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# *RELATIONSHIP BETWEEN LENGTH, WEIGHT OF FISH AND THE CONCENTRATIONS OF Zn, Cu, Mn AND Pb IN SOME MARINE AND FRESH WATER FISH SPECIES OF EGYPT.*

**BY**

**M.M. ABBAS* AND L.M. SHAKWEER**

**National Institute of Oceanography & Fisheries, Alexandria, Egypt.*

**Key words: Trace elements, Oreochromis niloticus, Oreochromis auraeus, Sardinella aurita, Lake Edku, Mediterranean.**

## *ABSTRACT*

*Concentrations of Cu, Zn, Mn and Pb were determined in the tissues of the muscles and liver of the Cichlid fresh water fish species **Oreochromis niloticus**, surviving at Lake Edku and **Oreochromis auraeus** surviving at Lake Mariut. These metals were determined also in the same organs of the marine species **Sardinella aurita** surviving in the Mediterranean at the coastal area near to Alexandria province.*

*Correlation coefficients between the concentrations of each metal with both the length and weight of fish were calculated.*

*Zn, Cu and Mn concentrations in the muscle tissues exhibited positive correlation with both length and weight of fish in the case of **S. aurita**. The concentrations of these elements in the liver of such fish species decreased with the increase of its length and weight.*

*Zn and Cu concentrations increased with the size and weight in the muscle tissues of **Oreochromis auraeus**. The concentrations of these elements in the liver of such fish species exhibited negative correlation with both the length and weight.*

*Pb concentrations decreased with length and weight in the muscle tissues of the three fish species investigated. On the other hand the concentrations of this element in the liver tissues of* ***Oreochromis niloticus*** *showed positive correlation with their lengths and weights. The correlation coefficient was negatively significant at high levels when the concentrations of Pb in the liver of* ***Sardinella aurita*** *was correlated with fish length or weight.*

*However, it is believed that it is difficult to find out a general conception that may commonly describe the relationship between the trace elements concentrations in the different organs of fish body and their sizes or weights. The concentrations of these elements increase in some cases with the length or weight of fish, in other cases these concentrations decrease when the fish grows up. The environmental conditions, the biological characters and the feeding behavior during the larval and adult stages are believed to play an important role that may affect the direction of such relationship either to the positive or negative directions.*

## *INTRODUCTION*

The investigations which are concerned with the environmental and physiological processes that regulate the concentrations of trace metals in the marine organisms have been undertaken by various authors in different parts of the world.

According to Bryan 1980, when a marine organism absorbs metals at a rate proportional to the environmental concentration there are at least three possible types of relation between the concentration achieved by different organs and those of the environment:

1- The organism excretes the metal at a rate proportional to the body burden and therefore the concentration in the body is proportional to environmental availability and usually remains fairly constant or tends to fall with increasing length which is related to its age.

2- The organism has limited powers of excretion and tends to store the absorbed metals. In this case the concentration in the organism may still be directly proportional to environmental availability but unless it grows fast enough to dilute the metal, the level in the body tends to increase with length.

3- The organism is able to increase the efficiency of excretion in response to increase the absorbtions and therefore the concentration in the body does not increase in proportion to environmental availability.

It appears therefore that there is evidence that the concentration of certain metal, sometimes either increases or decreases with body size or age.

In this concern it has been shown that the concentrations of total Hg increased with age in the whole body of lake trout (***Salvelinus namayeush***) (Bache ***et al***, 1971) and in muscle of northern pike (***Esox lucius***) (Johnels and Wester mark, 1969), spiny dogfish (***Squalus acanthius***) (Forrester ***et al***, 1972), three species of tuna, ***Thunnus thynnus***, ***T. albacora***, and ***T. alalunga*** (Cumont ***et al***, 1972) and a bathy-demersal fish ***Antimora rostrata*** (Barber ***et al***, 1972).

In contrast the concentrations of Mn, Fe and Zn decrease with size in whole juvenile estuarine fish (Cros and Brooks, 1973) as do concentrations of Cu and Zn in whole striped bass fingerlings (***Morone saxatilis***) for wet weights less than 15 g. (O'Rear, 1971). or striped bass ranging from 15 to 60 g, concentrations of Cu and Zn were constant with weight. Concentrations of cadmium (Cd) in the whole body of one to 12 years old lake trout were not age dependent (Lovett ***et al.***, 1972).

Cross ***et al*** (1973) pointed out that the concentrations of Fe, Cu, Cd and Zn either decrease or remain constant in the whole fish body as a function of age (weight, length) but concentrations of Hg increase with age in both muscle and whole fish.

Evans ***et al*** (1993) indicated that Zn, Fe and some other essential elements usually do not increase in concentrations with age or size because they are thought to be under homeostatic control.

Bollingberg and Johansen (1979) pointed out that more concentrations of Pb are common among young fish than older fish in spotted wolfish. They attributed these higher concentrations to the idea that the smaller ones of this fish species are more stationary and have lived most of their lives in the contaminated areas.

However, objective of the present paper is to investigate the relationship between total body length or weight with the concentrations of Zn, Cu, Mn and Pb in both the muscle tissues and liver of the marine fish species ***Sardinella aurita*** taken from the Mediterranean water and the fresh water fish species, ***Oreochromis niloticus*** of Lake Edku as well as ***Oreochromis auraeus*** of Lake Mariut.

**Methods:**

The commercial marine fish species ***Sardinella aurita*** was collected during 1995 from the commercial catch taken by purse series from the Mediterranean coast of Alexandria.

The fresh-water fish species ***Oreochromis niloticus*** was collected from the catch taken by artisinal fishing boats operating at Lake Edku during 1995.

***Oreochromis auraeus*** was sampled from the commercial catch of the boats fishing at the whole fishing localities of Lake Mariut during the various fishing seasons of 1995.

The sampled fish were weighed, measured and filleted. The liver was removed of such fish. The filets and liver were kept frozen in polyethylene bags at - 20°C until chemical analyses were begun.

The muscle tissues and liver for each species were collected separately and were digested by the use of 60% $HNO^3$ at 60°C. Two grams were taken as analytic sample and digested with the acid inside closed Teflon crucible in a steel block and a hot plate with thermostatic control.

Determination of the concentrations of Zn, Cu, Mn and Pb was carried out by the use of atomic adsorption spectrophotometer, (Perkin Elmer model 2380).

The numbers, total lengths and weights of the different specimens are shown in Table (1).

Table (1): Number, length and weight of fish sampled from Mediterranean water, Lake Mariut and Lake Edku.

| Species | No. of Samples | Length (cm) | | | Weight (gm) | | |
|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Average | Min | Max. | Average |
| ***Sardinella aurita*** | 33 | 15.0 | 24.0 | 20.5 | 27.5 | 111.9 | 70.40 |
| ***Oreochromis auraeus*** | 35 | 14.0 | 24.0 | 17.4 | 55.0 | 225.0 | 106.60 |
| ***Oreochromis niloticus*** | 30 | 15.0 | 24.0 | 17.1 | 62 | 225 | 137.80 |

## *RESULTS AND DISCUSSION*

The present study is carried out to correlate between the concentrations of Zn, Cu, Mn and Pb in the fish muscles and liver with the length or weight of ***Sardinella aurita***, ***Oreochromis niloticus*** and ***Oreochromis auraeus***. From the statistical point of view it is preferable to carry out such type of correlation on numerical basis. In this case the numerical correlative figure is termed as correlation coefficient. The advantage of such coefficient is that it describes not only the magnitude of correlation but also its direction.

Table (2) shows the average concentrations of Cu, Zn, Mn and Pb (mg/kg) in the flesh and liver of fish investigated.

Table (2): Average concentrations of Cu, Zn, Mn and Pb (mg/kg) in the flesh and liver of fish investigated.

| Species | Cu | | Zn | | Mn | | Pb | |
|---|---|---|---|---|---|---|---|---|
| | Flesh | Liver | Flesh | Liver | Flesh | Liver | Flesh | Liver |
| ***S. aurita*** | 2.35 | 13.23 | 15.80 | 58.93 | 0.75 | 4.22 | 0.77 | 29.78 |
| ***O. niloticus*** | 1.67 | 49.86 | 6.07 | 24.75 | 1.07 | 5.77 | 8.82 | 19.93 |
| ***O. uraeus*** | 1.39 | 25.50 | 8.54 | 15.20 | 0.61 | 2.12 | 3.55 | 5.74 |

The National Health and Medical Research Council, recommended that the standard concentrations of Cu and Pb for human consumption (Marks ***et al.***, 1980) are:

30.0 mg/kg for Cu and
2.0 mg/kg for Pb

As for the allowable concentrations of Zn in the fish flesh, western Australian Food and Drink Regulation listed a level of 40 mg/kg for human consumption (Marks ***et al.***, 1980).

Comparing the concentrations of heavy metals in the fish flesh as shown in table (2) with such permissible concentrations it can be indicated that the concentrations of Cu, Zn and Mn in the muscle tissues of fish collected are still below the allowable levels. On the other hand Pb concentrations in the fish flesh are higher than the permissible ones.

Tables (3) and (4) show the coefficient of correlation between the concentrations of Zn, Cu, Mn and Pb in the flesh and liver of fish sampled with their lengths and weights.

It can be indicated from the data given in this table that:

(1) Concentrations in the fish of some essential metals such as Zn and Cu exhibited muscles positive correlation with both length and weight of fish in cases of ***S. aurita*** and ***O. auraeus***; while negative correlation was existing in case of ***O. niloticus***.

(2) Mn concentrations in the fish muscles showed positive correlation with length and weight of both ***S. aurita*** and ***O. niloticus*** and negative correlation in case of ***auraeus***.

(3) Pb concentration in the fish muscles showed negative correlations with both length and weight in all fish samples studied.

Table (3): Correlation coefficients between length, weight of fish and Concentrations of Zn, Cu, Mn and Pb in the muscle tissues of species investigated.

| Fish species | Growth parameter | Correlation coefficient with | | | |
|---|---|---|---|---|---|
| | | **Zn** | **Cu** | **Mn** | **Pb** |
| ***Sardinella aurita*** | Length | + 0.604 | + 0.387 | + 0.400 | - 0.820 |
| | Weight | + 0.577 | + 0.258 | + 0.447 | - 0.785 |
| ***Oreochromis auraeus*** | Lenght | + 0.429 | + 0.210 | - 0.210 | -0.090 |
| | Weight | + 0.300 | + 0.360 | - 0.430 | - 0.060 |
| ***Oreochromis niloticus*** | Length | - 0.947 | - 0.495 | + 0.010 | - 0.620 |
| | Weight | - 0.950 | - 0.669 | + 0.257 | - 0.500 |

Table (4): Correlation coefficients between length, weight of fish and concentrations of Zn, Cu, Mn and Pb in the liver tissues of species investigated.

| Fish species | Growth parameter | Correlation coefficient with | | | |
|---|---|---|---|---|---|
| | | **Zn** | **Cu** | **Mn** | **Pb** |
| ***Sardinella aurita*** | Length | - 0.800 | - 0.229 | - 0.852 | - 0.978 |
| | Weight | - 0.817 | - 0.868 | - 0.845 | - 0.950 |
| ***Oreochromis auraeus*** | Length | - 0.600 | - 0.144 | - 0.168 | + 0.045 |
| | Weight | - 0.200 | - 0.186 | - 0.050 | + 0.206 |
| ***Oreochromis niloticus*** | Length | - 0.574 | + 0.695 | + 0.406 | + 0.546 |
| | Weight | - 0.639 | + 0.776 | + 0.063 | + 0.119 |

The above observations indicate that in most of the cases, the concentrations of Zn, Cu and Mn in the fish flesh exhibited positive correlations with either the length or weight of fish. Pb concentrations exhibited negative correlations in all cases. This means that the larger sized fish were able to regulate or decrease the concentration of such toxic elements in their muscle tissues.

The results indicate also that the correlations between the concentrations of the above mentioned metals in the liver muscles of ***S. aurita***, ***O. auraeus*** and ***O. niloticus*** with their lengths or weights can be described as follows:

(1) Zn concentrations in the liver of the three species investigated showed negative correlations with both the length and weight of fish.

(2) Cu and Mn concentrations in the fish liver decreased with the increase of either length or weight of ***S. aurita*** and ***O. aurateus***. The concentrations of these two elements increased in the larger fish of ***O. niloticus***.

(3) Pb concentrations in the liver exhibited positive correlation with both length and weight of the two Cichlid fresh water fish species. The concentration of such toxic element decreased in the larger fish of the marine-fish species ***S. aurita***.

It can be believed therefore that the adult fishes were able to decrease the concentrations of the three elements Zn, Cu and Mn in their liver than that in the younger ones.

However, it can be pointed out from the above mentioned points that the concentrations of Cu, Zn, ~~Mn and Pb~~ showed positive correlation with body length or weight in some cases. In other cases such correlation was negative. These achievements agree to a good extent with the achievements of other authors who are interested with the regulation of these metals in the bodies of marine organisms surviving at different areas of the world.

Cutshall ***et al*** (1977) pointed out that, although the concentration of certain metals sometimes either increase or decrease significantly with body size, this is not always the case.

Johnson (1987) in his study on element loading in fishes caught from Ontario Lakes (Canada) found that there was a decreasing order of occurrence. He indicated also those significant correlations between weight and Zn concentrations were observed in only five of 40 possible cases.

The positive relationship can be explained according to the proposal of Bryan (1980) that some marine organisms have limited powers of secretion and tends to store the absorbed metals in their bodies while they grow in length.

Uysal and Tuncer (1982) established positive relationships and attributed the increase of heavy metals concentrations in the bodies of larger fish to fish habitats and feeding behavior.

On the other hand reversible correlation has been established between the concentrations of heavy metals and their length or weight.

Cross ***et al*** (1969) pointed out that the significant decrease of zinc and copper concentrations with the increase of the weight of fish could be attributed to compositional changes in muscle, a decreased intake of metals in the diet of older fish or dilution by growth.

Cross and Brooks (1973) found that the concentration of Mn, Fe, Zn and Cu decrease with size in whole juvenile estuarine fish of the Atlantic. For striped bass ranging from 15-60 gm concentration of copper and zinc were constant with length or age.

Lett ***et al*** (1976) in their experimental study on the effect of copper on rainbow trout concluded that the initial response of trout at each copper concentration was the immediate cessation of feeding. However, within 15 days, food intake of fish under experiments had gradually increased to amount observed for control fish. Therefore the decrease of copper concentration by fish length may also be attributed to the cessation of fish to feed upon copper containing food until it becomes accommodated to such food or getting another uncontaminated feeding sources. In such a case the fish although becoming larger, may be able to avoid further copper accumulation in their bodies.

**Relationship equations between trace metals concentrations in fish body and its size or weight:**

In the cases where significant correlations at high levels between the size and/or weight of fish and trace element concentrations in either the flesh or liver are evidenced, it is attempted to establish linear function relationship between these variables.

These equations are established in the form:

$C = a + bL$ or $C = a + bW$ where:

C = trace metal concentration in mg/kg in the fish organ (flesh or liver).

L = Length of fish in cm.

W = Weight of fish in gm.

(a) and (b) are constants.

It is a matter of fact that many authors preferred to use such linear equations to describe the relationships between heavy metals concentrations and body length of fish. Among these authors are:

Cross ***et al*** (1973), Bohn and Fallis (1978), Portman and Woolner (1979).

In other cases, some authors used another forms or equations to describe such relationship.

Badsha and Saimsbury (1977), Milner (1979) used double logarithmic regressions.

Therefore it is tried in the present study to deriviate curvilinear regression equations that may be more fir in describing the relationships which can be expected between the above mentioned variables. The equations as well as their graphical representation are given in the fig. from 1 to 7.

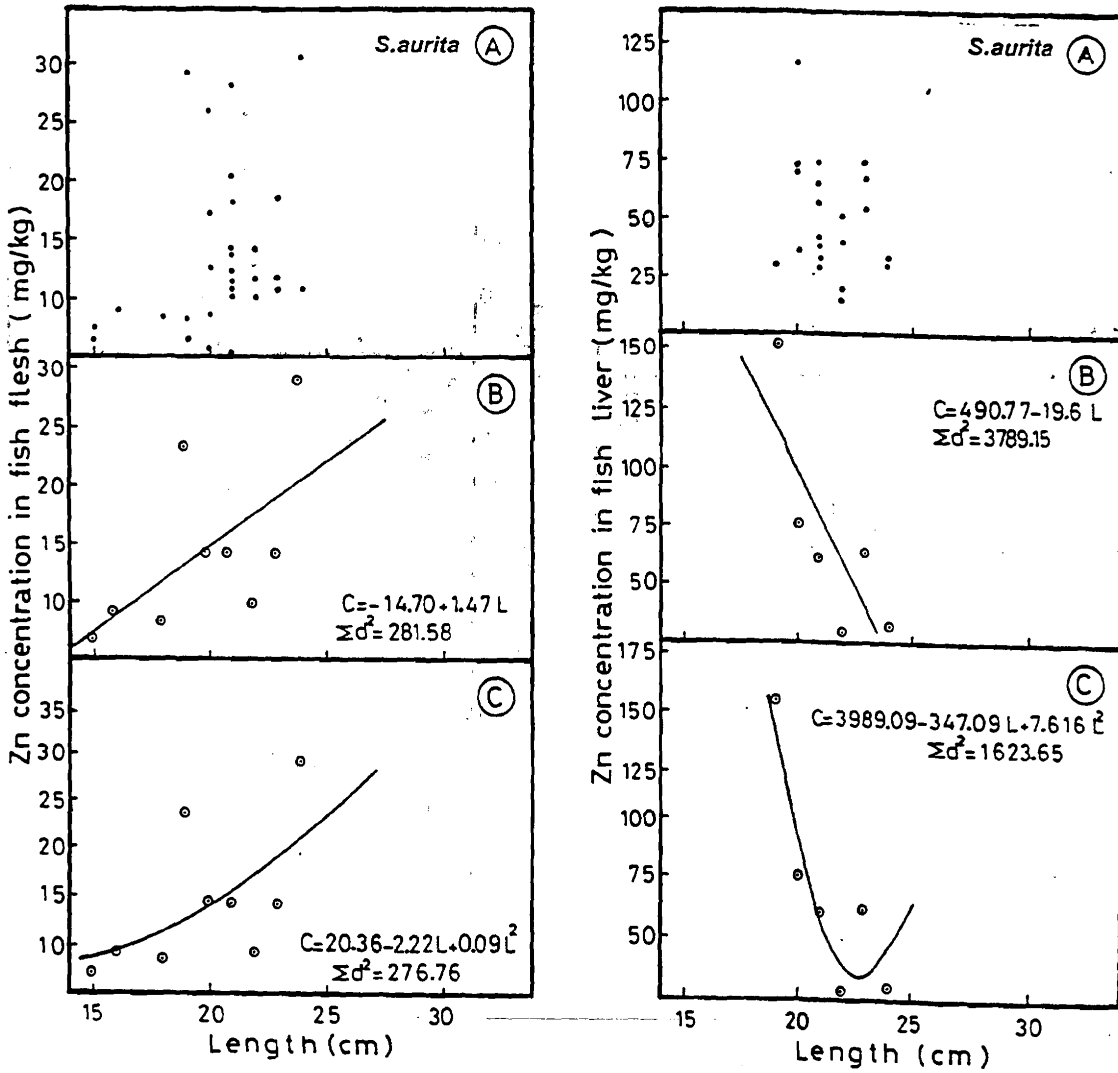


**Fig. (1): Zn concentrations in the flesh and liver of *S.aurita* in relation to length, (A) : represents individual concentrations, (B) and (C) represent first and second order relationship equations.**

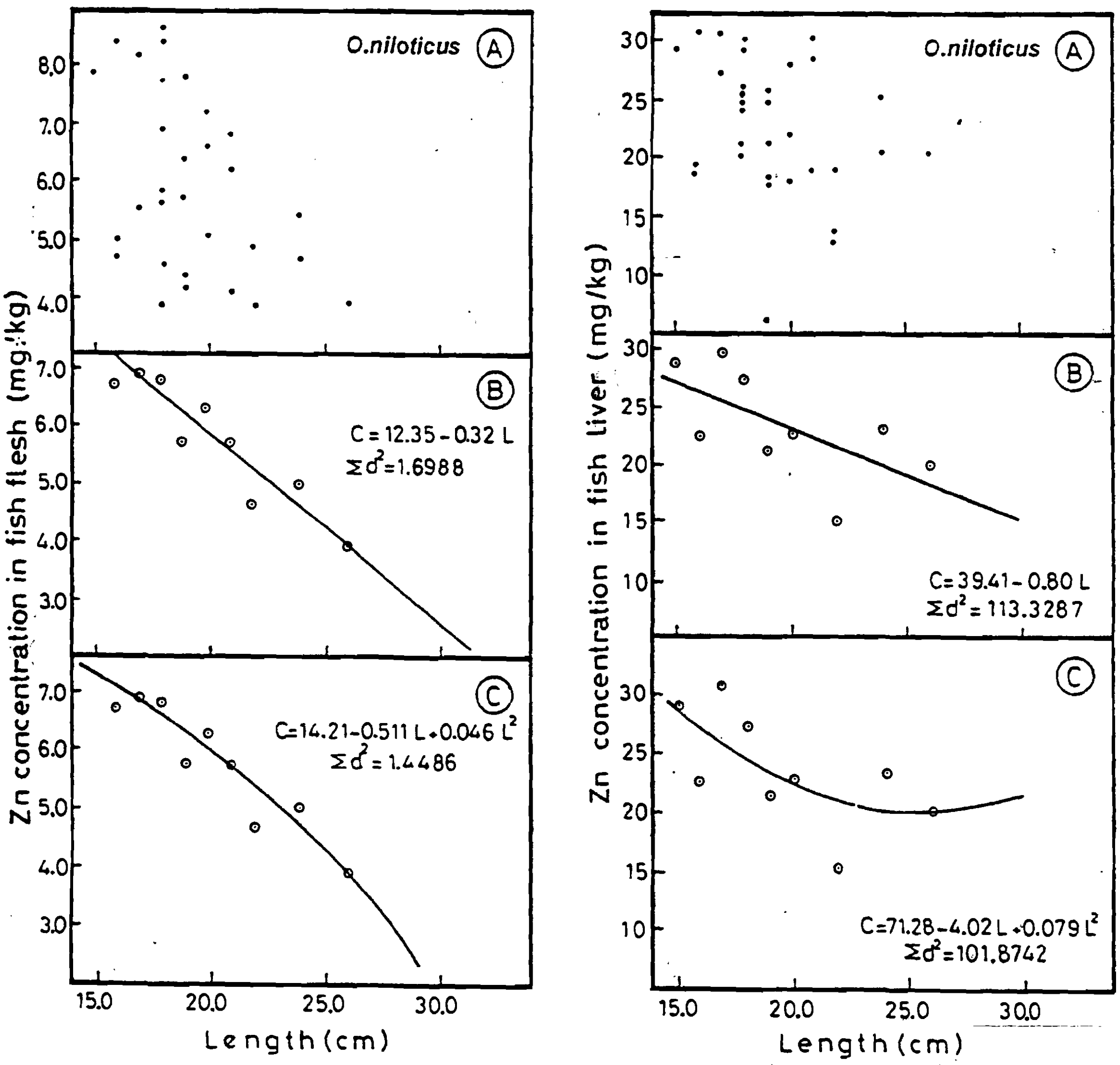


**Fig. (2): Zn concentrations in the flesh and liver of *O.niloticus* in relation to length, (A) : represents individual concentrations, (B) and (C) represent first and second order relationship equations.**

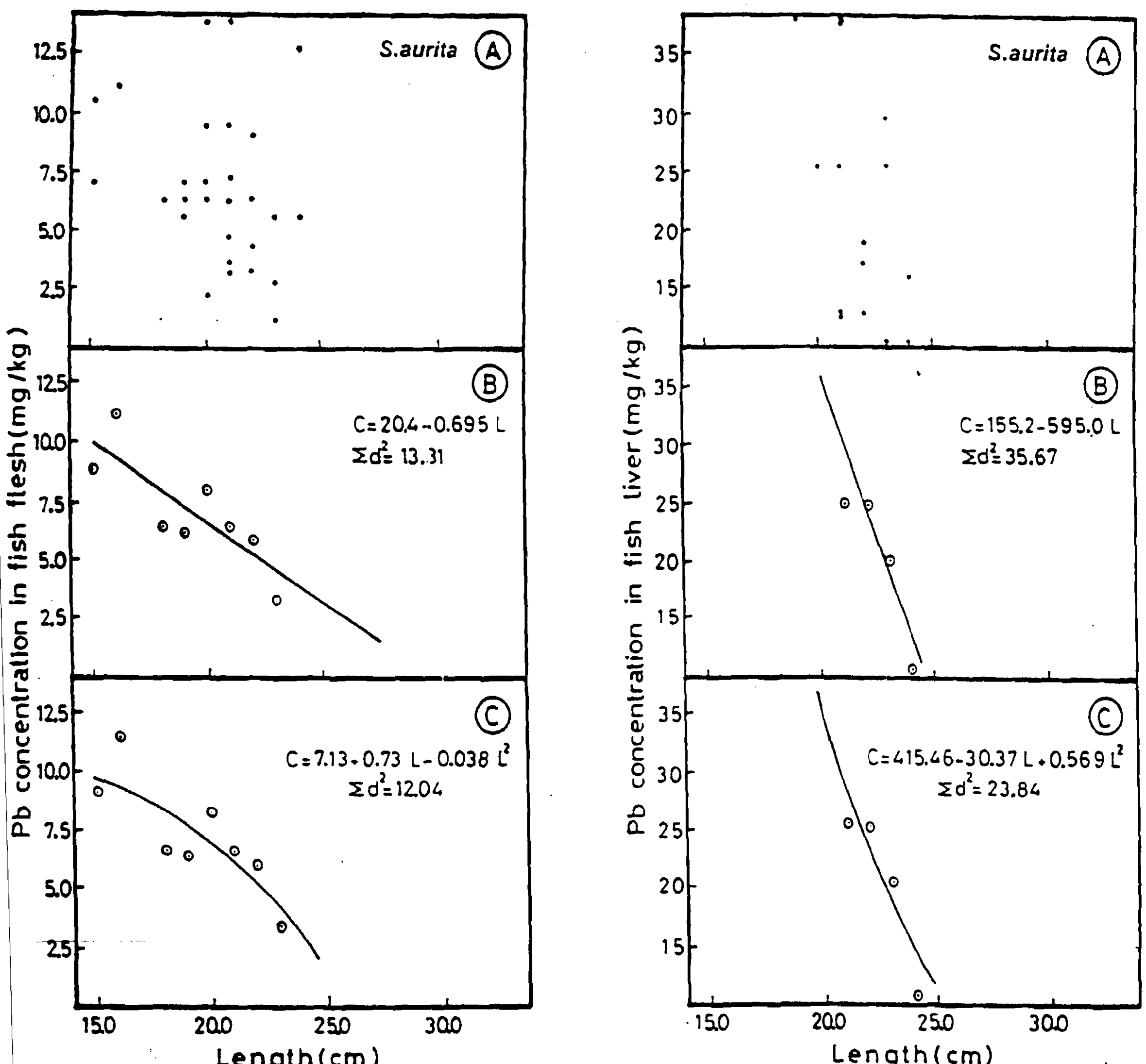


**Fig. (3): Pb concentrations in the flesh and liver of *S.aurita* in relation to length, (A) : represents individual concentrations, (B) and (C) represent first and second order relationship equations.**

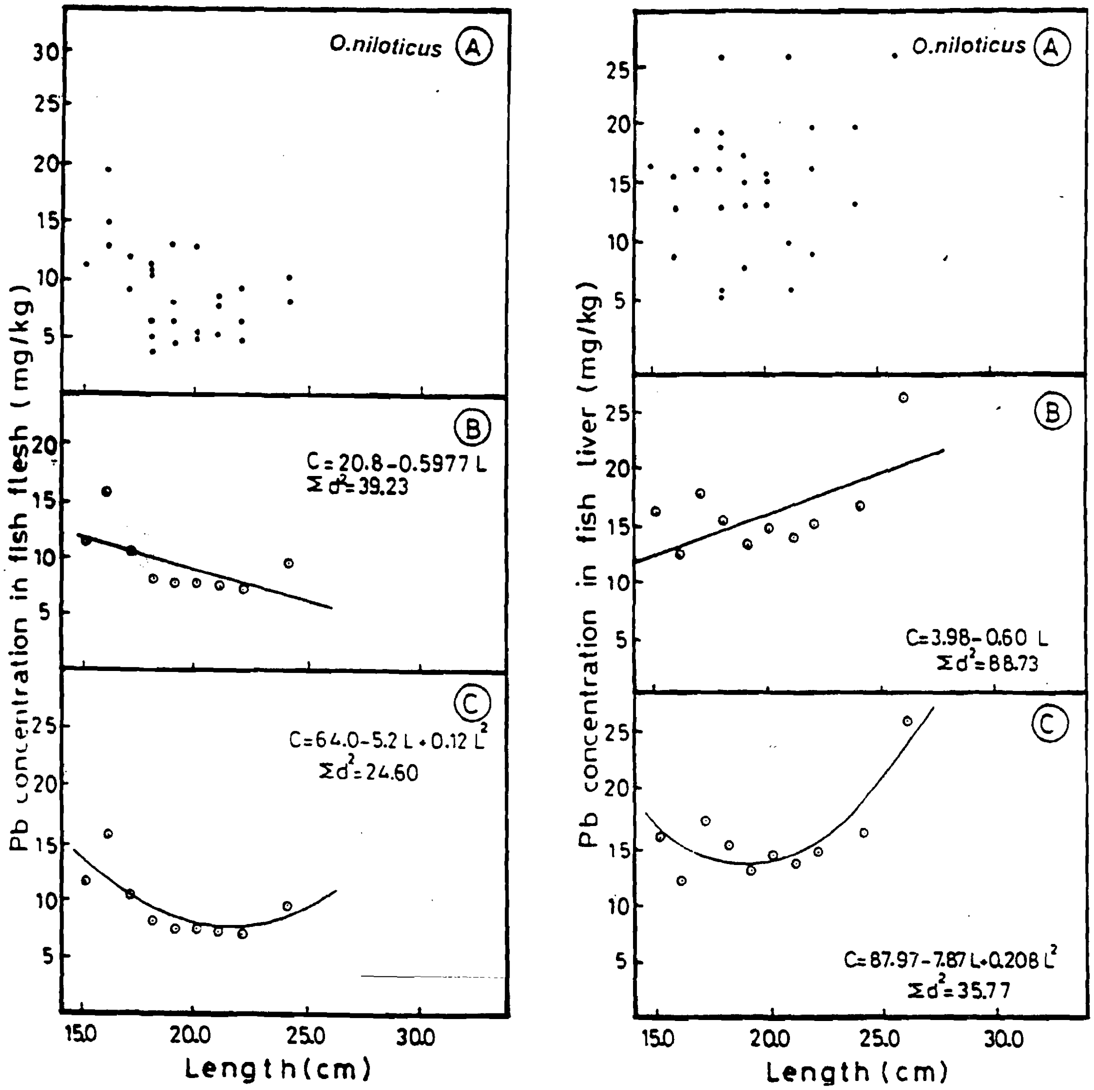


**Fig. (4): Pb concentrations in the flesh and liver of *O.niloticus* in relation to length, (A) : represents individual concentrations, (B) and (C) represent first and second order relationship equations.**

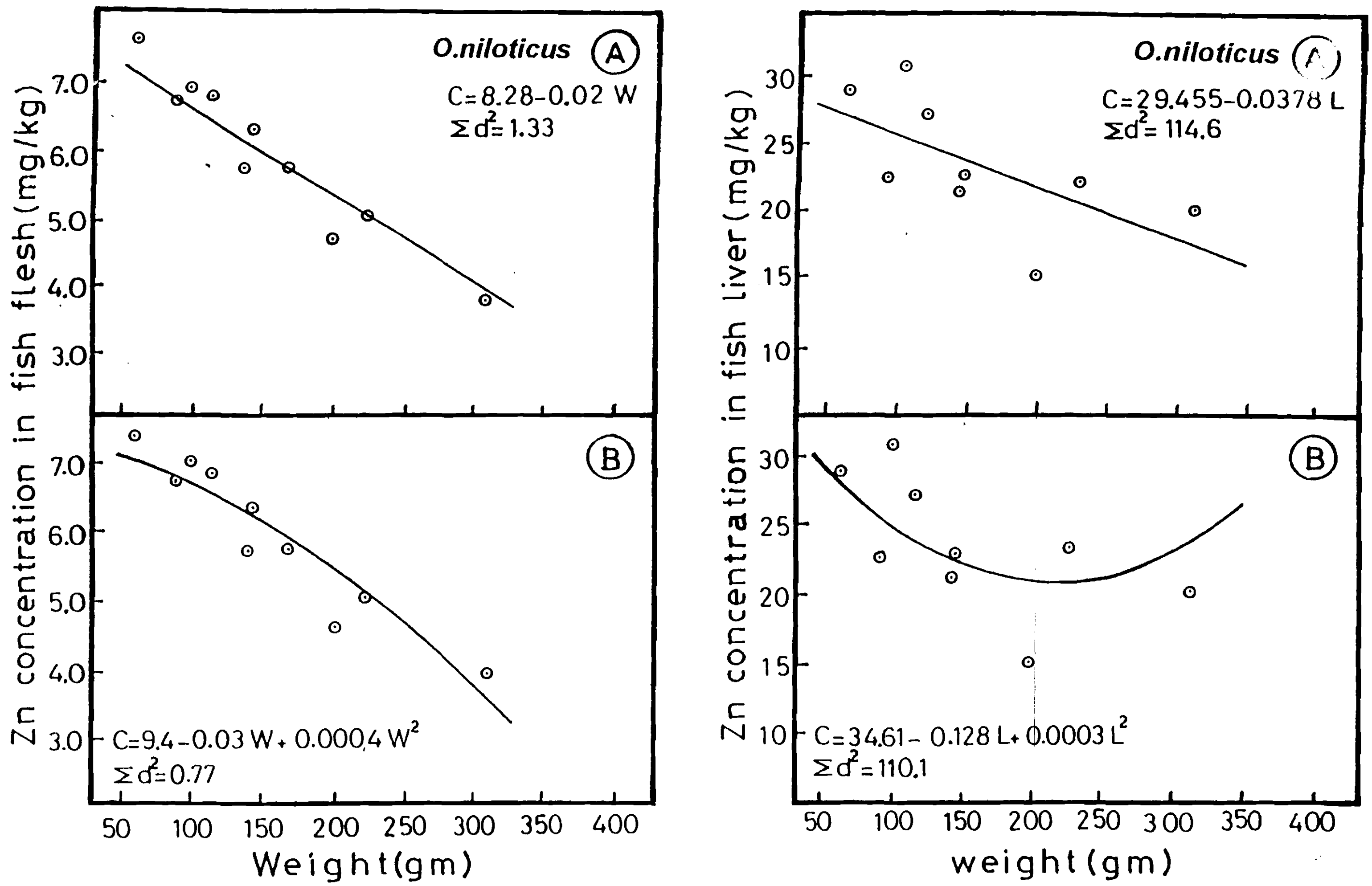


**Fig. (5): Zn concentrations in the flesh and liver of *O.niloticus* in relation to weight, (A) and (B) represent first and second order equations.**

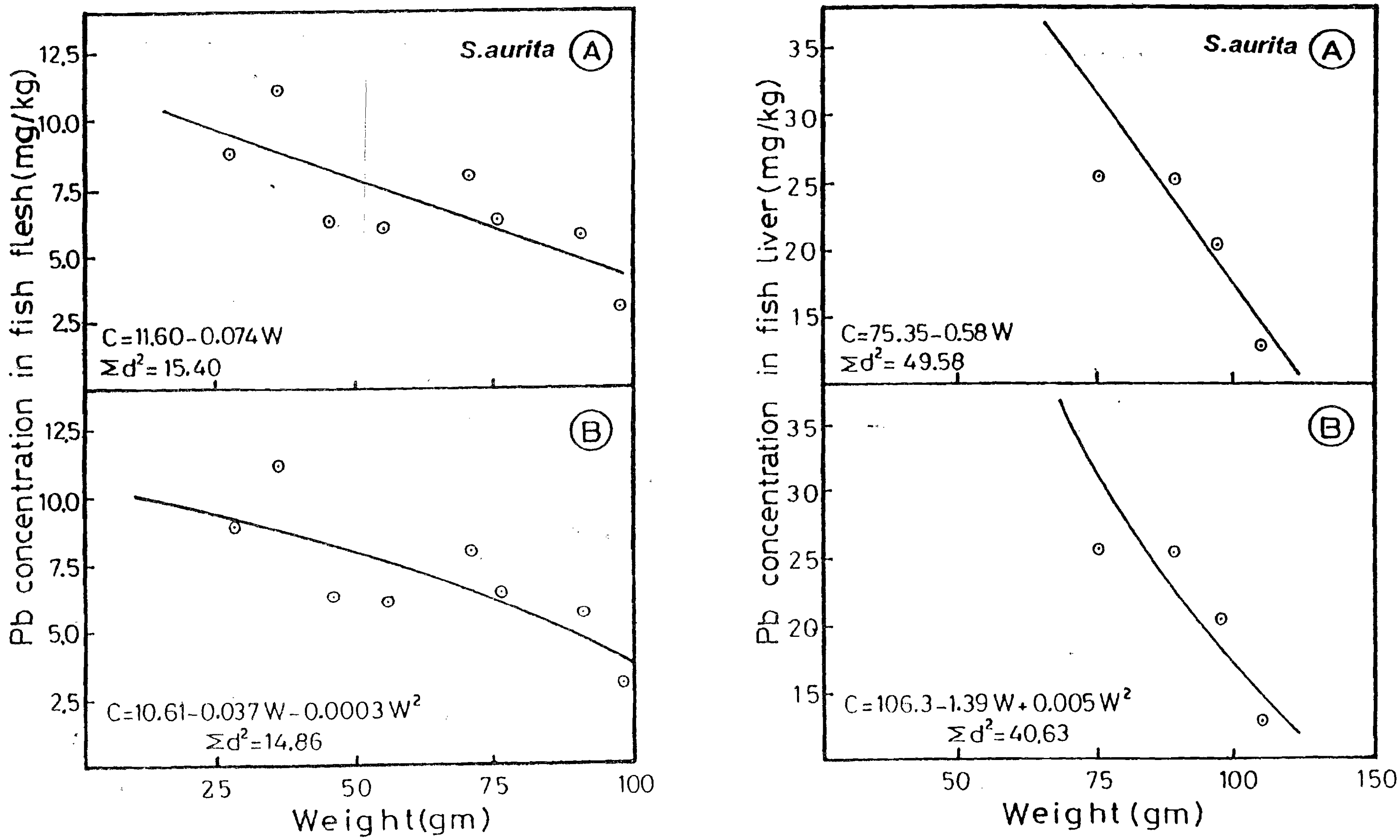


Fig. (6): Pb concentrations in the flesh and liver of *S. aurita* in relation to weight, (A) and (B) represents first and second order equations.

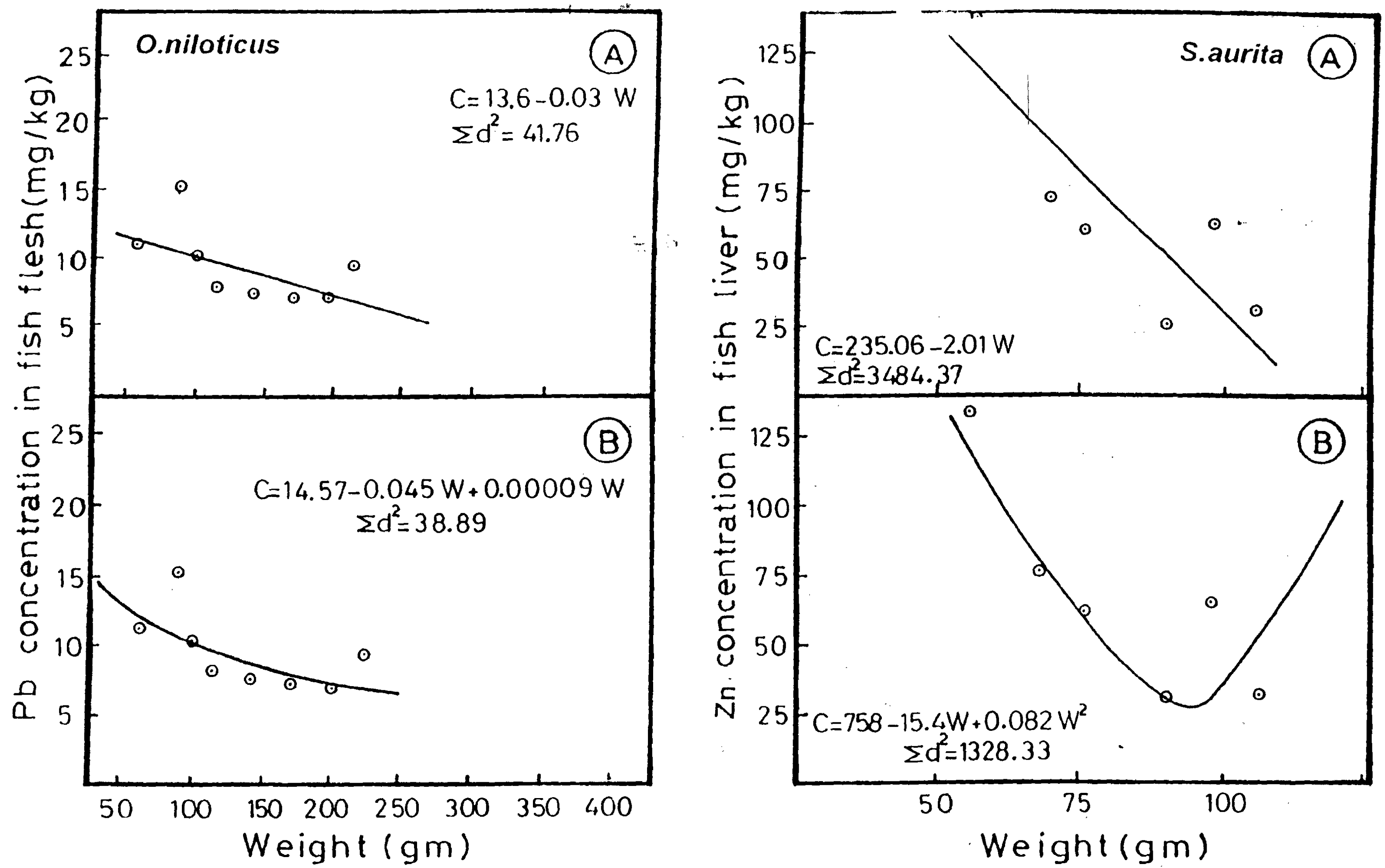


**Fig. (7): Pb & Zn concentrations in the flesh and liver of *O.niloticus* & *S. aurita* respectively in relation to weight, (A) and (B) : represents first and second order equations.**

It can be pointed out in this situation that the slopes of the deriviated linear or curvilinear equations represent only the cases where the correlation coefficients between the concentration of trace metal and the length or weight of fish were significant at high levels. These cases constitute only 22 cases while the whole cases are 48. Therefore, these equations may not represent the whole trends of the relations between trace metals concentrations and size of fish which have been pointed out according the values of correlation coefficients indicated in Tables (3 & 4).

These equations are given in the form:
$C = a + bL + Cl$ or $C = a + bW + cw^2$
where a, b and c are constants.
The derived equations are given in tables 5 and 6.

It can be indicated from these equations that:

(1) The linear and curvilinear function equations that describe the relationships between the concentrations of Zn and Pb in the fish flesh with their length or weight are descending i.e. having negative slope in most of the cases. The only case that exhibited positive relationship was the case of ***S. aurita*** as shown in Fig. (1). In agreement with this observation, Majori ***et al*** (1978), in their study on the contamination level in ***Mytilus galloprovincialis*** observed that in 50% of the cases, Zn can not be correlated with the size of the animal. In two cases there was a significant increase in the concentration with increasing size. In other cases the concentrations of Zn decreased significantly as the size of animal increases.

Papadopoulou ***et al*** (1976) investigated the Zinc content in the otolith of ***Scomber japonicus*** in the Aegeen Sea (Greece). They found that the Zinc content is a function inversely proportional with the age and length of the fish. The decrease of this metal concentration in the older fish was attributed by these authors to metabolic factor differences, to food intake of larger fish, or to the fish movement.

Hardisty (1974) noted that there is a decrease in the Zn content in tissues of ***Platyehthyes flesus*** with the age. His samples were taken from Bristol channel (England).

Table (5): Linear equations expressing the relationships between length, weight of fish and Concentrations of Zn, Cu, Mn and Pb in the muscle tissues of species investigated.

| Fish species | Growth parameter | Relationship between growth parameter with concentration of: | | | |
|---|---|---|---|---|---|
| | | Zn | Cu | Mn | Pb |
| *Sardinella aurita* | Length | C = - 14.70 + 1.47 L | - | - | C = 20.4 - 0.695 L |
| | Weight | - | - | - | C = 11.6 - 0.074 W |
| *Oreochromis auraeus* | Lenght | - | - | - | - |
| | Weight | - | - | - | - |
| *Oreochromis niloticus* | Length | C = 12.35 - 0.32 L | - | - | C = 20.8 - 0.60 L |
| | Weight | C = 8.28 - 0.02 W | C = 2.32 - 0.005 W | - | C = 13.60 - 0.03 W |

Table (6): Linear equations expressing the relationships between length, weight of Fish and concentrations of Zn, Cu, Mn and Pb in the liver tissues of species Investigated.

| Fish species | Growth parameter | Relationship between growth parameter and concentration of: | | | |
|---|---|---|---|---|---|
| | | Zn | Cu | Mn | Pb |
| *Sardinella aurita* | Length | C = 490.77 - 19.60 L | - | C = 33.10 - 1.33 L | C = 155.2 - 5.95 L |
| | Weight | C = 235.06 - 2.01 W | C = 41.68 - 0.34 W | C = 15.44 - 0.13 W | C = 75.3 - 0.58 W |
| *Oreochromis auraeus* | Lenght | C = 61.97 - 1.89 L | - | - | - |
| | Weight | - | C = 6.92 - 0.02 W | - | - |
| *Oreochromis niloticus* | Length | C = 39.41 - 0.81 L | C = - 107.16 + 8.16 L | - | C = 3.98 + 0.60 L |
| | Weight | C = 29.46 - 0.04 W | C = - 13.10 + 0.44 W | - | - |

Shakweer (1993) indicated that Pb concentrations decrease in the fish body with the increase in length or weight. She attributed this decrease to the movement of the adult fish from the polluted areas to another ones.

On the other hand, a positive relationship between the concentration of Zinc and size of fish was achieved by Cutshall ***et al*** (1977). They pointed out that the Zinc concentration in the muscle tissues of ***Merluccius productus*** increased with body weight. This achievement agrees with the positive relationship, which was found in the present study where Zn concentration increased with body length in case of ***S. aurita***.

(2) The slopes of the equations describing the relationships between trace metal concentrations in the fish liver with either the length or weight of the animal do not differ in most of the cases in their signs from that found in the case of the fish muscles.

(3) The Curvilinear function equations were found to be statistically better in fitting and describing the above mentioned correlations if compared with the linear function equations. This can be emphasized by the calculation of the summation of the squares of derivations ($\Sigma d^2$) which exhibited less values in the case of using curvilinear equations than the linear ones as given in Fig. (1-7).

(4) The establishment of either the first or second order function equations in the present investigation may help us in determining the length or weight of fish at which it is expected that the concentrations of trace metals reach or exceed the internationally allowable concentrations.

## *CONCLUSIONS*

It can be concluded from the present investigation that:

(1) The concentrations of Zn, Cu and Mn in the flesh of fish exhibited positive correlations with either the length or weight of fish in many cases. Pb concentrations exhibited negative correlations in all cases.

This indicates that the large sized fish were able to decrease or regulate the concentrations of Pb in their muscle tissues.

(2) Zn and Cu concentrations in the liver of ***S. aurita*** and ***O. niloticus*** decreased with the increase of either the length or weight of fish.

On the other hand Pb concentrations in the liver of the fresh water fish species increased with length or weight.

(3) The concentrations of Pb in the liver of the marine fish species ***S. aurita*** decreased with length. This indicates that the larger sized fish of ***S. aurita*** were able to avoid the contaminated areas by Pb. It is decreased with length. This indicates that the larger sized fish of ***S. aurita*** were able to avoid the contaminated areas by Pb. It is well known that such pelagic fish species, is a migratory species. Therefore it can move away from the contaminated areas of the sea. (Shakweer, 1993).

(4) In the cases where the correlation coefficients between trace element concentrations and length or weight of fish were significant at high levels. linear and curvilinear the relationships between these variables were established to describe the relationships between these variables. It has been found that the

Curvilinear equations fitted better such relationship if compared with the linear equations.

(5) It can be evidenced from the present study that the concentrations of trace metals may increase or decrease with body size or weight. The environmental conditions, the biological characters of fish and its feeding behavior, during its larval and adult stages of life all these factors are believed to affect the concentrations of trace metals in the body of fish during the successive years of its life.

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