in flesh and liver, respectively, while the Co range was 3.9-5.0 and 7.6-10.3 µg/g. These results agree with the present findings but with slight increase in Ni muscle level.

The obtained results showed that the fluctuation of metal concentration in muscle tissues for *O. niloticus* and *T. zillii* exhibited the following descending order. Fe>Zn>Mn=Cu=Ni=Co=Pb>Cd. while the abundance order of metal concentration in liver tissue was Fe>Cu>Zn>Mn>Ni>Co= Pb>Cd.

It can be can concluded that the accumulation levels of heavy metals in the studied organs of fish reflect to high extent the degree of aquatic environmental pollution by such metals. Therefore, fish can be considered as a valid indicator for pollution of the aquatic environment (Shakweer. 1998)

Also, the study gives a declaration of the elevated levels metal pollution in the different studied areas due to continuously discharging of industrial, agricultural and domestic effluents. Therefore, strict environmental regulations will require the development of better indicators of metal effects on aquatic ecosystems including fish.

b. Macronutrients:

Concentration distribution of macronutrients in the studied fish species during different seasons are collected in Tables (9-12).

It is clear from the present results that the accumulation pattern of Na showed a similar trend in both fish species with a noticeable increase in the liver (3.014-7.96 mg/g) than the muscle(2.341- 3.73 mg/g). These results can be explained on the basis of tendency of soft tissues to accumulate the metals than hard ones (Abdel-Moneim *et al.*, 1994 a).

The accumulation pattern of macronutrients showed slight increase in the muscle of *T. Zillii* during most seasons for the fish collected from Lake Qarun. Also, Ca and Mg liver content showed the same phenomena in Lake Qarun. Meanwhile, high levels of liver Na and K were recorded in Lake Manzalah and El-Salam Canal fishes. However, several instances of individual variability could be observed in the macronutrient data with respect to various fish from different sites.

The obtained results showed that, the fluctuation of macronutrients concentrations in fish organs (muscle and liver) exhibited the following descending order Na=K>Ca>Mg.

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Table (1): Seasonal variations of iron concentration (mg/gdry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	0.050	0.052	0.059	0.050	0.114	0.042	0.053	0.055	0.07 ±0.03	0.05 ±0.01
2	0.041	0.045	0.058	0.044	0.039	0.051	0.064	0.132	0.05 ±0.01	0.07 ±0.04
3	0.046	0.049	0.043	0.050	0.043	0.045	0.064	0.047	0.05 ±0.01	0.05 ±0.00
4	0.041	0.043	0.049	0.055	0.043	0.050	0.049	0.05	0.05 ±0.00	0.05 ±0.00
5	0.036	0.045	0.055	0.053	0.044	0.039	0.042	0.055	0.04 ±0.01	.05 ±0.01
6		0.077		0.063		0.052		0.079		0.07 ±0.01
Liver										
1	0.301	0.332	0.304	0.443	0.502	0.510	0.641	0.642	0.44 ±0.17	0.48 ±0.13
2	0.325	0.340	0.339	0.315	0.593	0.324	0.690	0.701	0.49 ±0.18	0.42 ±0.19
3	0.334	0.329	0.301	0.414	0.631	0.642	0.710	0.905	0.49 ±0.21	0.57 ±0.26
4	0.305	0.325	0.332	0.315	0.414	0.451	0.469	0.603	0.38 ±0.08	0.42 ±0.13
5	0.305	0.341	0.392	0.395	0.503	0.459	0.676	0.734	0.47 ±0.16	0.48 ±0.17
6		0.326		0.313		0.219		0.408		0.32 ±0.08

Table (2): Seasonal variations of manganese concentration (µg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	2.305	2.305	1.904	3.010	5.210	2.305	3.707	3.812	3.28 ±1.50	2.86 ±0.72
2	3.010	2.806	2.010	3.307	4.810	4.748	5.512	5.511	3.84 ±1.61	4.09 ±1.25
3	2.415	2.501	2.806	2.948	2.806	3.080	3.607	2.906	2.91 ±0.50	2.88 ±0.25
4	2.948	2.301	3.106	2.664	3.707	4.112	4.812	4.639	3.64 ±0.84	3.43 ±1.12
5	5.010	2.405	3.106	2.806	7.010	2.305	2.505	3.507	4.41 ±2.04	2.76 ±0.55
6		4.380		3.030		3.140		4.698		3.81 ±0.85
Liver										
1	25.21	28.02	26.34	21.32	21.35	22.56	35.27	36.20	27.04 ±5.89	27.03 ±6.77
2	16.87	17.62	15.66	19.73	15.28	15.56	32.35	23.87	20.04 ±8.23	19.20 ±3.55
3	22.31	21.80	19.73	19.85	25.04	27.30	50.40	25.47	29.37 ±14.19	23.61 ±3.39
4	16.87	16.92	18.53	16.87	21.35	30.20	26.29	28.34	20.76 ±4.12	23.61 ±7.18
5	19.82	20.51	19.94	25.19	28.79	26.99	40.51	51.45	27.27 ±9.78	31.03 ±13.88
6		18.21		17.95		19.75		19.92		18.96 ±1.02

O.n : *O. niloticus*

Table (3): Seasonal variations of zinc concentration (µg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	17.76	14.70	15.30	22.68	17.10	21.60	13.50	26.10	15.92 ±1.02	21.27 ±4.78
2	18.60	19.92	16.20	24.06	26.22	23.43	16.98	29.88	19.50 ±4.59	24.32 ±4.13
3	20.30	19.80	18.60	22.96	20.70	24.58	18.90	18.96	19.63 ±1.03	21.58 ±2.04
4	19.95	21.54	19.63	18.89	21.54	22.36	20.14	24.32	20.32 ±0.84	21.78 ±2.25
5	20.58	17.70	17.70	23.40	19.40	21.80	22.96	24.60	20.16 ±2.21	21.88 ±3.01
6		26.76		29.65		25.54		35.56		29.38 ±4.47
Liver										
1	40.25	38.76	51.78	38.73	44.23	46.87	37.39	47.91	43.41 ±6.25	43.07 ±5.01
2	42.56	44.23	39.96	39.27	70.62	44.00	73.13	56.65	56.57 ±17.74	46.04 ±7.43
3	47.64	51.34	41.56	53.61	55.98	61.32	80.06	74.86	65.57 ±16.90	60.28 ±10.62
4	44.23	47.64	41.56	55.34	55.98	71.34	61.32	63.42	50.77 ±9.42	59.44 ±10.22
5	53.18	42.25	41.07	60.12	68.69	54.25	82.22	72.53	61.29 ±17.56	57.29 ±12.59
6		38.62		44.96		36.98		56.69		44.31 ±8.94

Table (4): Seasonal variations of copper concentration (µg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	3.93	3.10	2.69	2.07	2.69	4.14	5.17	6.54	3.62 ±1.19	3.96 ±1.91
2	2.07	2.48	3.10	2.69	3.72	3.66	4.28	7.66	3.29 ±0.95	4.12 ±2.41
3	3.05	3.20	3.10	3.32	3.93	4.35	4.76	5.17	3.71 ±0.81	4.01 ±0.93
4	2.13	3.45	2.98	2.76	3.36	3.54	5.12	5.43	3.40 ±1.26	3.80 ±1.14
5	2.48	4.14	3.72	2.28	2.07	2.28	8.28	5.35	4.14 ±2.85	3.51 ±1.51
6		5.14		3.81		3.78		5.54		4.57 ±0.91
Liver										
1	66.31	63.64	78.98	89.40	115.90	124.68	117.96	132.00	94.79 ±26.10	102.4 ±31.85
2	60.32	67.69	73.72	88.90	72.31	81.96	127.45	119.01	83.45 ±29.94	89.39 ±21.63
3	77.95	82.65	65.98	89.35	116.62	124.64	149.20	129.23	102.4 ±37.93	106.4 ±23.87
4	49.35	51.24	53.26	49.95	60.43	80.39	120.41	135.26	70.86 ±33.35	79.21 ±39.92
5	59.23	46.59	38.65	39.95	58.61	102.39	173.80	119.20	82.57 ±61.56	77.03 ±39.68
6		126.36		92.25		127.39		131.32		119.3 ±16.18

O.n : O. niloticus

Table (5): Seasonal variations of lead concentration (μg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	4.00	3.20	2.05	2.03	4.00	4.10	2.60	4.01	3.16 ±0.99	3.34 ±0.96
2	2.00	3.60	2.40	4.80	5.20	5.60	3.60	3.40	3.30 ±1.44	4.35 ±1.04
3	3.05	4.09	2.60	3.60	3.40	4.09	5.60	4.60	3.66 ±1.33	4.10 ±0.41
4	4.310	4.75	5.21	5.42	4.92	4.31	5.34	5.64	4.95 ±0.46	5.03 ±0.61
5	5.60	4.40	3.40	7.80	5.80	3.10	4.20	4.60	4.75 ±1.15	4.98 ±2.00
6		6.77		7.71		5.72		8.79		7.25 ±1.31
Liver										
1	6.86	4.80	4.60	6.86	7.71	8.12	9.43	11.00	7.15 ±2.01	7.69 ±2.59
2	4.09	5.20	4.61	4.20	12.76	10.87	15.20	13.35	9.16 ±5.65	8.41 ±4.42
3	5.65	6.86	5.29	6.21	10.56	11.84	17.09	19.04	9.65 ±5.51	10.99 ±5.93
4	7.01	6.83	6.51	7.64	8.35	11.42	16.39	15.84	9.57 ±4.62	10.43 ±4.12
5	6.50	6.24	6.04	7.89	11.84	12.65	15.64	19.06	10.00 ±4.59	11.40 ±5.75
6		9.46		8.07		7.95		10.87		9.09 ±1.37

Table (6): Seasonal variations of cadmium concentration (μg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	1.214	1.513	0.785	0.725	0.949	0.678	0.637	0.785	0.90 ±0.25	0.93 ±0.39
2	0.552	0.902	0.589	0.472	0.489	0.547	0.568	0.788	0.55 ±0.04	0.68 ±0.20
3	0.447	0.547	0.457	0.678	0.447	0.561	0.536	0.757	0.47 ±0.04	0.64 ±0.10
4	0.453	0.464	0.593	0.674	0.634	0.728	0.732	0.689	0.60 ±0.12	0.64 ±0.12
5	0.438	0.561	1.167	0.725	0.587	0.568	0.628	0.799	0.71 ±0.32	0.66 ±0.12
6		1.002		0.986		1.030		1.628		1.16 ±0.31
Liver										
1	1.364	2.153	1.084	1.437	1.325	0.788	1.289	1.415	1.27 ±0.12	1.45 ±0.56
2	1.084	1.547	1.364	1.809	2.877	1.615	1.030	1.289	1.59 ±0.87	1.57 ±0.21
3	1.256	0.949	1.287	1.289	2.015	2.006	2.035	3.371	1.65 ±0.44	1.90 ±1.07
4	0.931	0.890	1.13	1.152	1.635	1.594	2.151	2.53	1.46 ±0.55	1.54 ±0.72
5	0.757	0.874	1.230	1.208	1.547	2.195	2.390	2.440	1.48 ±0.69	1.68 ±0.76
6		2.225		2.199		2.035		3.440		2.47 ±0.65

O.n : O. niloticus

Table (7): Seasonal variations of nickel concentration (µg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	3.996	6.235	4.570	3.996	5.075	3.987	3.457	4 920	4 27±0 70	4 78±1 06
2	3.780	2.570	2.063	2.376	3.672	3.820	6.804	5.103	4 08±1.98	3 47±1 26
3	3.512	3.487	2.165	2.380	2.970	3.420	7.020	5.940	3 92±2 14	3 81±1 51
4	3.120	3.790	3.460	3.780	3.230	3.748	4.292	4.185	3 53±0 53	3 88±0 21
5	4.185	2.484	5.521	3.748	2.640	2.620	3.194	5 130	3 69±1 26	3 50±1 23
6		4.108		3.856		4.430		4.870		4 32±0 44
Liver										
1	5.436	5.874	5.900	6.870	7.920	8.890	10.802	15.025	7 51±2 44	9 16±4 10
2	6.248	6.928	6.090	7.160	12.140	10.940	28.910	41.440	13 35±10 75	16 62±16 65
3	5.980	6.305	7.540	7.690	10.500	13.201	15.180	26.750	9 80±4 05	13 49±9 33
4	8.230	8.541	9.280	9.631	11.220	10.630	14.251	13.960	10.75±2 65	10 69±2 34
5	8.690	9.230	9.028	12.231	12.732	10.100	22.350	15.020	13 2±6 37	10 69±2 34
6		8.056		8.450		11.012		11.568		11.65±2 85

Table (8): Seasonal variations of cobalt concentration (µg/g dry wt.) in muscle and liver of O. *niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	6.10	5.90	3.99	3.69	5.05	3.75	3.75	4.05	4.72±1 08	4 35±1 05
2	2.50	3.69	5.12	3.25	3.25	4.23	2.70	4 90	3 39±1.19	1 02±0 71
3	2.60	3.05	2.70	2.91	3.50	4.10	3.25	5.23	3 01±0 43	3 82±1 08
4	2.94	3.12	2.65	3.18	3.45	4.32	4.51	4.23	3 39± 82	3 71±0 65
5	2.65	2.70	5.93	4.60	3.19	4.29	3.52	3.75	3 82±1 45	3 84±0 83
6		4.07		3.58		4.09		4 32		4 01±0 31
Liver										
1	6.51	6.98	6.92	6.98	8.05	7.21	11 20	13.25	8 17±2 12	8 61±3 10
2	4.56	4.31	4.95	5.54	12.85	4 91	7.83	10.31	7 55±3 82	6 27±2 74
3	5.13	5.83	4.30	6.70	9.25	9 98	15.01	19.39	8 42±4 90	10 48±6 21
4	4.67	5.05	6.12	6.90	6.24	7.34	9.81	9.01	6 71±2 19	7 08±1 63
5	5.01	5.36	4.19	6.03	5.98	7.22	19.64	16 19	8 71±7 33	8 70±5 05
6		8.07		10.18		10.25		13.02		10 38±2 03

O.n : O. niloticus

Table (9): Seasonal variations of sodium concentration (mg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	2.751	2.458	2.517	2.634	2.341	2.739	2.517	2.634	2.53±0.17	2.62±0.12
2	2.868	2.798	2.985	2.458	2.380	2.458	2.868	2.482	2.78±0.27	2.55±0.17
3	2.901	2.930	2.634	2.634	2.560	2.576	2.576	2.552	2.70±0.16	2.67±0.17
4	2.831	2.890	2.641	2.530	2.451	2.517	2.341	2.459	2.57±0.22	2.60±0.20
5	2.927	2.751	2.482	2.458	2.459	2.517	2.517	2.341	2.60±0.22	2.52±0.17
6		3.730		3.390		3.059		3.390	3.99±0.65	3.30±0.27
Liver										
1	3.415	3.620	3.532	3.014	4.212	4.304	4.820	5.060	3.99±0.65	4.00±0.88
2	4.012	4.212	3.995	3.025	6.301	5.060	6.976	6.149	5.32±1.55	4.61±1.32
3	4.030	4.158	4.212	4.489	4.965	5.060	6.549	7.960	4.94±1.15	5.42±1.74
4	4.489	5.981	4.601	4.660	5.062	6.143	6.292	6.517	5.11±0.83	5.83±0.81
5	4.660	4.525	4.660	4.212	5.980	6.290	7.960	6.517	5.82±1.56	5.39±1.19
6		4.304		4.162		4.304		4.660		4.36±0.21

Table (10): Seasonal variations of potassium concentration (mg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	2.599	2.657	2.783	2.857	2.626	4.414	4.914	4.914	3.23±1.13	3.71±1.12
2	4.171	3.257	3.599	3.371	3.629	3.744	5.142	3.599	4.14±0.72	3.49±0.22
3	3.428	3.839	4.543	4.171	4.428	3.964	3.285	2.626	3.92±0.66	3.65±0.70
4	4.743	4.628	3.371	3.520	4.114	3.821	4.022	4.12	4.06±0.56	4.02±0.47
5	4.885	4.628	2.857	2.326	3.748	3.371	4.114	4.343	3.90±0.84	3.67±1.04
6		4.108		3.856		4.430		4 870		4.32±0.44
Liver										
1	3.839	3.925	3.744	3.251	4.543	4.885	5.056	5.056	4.30±0.62	4.28±0.85
2	4.628	3.785	3.748	3.443	5.880	3.747	7.481	6.139	5.43±1.62	4.28±1.25
3	4.428	4.885	4.343	4.628	5.056	4.914	7.686	6.647	5.38±1.57	5.27±0.93
4	4.628	4.885	4.52	4.628	5.34	5.860	5.842	6.212	5.80±0.62	5.40±0.76
5	4.428	4.628	3.448	4.885	5.642	5.659	7.750	7.686	5.32±1.85	5.71±1.39
6		3.655		3.925		3.747		3.964		3.82±0.15

O.n : O. niloticus

Table (11): Seasonal variations of calcium concentration (mg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	0.765	0.668	1.235	1.106	0.870	1.913	0.699	0.858	0.89 ±0.24	1.44 ±0.55
2	1.026	1.320	1.043	1.385	1.217	1.320	0.799	1.061	1.02 ±0.17	1.27 ±0.14
3	0.692	0.765	1.168	1.026	0.873	1.061	1.112	1.009	0.96 ±0.22	0.97 ±0.14
4	0.699	0.701	0.692	0.642	0.873	0.974	0.741	0.852	0.75 ±0.08	0.79 ±0.15
5	0.786	0.765	0.741	1.078	0.852	0.974	0.692	0.984	0.77 ±0.07	0.95 ±0.13
6		2.679		2.149		2.464		2.453		2.44 ±0.22
Liver										
1	0.873	0.680	1.858	1.179	0.974	2.453	0.858	1.061	1.14 ±0.48	1.34 ±0.77
2	1.217	1.485	1.368	0.584	2.464	2.044	2.943	2.053	2.00 ±0.84	1.54 ±0.69
3	0.798	0.873	1.217	1.389	1.320	1.168	1.560	1.862	1.22 ±0.32	1.32 ±0.42
4	0.858	1.030	1.140	0.984	1.423	1.210	1.830	2.016	1.31 ±0.41	1.31 ±0.48
5	0.974	0.858	0.974	1.210	1.030	1.210	1.846	2.080	1.21 ±0.43	1.34 ±0.52
6		3.003		2.960		3.105		3.320		3.10 ±0.16

Table (12): Seasonal variations of magnesium concentration (mg/g dry wt.) in muscle and liver of *O. niloticus* and *T. Zillii*

season	Autumn		Winter		Spring		Summer		Mean ± SD	
organ/site	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*	*O.n*	*T.zillii*
Muscle										
1	0.155	0.154	0.158	0.148	0.156	0.149	0.157	0.158	0.16 ±0.00	0.15 ±0.00
2	0.154	0.153	0.148	0.149	0.158	0.161	0.150	0.157	0.15 ±0.00	0.16 ±0.01
3	0.153	0.153	0.154	0.155	0.161	0.162	0.156	0.154	0.16 ±0.00	0.16 ±0.00
4	0.154	0.156	0.158	0.162	0.159	0.159	0.158	0.161	0.16 ±0.00	0.16 ±0.00
5	0.156	0.159	0.154	0.158	0.162	0.154	0.159	0.154	0.16 ±0.00	0.16 ±0.00
6		0.262		0.234		0.209		0.262		0.24 ±0.03
Liver										
1	0.191	0.199	0.187	0.179	0.179	0.199	0.205	0.262	0.19 ±0.01	0.21 ±0.04
2	0.199	0.205	0.192	0.191	0.395	0.299	0.369	0.299	0.29 ±0.11	0.25 ±0.06
3	0.198	0.199	0.192	0.205	0.220	0.299	0.327	0.423	0.23 ±0.06	0.28 ±0.10
4	0.187	0.199	0.198	0.201	0.301	0.294	0.220	0.299	0.23 ±0.05	0.25 ±0.06
5	0.191	0.199	0.187	0.205	0.201	0.300	0.592	0.383	0.29 ±0.20	0.27 ±0.09
6		0.299		0.395		0.369		0.395		0.36 ±0.05

O.n : O. niloticus

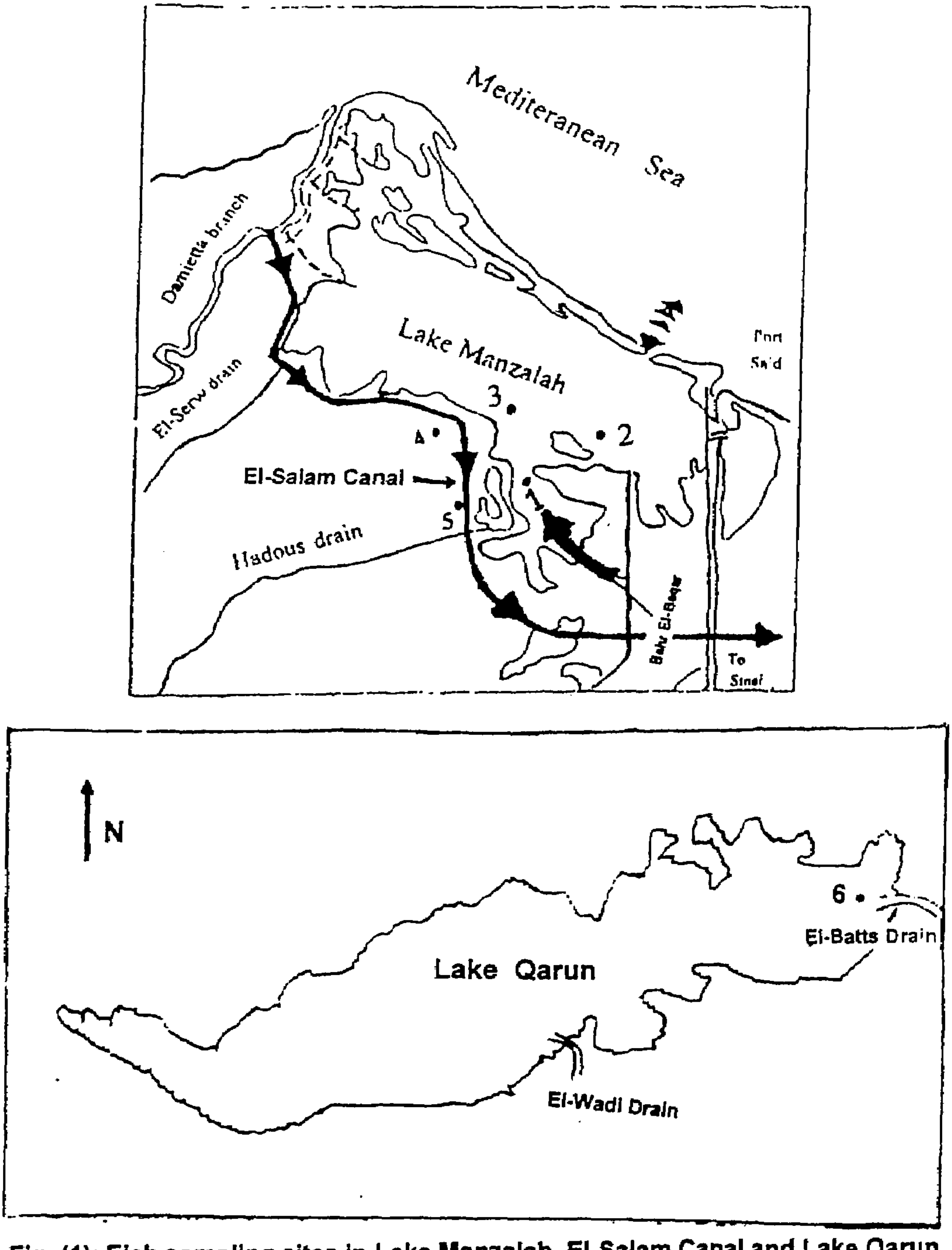

Fig. (1): Fish sampling sites in Lake Manzalah, El-Salam Canal and Lake Qarun.