Chapter 9
Fishes and Fisheries

9.1. SPECIES COMPOSITION

The occurrence of brackish and saline waters in Lake Burullus resulted in a large variety of fish species inhabiting the Lake during the seventies and early eighties of the last century. Approximately 32 species were recorded in the Lake during these periods (Libosvarsky *et al*. 1971; El-Sedfy 1971). Table 9.1 includes both freshwater and marine species arranged according to their systematic relevance.

The fish stock consisted of a variety of fishes differing in their requirements to saline water. Thus, several pure marine species, such as *Engraulis encrasicholus. Belone belone, Sparus aurata, Johnius hololepidotus, Pomatoschistus minutus* and *Solea solea* invade the Lake for some time along with the halophilous species of mullets (*Chelon labrosus, Liza aurata and L. saliens*). Broader distribution in the brackish water includes *Aphanius fasciatus, Atherina mochon*, while other representatives of family Gobiidae. *Anguilla anguilla, Mugil cephalus* and *Liza ramada* belong to a separate group of obligatory migrants. In the life history of these species, two phases have been differentiated; where spawning occurs in the sea, then the young individuals migrate into the Lake to continue their growth till adult stage is attained, which migrates to the sea to spawn.

Some Nile fishes inhabit the lake, such as *Hydrocynus forskalii*, *Labeo niloticus, Barbus bynni, Barbus perince, Clarias gariepinus*, *Bagrus bajad, Lates niloticus* as well as the cichlids belonging to five genera namely: *Hemichromis, Haplochromis, Tilapia, Oreochromis and Sarotherodon.*

Tilapia zillii is widely distributed in the Lake on account of its high tolerance to saline water; while *Oreochromis niloticus* was the second common species of cichlids. *Sarotherodon galilaeus* as well as another cichlid, *Hemichromis bimaculatus*, avoid salty water. Their occurrence was restricted to areas of low chlorosity. *Mugil cephalus* and *Liza ramada* are spread out all over the lake. The introduced species *Gambusia affinis* shows a similar wide distribution.

Table 9.1. **Fish species in Lake Burullus.**

Family	**Species**	**Arabic name**	**Habitat**
Engraulidae	*Engraulis encrasicholus* (Linnaeus, 1758)	انشوجة	Sea water
Characidae	*Hydrocynus forskalii* (Cuvier, 1819)	كلاب السمك	Fresh water
Cyprinidae	*Labeo niIoitcus* (Forskal, 1775)	لبيس نيلى	Fresh water
	Barbus bynni(Forskal,1775)	بنى أصلى	Fresh water
	Barbus perince Ruppell 1837	بنى برنس	Fresh water
Siluridae	*Clarias gariepinus* (Burchell,1822)	حوت	Fresh water
	Bagrus bajad (Forskal , 1775)	بياض	Fresh water
Anguillidae	*Anguilla anguilla* (Linnaueus, 1758)	حنش	Fresh / saline water
Belonidae	*Belone belone* (Linnaeus, 1758)	خرم	Saline water
Cyprinodontidae	*Aphanius fasciatus* (Valenciennes, 1821)	بطريق	Brackish water
Poecilidae	*Gambusia affinis* (Baird & Girard , 1853)	جامبوزيا	Brackish water
Atherirudae	*Atherina mochon* Cuvier, 1829	بساريا	Brackish water
Mugilidae	*Mugil cephalus* Linnaeus, 1758	بورى	Fresh / saline water
	Liza ramada (Risso, 1826)	طوبارة	Fresh / saline water
	Liza aurata (Risso,1810)	هليلى - دهبانة	Saline water
	Liza saliens (Risso,1810)	جران	Saline water
	Chelon labrosus (Cuvier, 1829)	بورى سودانى	Saline water
Serranidae	*Lates niloticus* (Linnaeus, 1762)	قشر بياض	Fresh water
	Dicentrarchus labrax (Linnaeus, 1758)	قاروص	Saline water
	D. punctatus (Bloch, 1792)	قاروص منقط	Saline water
Cichlidae	*Hemichromis bimaculatus* Gill , 1862	هيمكروس مخطط	Fresh water
	Haplochromis bloyeti (Sauvage,1883)	هابلوكروس قزم	Fresh water
	Tilapia zillii (Gervais, l848)	بلطى اخضر	Fresh / saline water
	Oreochmmis niloticus niloticus (L.,1757)	بلطى نيلى	Fresh water
	Oreochromis aureus (Steindachner,1864)	بلطى ازرق	Fresh water
	Sarotherodon galilaeus (Artedi,1757)	بلطى جليلى	Fresh water
Sparidae	*Sparus aurata* Linnaeus, 1758	دنيس	Saline water
Sciaenidae	*Lohnius hoIolepidotus* (Lacepede, 1803)		Saline water
Gobiidae	*Pomatoschistus minutus* (Pallas ,1767)	ابو كرش	Brackish water
	Pomatoschistus (lliinia) microps (Krover ,1838)		Brackish water
	Lesueuria lesueuri (Risso,1810)	ابو كرش	Brackish water
Soleidae	*Solea solea* (Linnaeus,1758)	موسى	Saline water

The largest number of fish species were caught at the lake side of El-Boughaz opening. 21 species were sampled at that locality (Libosvarsky, *et al.* 1971). The collection consisted of a blend of marine as well as freshwater and euryhaline fishes. Also, the area at the mouth of Nasser drain was found to be rich in fish species, 17 species were recorded at that site. Pure marine fishes were absent from that locality; they were replaced by fishes of Nile origin, such as *Hydrocynus forskalii*, *Labeo niloticus*, *Barbus bynni* and *Lates niloticus*. The number of fish species captured in the remaining localities shows low frequency. This phenomenon, rather peculiar in faunisitic surveys, is associated with the different ranges of requirements of the species towards the salinity of water.

9.1.1. Present status of fish species

During 2000 – 2002 period, the field survey of Khalil and El-Dawy (2002) showed that the diversity of fishes in Lake Burullus declined from 32 species to 25 ones. All species which have disappeared from the lake are of marine origin, these are: *Engraulis encrasicholus*, *Belone belone*, *Pomatoschistus minutus*, *Pomatoschistus (Iljinia) microp*, *Lesueuria lesueuri*, *Liza aurata* and *Chelon labrosus*.

9.2. FISH PRODUCTION

The total fish production of Lake Burullus for the years 1963 to 2003 is shown in Table 9.2, Fig. 9.1. Following different years of the survey, it is seen that the total production of the lake increased gradually from 7349 ton in 1963 to a maximum of 59000 ton in 2002. In the course of these fourty years a sharp decline in the total yield was recorded, especially in the mid seventies of the last century, where the production was declined to 4556 and 4875 ton in 1973 and 1974, respectively. Higher yields were regained in 1976 (6573 ton).

As far as the main groups of fishes are concerned, a gradual decline in the mullets catch was recorded in 2000 from about 44.7% in 1963 to 17% of the total catch. This was accompanied by an increase of tilapia production from 42.8% in 1963 to 72% in 1992, then decreased to about 67.8% in 2003. The shift was more pronounced during the eighties of the last century. On the other hand, the annual production of certain freshwater fish species has gradually increased, especially during the last five years. This relates particularly to two species namely: *Clarias gariepinus* and *Bagrus bajad*, where their production increased from 188 and 220 ton in 1963 to 2150 and 744 ton in 2003, respectively (GAFRD 2003). Meanwhile, the production of marine fishes, such as *Johnius hololepidotus* and *Dicenlrarchus labrax* greatly decreased.

Table 9.2. **Fish production of Lake Burullus from 1963 to 2003.**

Year	Total production (Ton)	Year	Total production (Ton)
1963	7549	**1984**	9854
1964	7796	**1985**	11947
1965	7242	**1986**	19908
1966	6769	**1987**	22510
1967	9149	**1988**	24274
1968	6002	**1989**	38070
1969	8597	**1990**	52520
1970	9257	**1991**	47068
1971	8236	**1992**	47501
1972	7497	**1993**	43620
1973	4556	**1994**	49000
1974	4875	**1995**	53000
1975	5469	**1996**	53000
1976	6573	**1997**	53000
1977	6587	**1998**	53000
1978	6514	**1999**	55000
1979	7018	**2000**	52000
1980	7137	**2001**	59200
1981	6742	**2002**	59785
1982	7273	**2003**	55323
1983	8205		

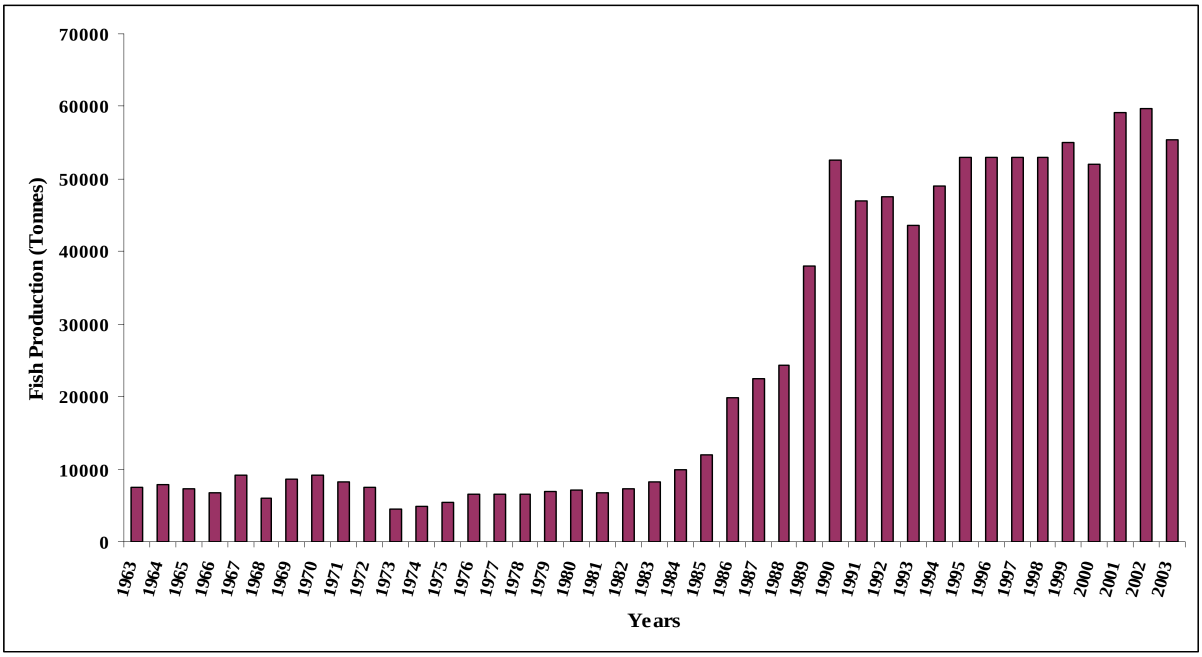


Fig. 9.1. **Fish production of Lake Burullus from 1963 to 2003.**

All these findings confirm a pronounced predominance of freshwater components in the fish stock of the lake, reflecting the changes that took place in the lake in the water supply, mostly from drains, and reducing chlorosity of water, specially in the eastern part of the lake, in association with the new huge drains constructed at that area.

9.3. FISHERIES OF LAKE BURULLUS

9.3.1 Biology of Cichlidae

Cichlids are represented in Lake Burullus by four main species which are *Tilapia zillii, Sarotherodon galilaeus, Oreochromis niloticus* and *O. aureus,* in addition to two species of cichlids (*Hemichromis bimaculatus* and *Haplochromis bloyeti*) that are of little economic importance due to their small sizes.

9.3.1.1. Abundance of different cichlid species in Lake Burullus

The catch per unit effort (CPUE) of trammel nets left over-night (Table 9.3) shows that *T. zillii* is the most abundant cichlid, followed by *O. aureus, S. galilaeus,* then *O. niloticus.* This method is usually set near the vegetated areas, which are the most preferable feeding zones for *T. zillii* (Al-Kholy & Abdel-Malek 1972), while the CPUE of trammel nets using a sound stimulus showed that *S. galilaeus* dominates the catch followed by *O. aureus* and *O. niloticus* (Table 9.3).

Table 9.3. **Catch per unit effort of different fishing gears according to fish species in Lake Burullus.**

Species	Trammel nets without stimulus			Trammel nets with stimulus			Wire traps (Gawabi)		
	No.	Wt (g)	Wt (%)	No.	Wt (g)	Wt (%)	No.	Wt (g)	Wt (%)
Tilapia zillii	29	1196	36	2	82	2	4	1708	12
Sarotherodon galilaeus	10	354	11	45	1747	50	166	4831	33
Oreochromis niloticus	7	350	11	7	401	12	62	2808	19
Oreochromis aureus	13	618	18	23	1027	29	88	3t35	22
Mugil cephalus	1	33	1	-	-	-	-	-	-
Liza ramada	3	91	2	-	-	-	-	-	-
Hemichromis bimaculatus	42	556	17	-	-	-	-	-	-
Catfishes	2	128	4	-	-	-	-	-	-
Other fish species	1	13	-	1	229	7	5	2114	14

The abundance of *S. galilaeus* in the catch of wire traps may be due to its bigger body girth. In addition, the paucity of *T. zillii* in the catch of wire traps and its dominance in the catch of trammel nets may be attributed to its relatively small sizes and the use of nets with small mesh sizes than that of wire traps

9.3.1.2. Seasonal variations of cichlid species in the catch

Investigation of seasonal variation of the cichlid species in the catch shows that spring and summer are the proper time for fishing cichlids with trammel net left over-night. This is because cichlid species are more active during warm seasons, in addition that most fishermen are accustomed to use other fishing gears and techniques for catching mullet species during autumn and winter months. *T. zillii* is the most abundant species in the catch during spring followed by *O. aureus* and *S. galilaeus* then *O. niloticus*, while in summer *Haplochromis bimaculatus* is the most abundant species followed by *T. zillii*, then *O. niloticus*, *O. aureus* and *S. galilaeus*. In autumn, *O. niloticus* is the most abundant species followed by *S. galilaeus* and *O. aureus*, while *T. zillii* is rare. In winter, *T. zillii* is the most abundant, followed by *O aureus*, then *S. galilaeus*, while *O. niloticus* is rare.

In the catch of trammel nets with sound stimulus, *O. aureus* was found to be a dominant species during winter. This may be due to its greater activity than other cichlid species during that season. In spring, *O. niloticus* is abundant only by weight, while *S. galilaeus* is dominant by number. Furthermore, *S. galilaeus* is dominant in summer and autumn, indicating that it shows more response to sound stimulus. *O. niloticus* and *O. aureus* come next in order of abundance.

For wire traps in winter, the catch is generally very poor and this could be attributed to the low water temperature that prevails in the lake, especially in areas of dense vegetation, where traps are usually set. The four tilapia species are more or less of equal abundance in the catch, however, they can be arranged as follows: *T. zillii* has relatively more abundance, followed by *S. galilaeus* and *O. aureus*, then *O. niloticus*. In spring, *S. galilaeus* and *O. aureus* are represented by the same percentage in the catch, followed by *T. zillii* then *O. niloticus*. In summer and autumn, *S. galilaeus* is the most abundant species in the catch, followed by *O. niloticus* and *S. aureus*, while *T. zillii* is less abundant.

9.3.1.3. Length frequency of cichlids using various fishing gears

Analysis of length frequency of *T. zillii* in the catch of trammel nets, shows fish as small as 5 cm in total length (TL), while the largest fish has a maximum size of 21 cm, with a modal length of 10 cm (Hashem *et al.* 1993). Small-sized fishes (<10 cm TL) represent 47% of the catch and medium-sized fishes (11-15 cm TL) represent 49%, while larger fishes *(>15* cm TL) represent only 4% of the catch. This disagrees with the finding of Ishak *et al.* (1985), who pointed out that about 90% of the catch of *T. zillii* caught from Lake Burullus were less than 10 cm.

In the catch of wire traps, the minimum size of *T. zillii* is 7 cm and the maximum size is 24 cm, with a modal length at 13 cm. Medium-sized fishes (11-15 cm TL) are the most abundant, representing 80% of the trap catch. This must be due to the smaller mesh size used in trammel nets, while traps have larger mesh size (Hashem *et al*. 1993).

S. galilaeus in the catch of trammel nets is composed of fishes ranging from 6-23 cm (TL) with a modal length at 14 cm. The small-sized fishes (<10 cm TL) represent only *5%,* and the medium-sized fishes (10-15 cm TL) represent 85 %, while larger fishes (16-20 cm TL) represent only 10 % of the catch. For wire traps, the range of total length is from 5-17 cm (TL) with a modal length at 12 cm. Most of the catch (85%) were of medium-sized fishes (11-15 cm), while small fishes represent 9%, and large fishes 6% of the catch.

O. niloticus in the catch of trammel nets is composed of fishes ranging from 8-27 cm (TL) with a modal length at 16 cm. Small fishes (<10 cm TL) represent only 8%, while the medium-sized and large fishes (11-15 cm, and 16-20 cm TL) are the most abundant.

Efficiency of various fishing gears for different species shows percentage composition of length groups for tilapia species in Lake Burullus.

For the wire traps, the maximum size is 37 cm with a modal length of 16 cm. Medium-sized fishes represent 42% of the catch, while large fishes (>16 cm) are most abundant (55% of the catch).

O. aureus caught by trammel nets has a minimum size of 7 cm (TL), while the maximum is 19 cm and the modal length at 13 cm. The small fishes (<10 cm) represent 6% of the catch, while medium sizes (10-15 cm) are the most abundant fishes in the catch (80% of the catch), and the large fish represent 14% of the catch.

For wire traps, the length range of fishes is 7-19 cm with a modal length at 13 cm. The medium-sized fishes (11-15 cm) are dominant in the catch (87% of the total catch), while large fishes (>16 cm) represent 15% of the catch.

Analysis of the efficiency of various fishing gears for catching tilapia species shows that traps are more efficient for catching *T. zillii* than trammel nets, while the efficiency of both gears are nearly similar for the other tilapia species. Furthermore, a high percentage of the catch of *T. zillii* and *O. aureus* is composed of medium sized fish (11-15 cm).

Many authors such as El-Zarka *et al.* (1970) and Moussa (2003) pointed out that the fishery management of cichlid species must be based on the criterion of gaining extra fish weight, because the mean size of cichlid species in the catch of the northern Delta lakes does not affect their breeding activities, i.e. first maturity is usually attained at small sizes. By this procedure, the total catch of cichlid species from the lakes is expected to increase a rather two or three times than that available today. These authors suggested that the most effective methods to attain such a gain were the regulation of the mesh of the fishing gears. Thus, Hosny & Hashem (1993) recommended that the stretched mesh size of the trammel nets should not be less than 2.86 cm (or mesh number 17) to catch cichlid fishes of mean selection length of 12.0 cm. However, El-Zarka (1961) as well as Ishak *et al.* (1985) recommended trammel nets with the same mesh 17 to catch fishes of about 15 cm for either *O. niloticus* or *T. zillii*. For traps, El-Zarka *et al.* (1970) suggested that the mesh size of wire traps should not be less than 25 mm (mesh bar) to give a mean selection length of 16 cm for *O. niloticus,*15.5 cm for *T. zillii* and 15 cm for *S. galilaeus.*

From the above findings, it is recommended that the minimum catcheable size should be 15 cm, instead of the present legal size (10 cm). Consequently, this will increase the average weight of individual fish from 10 to 60 gm and hence the total fish yield will be increased.

9.3.1.4. Mortality and survival rates

T. zillii has the lowest mortality rates (i.e. 0.646, 0.899 and 1.545 for natural, fishing and total mortality rates, respectively) (Table 9.4). *S. galilaeus* and *O. niloticus* rank next having more or less equal mortality rates (about 0.7, 1.3 and 2.1 for natural, fishing and total mortality rates, respectively). Meanwhile, *O. aureus* has the highest mortality rates (i.e. 0.868, 2.119 and 2.987 for natural, fishing and total mortality rates, respectively). It has to be mentioned that for *O. niloticus*, the highest survival rate occurs after the second year, while for the other three species it is after the first year (Hashem *et al.* 1993). This means that *T. zillii* would have the highest survival rate, i.e. about 21%, followed by *O. nilolicus* and *S. galilaeus* (each about 13%), while *O. aureus* has the lowest survival rate (about 5% from the population annually).

The high mortality rates and consequently the lower survival rates of the four cichlid species in Lake Burullus indicate that cichlid fishes in the lake suffer from annual decline in the stock.

The exploitation rates were estimated for the four cichlid species in the lake (Table 9.5) by Hashem *et al.* (1993), where *O. aureus* was the most exploited cichlid species (E = 0.71) followed by *O. niloticus* and *S. galilaeus* (E = 0.63) and at last *T zillii* (E = 0.58). It seems that the increase of the exploitation rate of cichlid species in Lake Burullus would increase the yield per recruit, but the biomass of these species will show an annual decrease in the Lake. Therefore, it is highly recommended to reduce the effort exerted on the cichlid populations in Lake Burullus, since higher effort would eventually severely deteriorate their biomass.

***Table 9.4*. Mortality and survival rates for the different cichlid species in Lake Burullus (Hashem *et al*. 1993).**

Species	Mortality			Survival (%)
	Natural	Fishing	Total	
Tilapia zillii	0.646	0.899	1.545	21.3
Sarotherodon galilaeus	0.771	1.301	2.072	12.6
Oreochromis niloticus	0.764	1.291	2.055	12.8
Oreochromis aureus	0.868	2.119	2.9S9	5.0

***Table 9.5*. Exploitation rate (E), yield per recruit (Y/R) and biomass per recruit (B/R) for different cichlid species in Lake Burullus (at predicted maximum yield per recruit) (Hashem *et al.* 1993).**

Species	Present situation			At maximum Y/R		
	E	Y/R	B/R	E	Y/R	B/R
Tilapia zillii	0.58	0.016	0.320	0.65	0.016	0.164
Sarotherodon galilaeus	0.63	0.021	0.231	0.85	0.032	0.073
Oreochromis niloticus	0.63	0.034	0.316	0.75	0.035	0.124
Oreochromis aureus	0.71	0.026	0.159	0.80	0.026	0.099

The recruitment patterns of cichlid species in Lake Burullus show that the new recruits enter the exploited population during almost all the year round. The recruits of *T. zillii* have two peaks, the first during November and December (44%), while the second in May (37%). For *S. galilaeus***,** there are two recruits, a pronounced one during December and January (41%), and a lesser in October (28%). *O. niloticus* on the other hand, has a peculiar pattern in its recruitment, it shows two groups of recruit with a wide overlap in their timing, extending from August to January with two peaks; a high one in September (59%) and a low peak in December (26%). For *O. aureus*, the recruitment pattern involves a prolonged period from September to June with two peaks; the higher one in March (72%) and the low in September (16%) (Hashem *et al.* 1993).

On the other hand, one of the most detrimental fishing method to the fishery of the lake (especially cichlid fishery) is the "Hosha" system (see 9.3.5.9 for definition of this fishing method). However, MacLaren (1981) stated that

Hosha may play an important beneficial role in reducing juvenile cichlid stock in the lake. While the construction and operation of "Hosha" in Lake Burullus is illegal, its number increases every year (under the name of fish culture ponds). Therefore, "Hosha" system needs a thorough evaluation on the basis of which, proper regulations should be enforced.

Moussa (2003) found that *Oreochromis niloticus* was the most abundant species in the 2002 catch, constituting more than 40.49 % of the total catch, followed by *Oreochromis aureus* 34.74 %, while *Sarotherodon galilaeus* was the least frequent species, contributing 24.77 %. In the eastern region, *Oreochromis aureus* is the most common one (38.48 %) followed by *Sarotherodon galilaeus* (31.45 %), then *Oreochromis niloticus* (30.08 %). In the middle and western region *Oreochromis niloticus* is the major one with 39.78% and 53.62 %, respectively. *Oreochromis aureus* represents 35.69 and 28.88 %, whereas *Sarotherodon galilaeus* is the minor one with 24.53 and 17.49 % in the two regions, respectively (Table 9.6).

Table 9.6. **Species composition of cichlid fish species (ind catch $^{-1}$) collected from three regions of Lake Burullus during 2002 (Moussa 2003).**

Species	**Sector**						**Total**	**%**
	Eastern		**Middle**		**Western**			
	Actual	**%**	**Actual**	**%**	**Actual**	**%**		
Oreochromis niloticus	351	30.08	467	39.78	518	53.62	1332	40.49
Oreochromis aureus	449	38.48	419	35.69	279	28.88	1143	34.74
Sarotherodon galilaeus	367	31.45	288	24.53	169	17.49	815	24.77
Total	**1167**	**-**	**1174**	**-**	**966**	**-**	**3290**	**100**

9.3.1.5. The length-weight relationship

The relation between the length and weight of a fish represents one of the most studied biological characters of fish biology. It is known that the weight of a fish increases as a function of its length. Length-weight relationship is an essential biological parameter needed to appreciate the suitability of the environment for any fish. Moussa (2003) calculated the length-weight relationship by the general formula $W = a L^n$. This equation from which weights were derived to show the different degrees of deviation from the cube relationship between weight and length. The logarithmic form of this equation which is actually used in calculation of weights in Tables (9.7, 9.8 and 9.9) can be written as follows: log W= log a+n log L. The computed equations representing the relation between length and weight for the mentioned fish species in the three sectors can be presented as follows:

For *Oreochromis niloticus:*

Eastern sector (Fig. 9.2.a): $W = 0.0163\ L^{2.8944}$ ($R^2 = 0.997$)
Middle sector (Fig. 9.2.b): $W = 0.0139\ L^{3.0042}$ ($R^2 = 0.995$)
Western sector (Fig. 9.2.c): $W = 0.0091\ L^{3.2940}$ ($R^2 = 0.991$)

Table 9.7. **Mean total length (Mtl: cm), emperical weight (Mew: g) and calculated weight (Mcw: g) for different length groups of *Oreochromis niloticus* collected from the three sectors of lake Burullus during 2002 (Moussa 2003).**

Length Group (cm)	Sector											
	Eastern				Middle				Western			
	Fish no.	Mtl	Mew	Mcw	Fish no.	Mtl	Mew	Mcw	Fish no.	Mtl	Mew	Mcw
8-10	36	9.21	10.4	10.1	44	9.23	11.2	11.1	78	9.11	11.5	13.4
10-12	85	11.1	17.3	17.3	156	11.3	19.3	20.6	96	11.3	27.3	27.3
12-14	66	12.9	28.3	26.6	78	13.4	32.4	33.7	103	13.2	47.9	44.5
14-16	74	15.1	40.3	42	65	14.9	52.5	46.7	129	15	81.4	68.8
16-18	47	16.8	53.7	57.8	51	16.9	74.1	68.8	84	16.9	112	101
18-20	19	18.6	70.5	76.9	18	19.3	95.5	102.0	8	19	148	148
20-22	12	20.8	103	107	24	21.3	129	137.0	15	21.2	195	212
22-24	8	23.0	155	143	12	23.2	182	177.0	5	22.9	245	275
24-26	2	25.2	198	186	-	-	-	-	-	-	-	-
26-28	2	27.1	228	229	-	-	-	-	-	-	-	-
Total	**351**	-	-	-	**448**	-	-	-	**518**	-	-	-
Mean		**18**	**90.5**	**89.5**		**16.2**	**74.5**	**74.6**		**16.1**	**109**	**111**

From these equations, it is evident that *O. niloticus* in the eastern sector decreases in weight by a rate less than the cube of length (n = 2.8944). In the middle sector the rate of increase in weight was nearly equal to the cube of length (n = 3.0042), whereas in the western sector this value exceeds 3 (n = 3.294).

For *Oreochromis aureus:*

Eastern sector (Fig. 9.3.a): $W = 0.0179\ L^{2.9036}$ ($R^2 = 0.9987$)
Middle sector (Fig. 9.3.b): $W = 0.0164\ L^{2.9471}$ ($R^2 = 0.9973$)
Western sector (Fig. 9.3.c): $W = 0.0153\ L^{2.9864}$ ($R^2 = 0.9979$)

Table 9.8 **Mean total length(Mtl), emperical weight (Mew) and calculated weight (Mcw) for different length groups of *Oreochromis aureus* collected from the three sectors of lake Borollus during 2002 (Moussa 2003).**

Length Group (cm)	Sector											
	Eatern				Middle				Western			
	Fish no.	Mtl	Mew	Mcw	Fish no.	Mtl	Mew	Mcw	Fish no.	Mtl	Mew	Mcw
8-10	75	9.13	11.9	11.3	54	9.22	10.5	11.4	33	8.97	13.7	10.5
10-12	136	11.4	21.4	22.2	112	11.3	19.5	21	68	11.3	21.7	20.6
12-14	118	13.5	34	36.8	99	13.4	36.8	34.1	92	13.8	37.2	37
14-16	63	15	46.2	50	86	14.9	50.1	47	43	15	52.5	46.5
16-18	34	17	66.7	72.2	37	16.9	67.6	68.7	31	17.1	74.1	68.8
18-20	13	19	96.6	100	27	19.3	93.3	101	4	19.3	104	98.2
20-22	6	21.5	127	145	2	21.3	138	134	6	21	138	125
22-24	4	23.1	163	180	2	23.2	174	173	2	22.8	175	159
24-26	-	-	-	-	-	-	-	-	-	-	-	-
26-28	-	-	-	-	-	-	-	-	-	-	-	-
Total	**449**	-	-	-	**419**	-	-	-	**279**	-	-	-
Mean		**16.2**	**70.8**	**77.3**		**16.2**	**73.7**	**73.9**		**16.2**	**77**	**70.7**

Table 9.9 **Mean total length(Mtl), emperical weight (Mew) and calculated weight (Mcw) for different length groups of *Sarotherdon galilaeus* collected from the three sectors of lake Burullus during 2002 (Moussa 2003).**

Length group	Sector											
	Eastern				Middle				Western			
	Fish no.	Mtl	Mew	Mcw	Fish no.	Mtl	Mew	Mcw	Fish no.	Mtl	Mew	Mcw
8-10	31	9.36	9.59	10.1	22	8.97	9.77	10.6	26	8.96	10	10.8
10-12	122	11.2	14.8	16.9	56	10.4	19.5	16.2	32	11	19.5	20
12-14	93	12.9	31.2	25.6	91	13.2	28.4	32.9	45	12.9	30.9	31.5
•;4-ie	75	15.3	42.7	41.2	64	15.1	49.8	48.3	25	15.1	55	51
16-18	32	16.9	57.5	55.2	42	17	66.3	68.3	27	16.1	77.6	61.1
18-20	10	18.9	77.9	75.2	7	19	96.7	94.8	5	19.1	102	102
20-22	4	21.1	97.7	103	4	21.2	138	130	6	21.2	120	138
22-24	-	23.1	126	135	2	23.1	162	168	3	23.1	170	179
24-26	-	-	-	-	-	-	-	-	-	-	-	-
26-28	-	-	-	-	-	-	-	-	-	-	-	-
Total	**367**	-	-	-	**288**	-	-	-	**169**	-	-	-
Mean		**16.1**	**57.2**	**57.8**		**16**	**71.4**	**71.2**		**15.9**	**73.2**	**74.2**

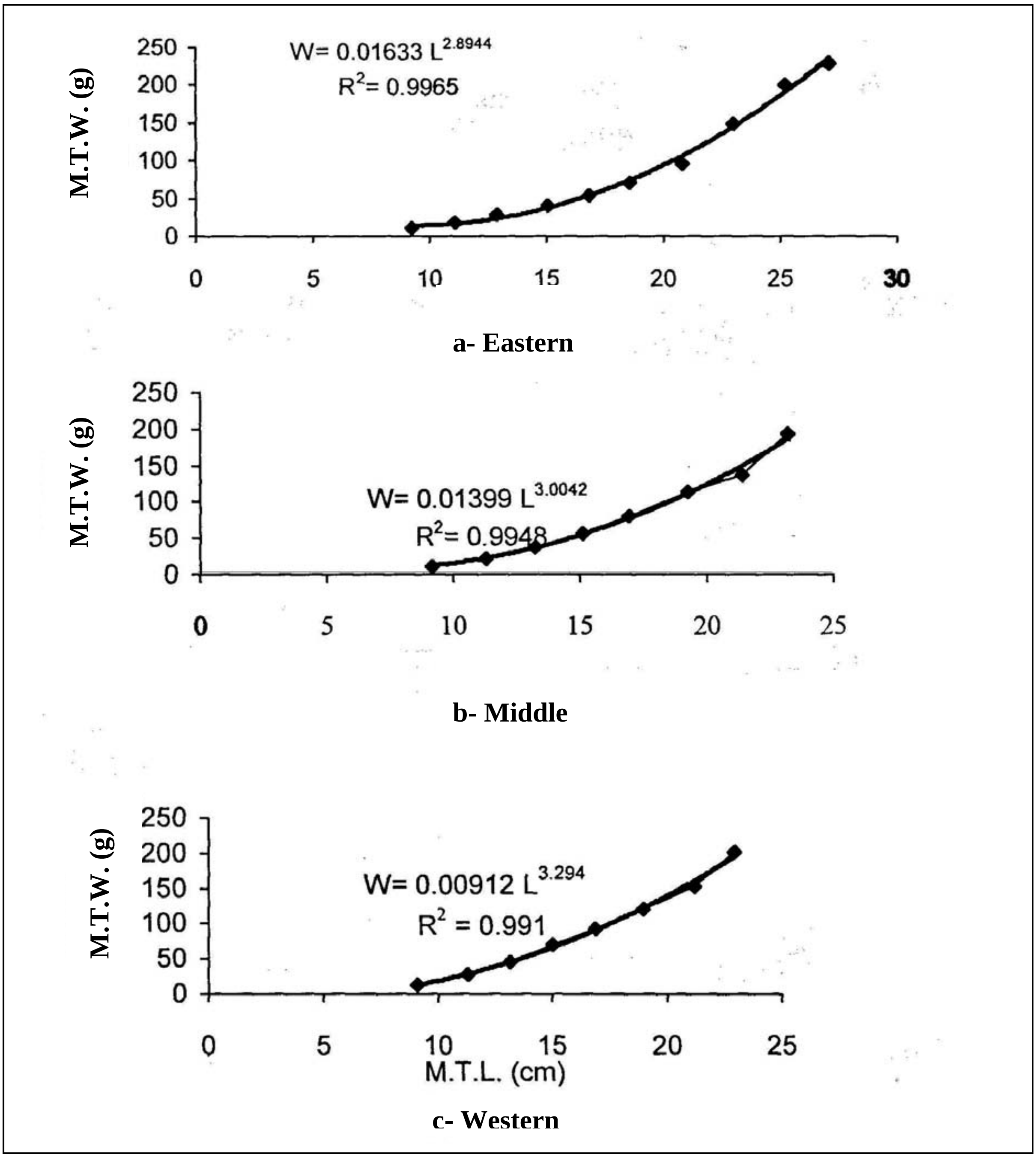


Fig. 9.2. **Length-weight relationship of *Oreochromis niloticus* in the three sectors of Lake Burullus during 2002 (Moussa 2003).**

From the above equations it is obvious that, the values of the exponent "n" or the regression factor (2.9036, 2.9471 and 2.9864, respectively) indicate that the rate of increase in weight was close to the cube (3) of length in the three sectors.

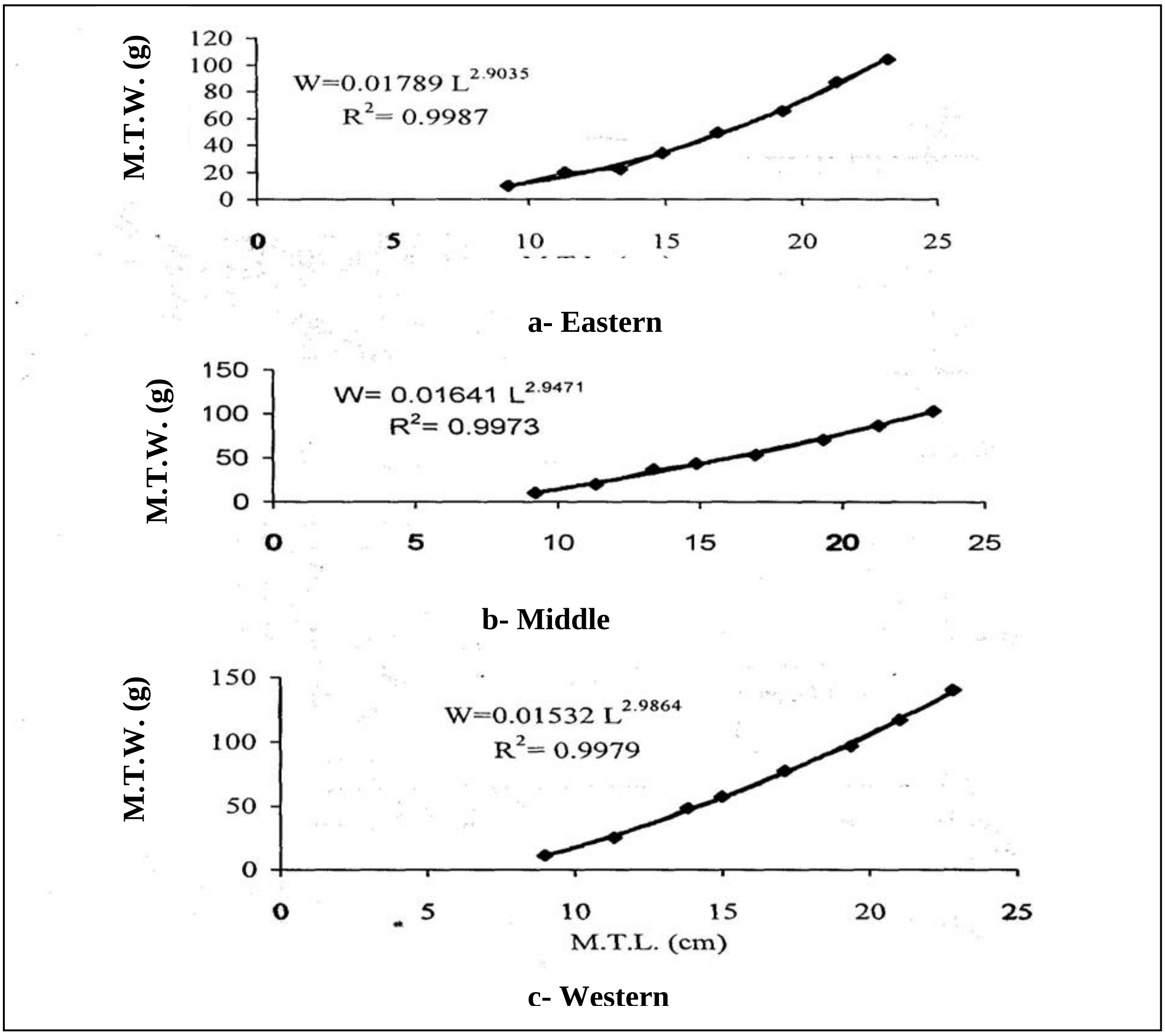


Fig. 9.3. **Length-weight relationship of *Oreochromis aureus* in the three sectors of Lake Burullus during 2002 (Moussa 2003).**

For *Sarotherodon galilaeus:*

Eastern sector (Fig. 9.4.a): $W= 0.0244\ L^{2.8668}$ ($R^2 = 0.9876$)
Middle sector (Fig. 9.4.b): $W= 0.0176\ L^{2.9179}$ ($R^2 = 0.9900$)
Western sector (Fig. 9.4.c): $W=0.0165\ L^{2.958}$ ($R^2 = 0.9861$)

From the above equations, the values of the exponent "n" (2.8668, 2.9179 and 2.958, respectively) indicate that the rate of increase in weight was close to the cube (3) of length, however it decreases in the eastern sector than the others. Since the value of exponent "n" is so close to 3.0 for all fish species, it could be stated that the weight of *Oreochromis niloticus*, *Oreochromis aureus* and *Sarotherodon galilaeus* increased approximately as the cube of the length.

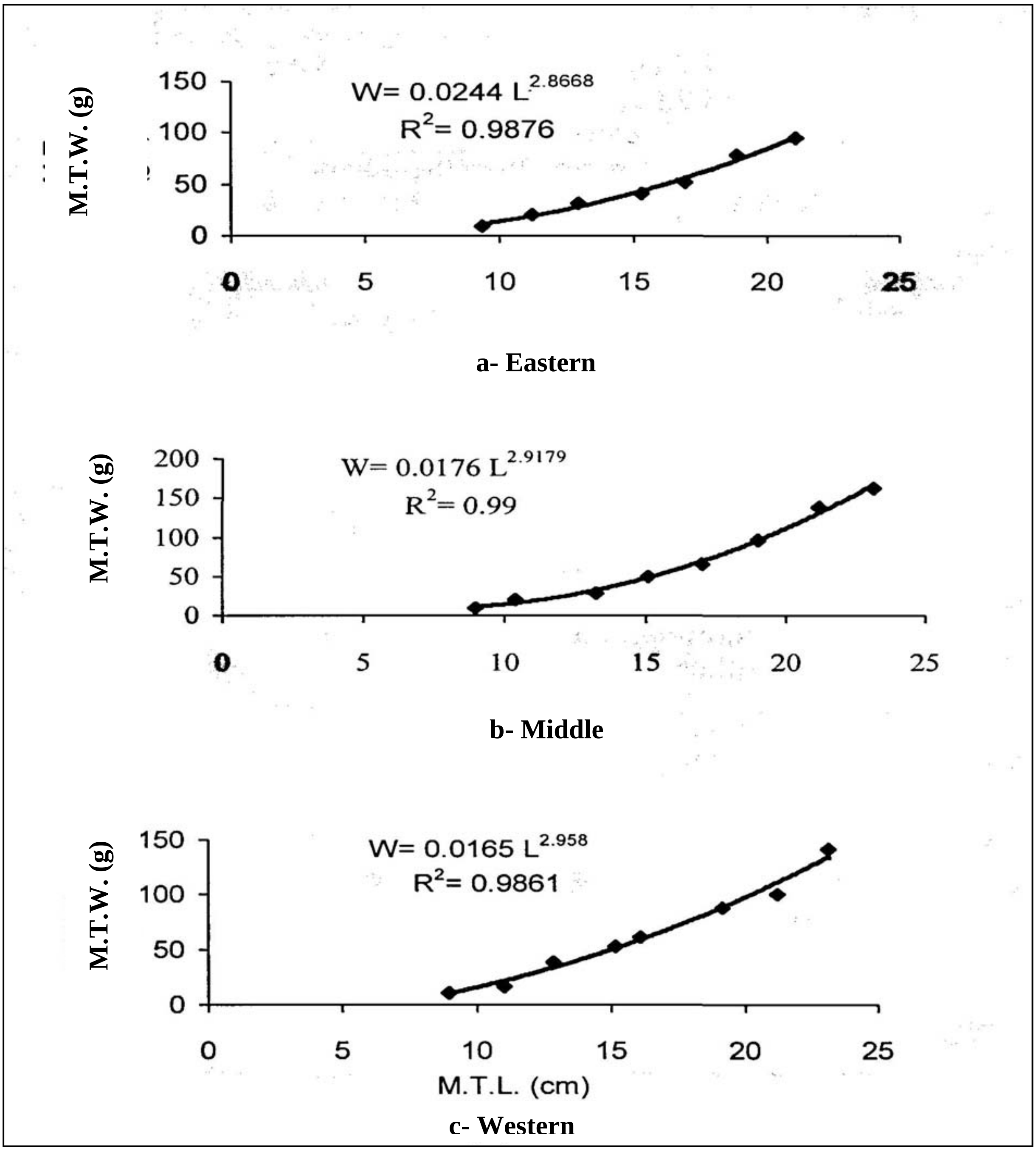


Fig. 9.4 **Length-weight relationship of *Sarotherodon galilaus* in the three sectors of Lake Burullus during 2002 (Moussa 2003).**

In comparing the weight of *O. niloticous* with other cichlid species (Tables 9.7, 9.8 and 9.9), it is obvious that *O. niloticous* was heavier than *O. aureus* and *S. galilaeus*. It was also noticed that the weight of *O. aureus* was little higher than that of *S. galilaeus.* For the same length group, we can see that fishes in the western sector are heavier than those in the eastern and middle sectors. This might be due to variations in the environmental conditions. In addition, this finding may reflect the higher fertility and the suitable environmental factors of Lake Burullus.

9.3.1.6. Condition factor (K)

From Table (9.10) and Figure (9.5) it is clear that the highest value of (K) was observed in winter season (average 1.60), whereas the lowest one was recorded in summer (1.33). Regionally, the maximum value of (K) was recorded in fishes of the western sector with an annual average of 1.69. The minimum value (annual average 1.26) was observed in fishes of the eastern sector.

Table 9.10 **Seasonal average of condition factor (K) of some cichlid fish species collected from the three sectors of lake Burullus during 2002 (after Moussa 2003).** ***On*****:** ***Oreochromis niloticus, Oa*****:** ***Oreochromis aureus*** **and** ***Sg*****:** ***Sarotherodon galilaeus*****. M: Mean.**

Season	Sector												Mean
	Eastern				Middle				Western				
	On	*Oa*	*Sg*	M	*On*	*Oa*	*Sg*	M	*On*	*Oa*	*Sg*	M	
Winter	1.34	1.53	1.22	1.36	1.64	1.57	1.52	1.58	2.29	1.67	1.59	1.85	1.60
spring	1.21	1.41	1.14	1.25	1.49	1.35	1.42	1.42	2.04	1.52	1.47	1.68	1.45
summer	1.13	1.26	1.11	1.17	1.17	1.29	1.29	1.25	1.93	1.39	1.35	1.56	1.33
Autumn	1.16	1.37	1.18	1.24	1.37	1.44	1.42	1.41	1.98	1.54	1.51	1.68	1.44
Mean	1.21	1.39	1.16	1.26	1.42	1.41	1.41	1.41	2.06	1.53	1.48	1.69	1.44

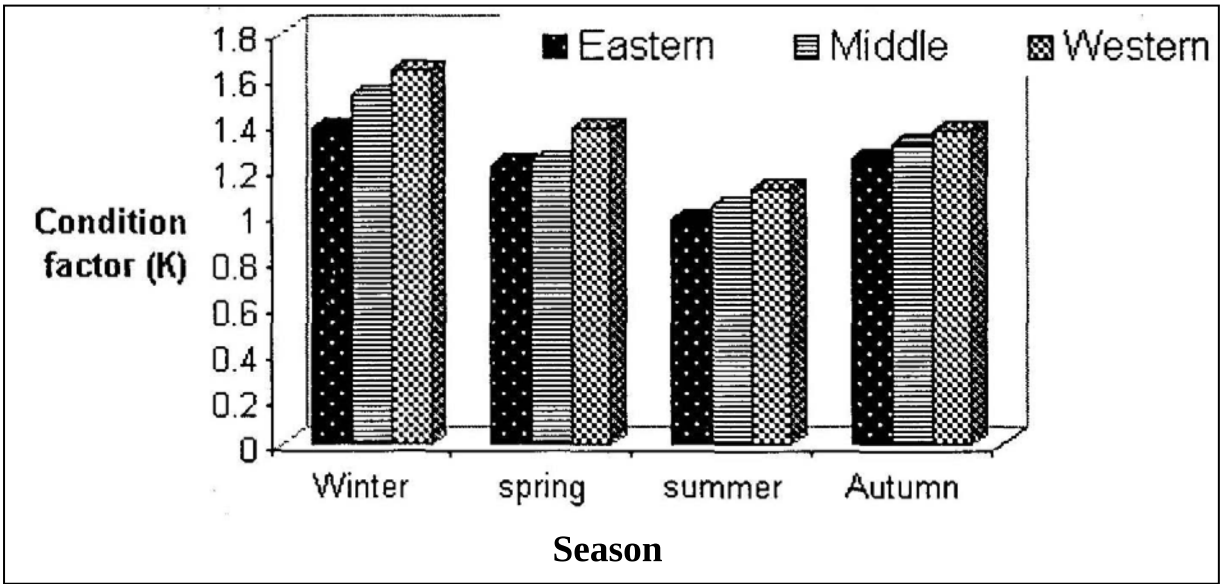


Fig. 9.5 **Seasonal variation of condition factor (K) of cichlid fish species collected from the three sectors of Lake Burullus during 2002 (after Moussa 2003)**

Regarding, the differences among fishes in different sectors, Table (9.11) and Figure (9.6) show that there is a difference in (K) value between the western sector (recorded highest mean of 2.06 ± 0.05) and both the eastern (recorded lowest mean 1.21 ±0.05) and the middle sector (average value 1.42 ± 0.05) for *O. niloticus.* No differences were present among the three sectors for *O. aureus.* For *S. galileus,* there is a significant difference between the western sector (mean 1.53 ± 0.03) and both the eastern and middle sectors. There is also a difference between the eastern (mean 1.16 ± 0.02) and middle (mean 1.41 ± 0.05) sectors.

***Table 9.11*. Annual mean ± standard error of condition factor (K) and hepato-somatic index (HSI) of some cichlid species collected from the three sectors of Lake Burullus during 2002 (Moussa 2003). Capital letters represent difference among the different sectors; small letters represent difference within the same sector. Means with the same exponent are not different.**

Fish species	Condition factor (K)			Hepato-somatic index (HIS)		
	Eastern	Middle	Western	Eastern	Middle	Western
Oreochromis niloticus	1.21 ^{Ba} ±0.05	1.42 ^{Ba} ±0.05	2.06 ^{Aa} ±0.05	1.29 ^{Aa} ±0.12	1.32 ^{Aa} ±0.13	1.40 ^{Aa} ±0.23
Oreochromis aureus	1.39 ^{Aa} ±0.06	1.42 ^{Ba} ±0.05	2.06 ^{Aa} ±0.05	1.29 ^{Aa} ±0.06	1.32 ^{Aa} ±0.08	1.40 ^{Aa} ±0.09
Sarotherodon galilaeus	1.16 ^{Cb} ±0.02	1.41 ^{Ba} ±0.05	1.53 ^{Ab} ±0.03	1.04 ^{Ab} ±0.09	1.19 ^{Ab} ±0.10	1.30 ^{Ab} ±0.1

Concerning the differences among cichlid fishes in the same sector, it is shown from Table (9.11) that there is a significant difference between *O. niloticus* and *O. aureus* on one side and *S. galilaeus* on the other side in the eastern sector. In the middle sector, no differences were exhibited among fishes. On the other hand, the western sector showed significant differences between *O. niloticus* on one side and *O. aureus* and *S. galilaeus* on the other one.

9.3.1.7. Hepato-somatic index (HSI)

From Table (9.12) and Figure (9.7) it is shown that the highest value of K was obtained in winter season (average 1.52), whereas the lowest one was recorded in summer (average 1.03). Regionally, the highest value of HSI was recorded in fishes of the western sector with an annual average value of 1.37, whereas the lowest value (annual average 1.21) was observed in fishes of the eastern sector.

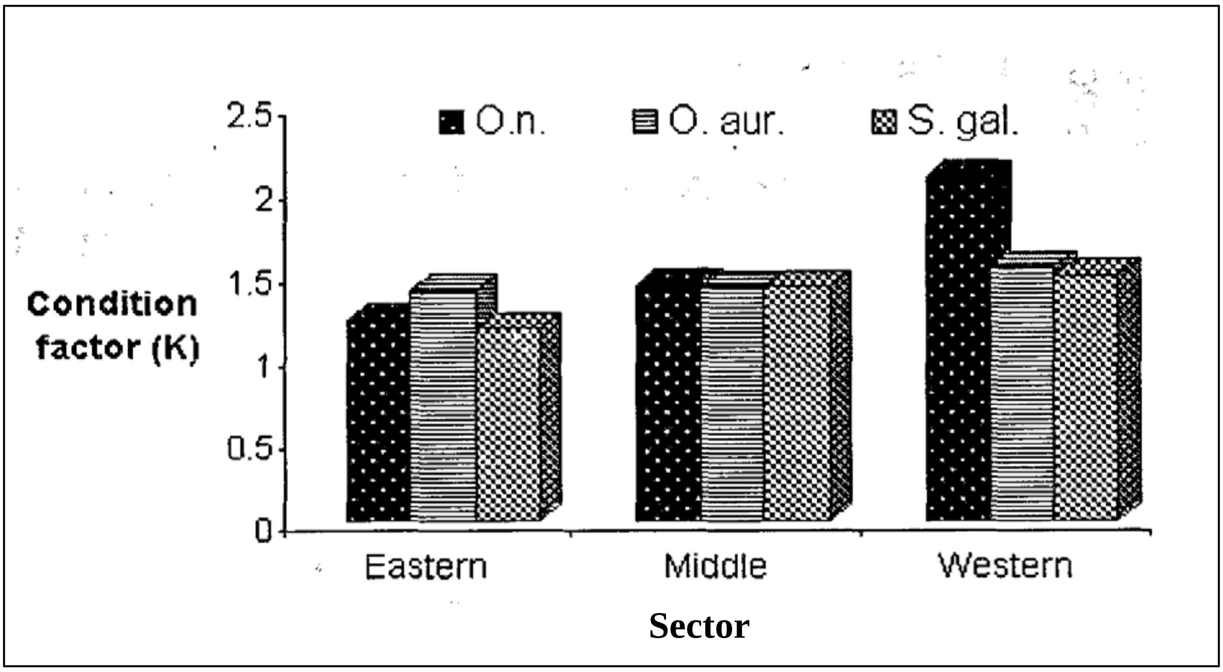


Fig. 9.6 **Comparison of condition factor (K) of cichlid fish species collected from the three sectors of Lake Burullus during 2002 (Moussa 2003).**

Table 9.12. **Seasonal average of hepato-somatic index (HSI) of some cichlid fish species collected from the three sectors of lake Burullus during 2002 (after Moussa 2003).** ***On*****:** ***Oreochromis niloticus, Oa*****:** ***Oreochromis aureus*** **and** ***Sg*****:** ***Sarotherodon galilaeus.*** **M: Mean**

Season	Sector												Mean
	Eastern				Middle				Western				
	On	*Oa*	*Sg*	M	*On*	*Oa*	*Sg*	M	*On*	*Oa*	*Sg*	M	
Winter	1.45	1.42	1.26	1.38	1.62	1.51	1.45	1.53	1.76	1.64	1.49	1.63	1.52
spring	1.36	1.31	0.98	1.22	1.36	1.22	1.12	1.23	1.41	1.43	1.29	1.38	1.28
summer	0.96	1.14	0.83	0.98	0.97	1.17	0.97	1.04	1.13	1.18	1.03	1.11	1.03
Autumn	1.37	1.27	1.09	1.24	1.31	1.41	1.23	1.32	1.29	1.40	1.40	1.36	1.26
Mean	**1.29**	**1.29**	**1.04**	**1.2**	**1.32**	**1.33**	**1.19**	**1.28**	**1.40**	**1.41**	**1.30**	**1.37**	**1.27**

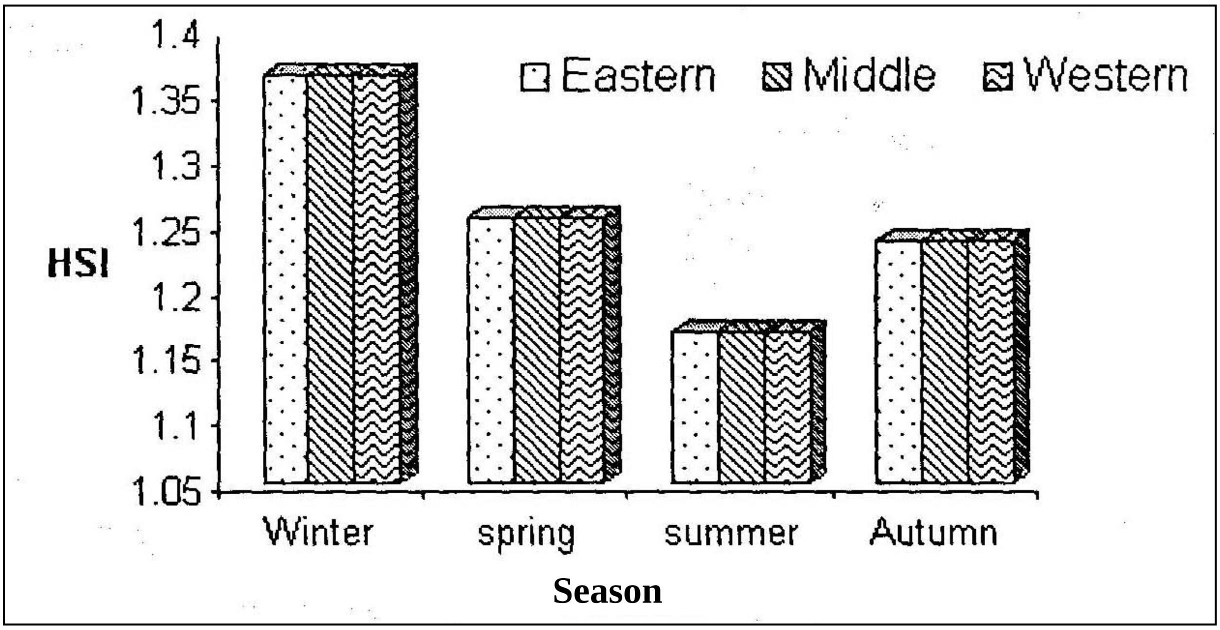


Fig. 9.7. **Seasonal variation of hepato-somatic index (HIS) of cichlid fish species collected from the three sectors of Lake Burullus during 2002 (after Moussa 2003).**

Regarding, the differences among fishes in different sectors, Table (9.11) and Figure (9.8) show that there is no difference in HSI values among the three sectors for *O. niolticus* (annual means of 1.39 ± 0.12, 1.32 ± 0.13 and 1.40 ± 0.23), *O. aureus* (annual means of 1.29 ± 0.06, 1.33 ± 0.08 and 1.40 ± 0.09) and *S. galilaeus* (annual means of 1.04 ± 0.09, 1.19 ± 0.10 and 1.30 ± 0.10) in the eastern, middle and western sector, respectively.

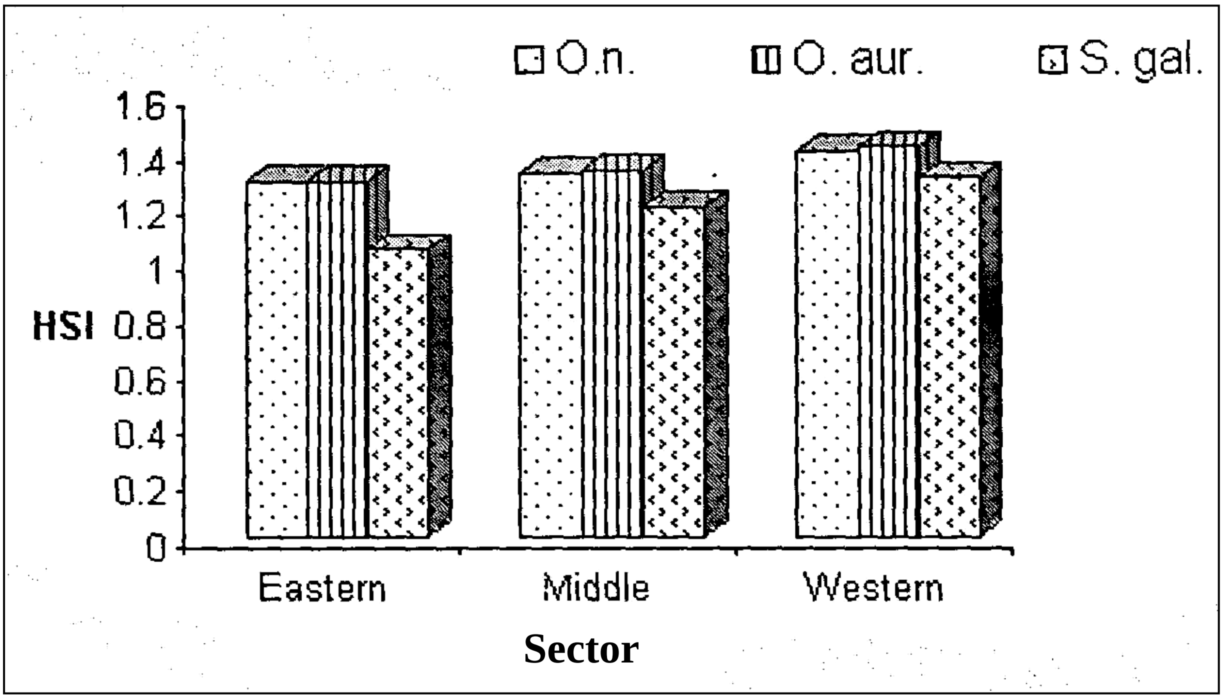


Fig. 9.8 **Comparison of hepato-somatic index (HIS) of cichlid fish species collected from the three regions of Lake Burullus during 2002 (after Moussa 2003)**

Concerning, the differences among cichlid fishes in the same sector, it is shown that, there is a significant difference between *O. niolticus* and *O. aureus* on one side, and *S. galilaeus* on the other side in the three sectors (Table 9.11). In general, it is clear that the value of K follows the same trend of HSI. *O. niloticus* seems more successful in Lake Burullus environment than the other two species, which have also better conditions.

9.3.2 Biology of Muglidae

Five species of mullets are present in Lake Burullus as follows: *Mugil cephalus* Linnaeus 1758, *Liza ramada* (Risso, 1826), *Liza aurata* (Risso. 1810), *Liza saliens* (Risso, 1810) and *Chelon labrosus* (Cuvier, 1829).

9.3.2.1. Seasonal fluctuation of the mullet catch

Liza ramada is the dominant species of mullet catch throughout the year. When the fish is fully ripe, it swarms and migrates from the lake to the sea. Its accessibility in the nets operating in the lake greatly increases during November and December when the fish is sexually ripe. The catch in autumn equals three times its production in any other season .

Mugil cephalus production ranks next to that of *L. ramada.* Its maximum yield is attained during summer, representing maturation period. Large-sized mature fish appear during July to September, where they swarm in the lake migrating to the sea to spawn.

The fishery of *Liza saliens* whose production comes next to that of *M. cephalus* extends from late spring to the beginning of autumn. The maximum fishing of this species was recorded in September, during which the fish leaves the area of the lake-sea connection, where it is localized and migrates to the sea.

Liza aurata and *Chelon labrosus* have disappeared completely from the mullet catch. They were only localized in the area of the lake-sea connection. Their absence from the water of the lake is explained by their disability to adjust to low salinity.

9.3.2.2. Monthly length frequency distribution of mullets

9.3.2.2.1. *Liza ramada*

The population of small sized individuals shows a clear modal distribution in January, February and March. These smaller size groups are well represented in such months, and represent immature fishes, which remain in the lake after the spawning migration of mature fish to the sea in the previous autumn. In March, large fishes (i.e. 210 & 240 mm TL), may represent the adult fish after performing their spawning in the sea.

The prominent peak which is obvious until June, declines down to be replaced by other modal peaks in July and August at 190, 200 and 220 mm TL.

This is due to rise in water temperature and the movement of fish from the vegetative areas to the open water (Hashem *et al.* 1973).

In September, all the length groups are well represented in the samples due to extensive fishing, so that there is no well identified modal distribution of length groups. Mature fishes start to swarm in the open water, coinciding with the ripening of their gonads. In November and December the older length groups not only lose their modal identity but also decrease in number, since they migrate to the sea. In December, a well-developed mode of younger individuals (150-170 mm) appears repeating the same behavior as in January .

It is possible to follow the monthly growth increment of length from the shift in the modal distribution of the length frequency. Starting from the mode of January at 160 mm, it shows a slight increase until April (170 mm). In May, the significant increase in the mode value is prominent, reaching 190 mm. In June and July, further pronounced increases in the mode value also take place (200 and 210 mm respectively). In the mean time, growth of the juvenile fish could be detected from other modes at 165, 180 and 190 mm in May, June and July, respectively.

9.3.2.2.2. *Mugil cephalus*

Prominent modes of small fish are represented in January, February, March and April. They represent young immature individuals in which the monthly increment of growth in length is slight. In May the small immature fish are still represented in the samples. The summer catch exhibits an increase in the percentage of large fishes. In June, large mature fishes appear mixed with smaller fishes and they form a distinct, but low mode at 300 and 320 mm. These large mature fishes persist in July, August and September; while the smaller individuals decrease considerably, because fishing is concentrated at that period on the larger mature fish swarming in the lake. They represent the fully ripe individuals, leaving the lake to spawn in the sea. From October till December, the younger individuals appear in the catch again.

9.3.2.2.3. *Liza saliens*

It is difficult to assess the monthly length distribution pattern for *L. saliens*, since the fish is confined to the area of the lake-sea connection, and its stay is limited (from May to September). From the observations recorded by Hashem *et al.* (1973), it was found that the unimodal distribution is represented in the whole catch. It is characterized by two distinct size groups, the first is nearly at 150 mm, and the second at 190 mm. These two values may characterise two distinct broods for the fish, which breeds twice, one in spring and the other in autumn.

9.3.2.3. Factors affecting the distribution of mullet fry

The hydrographic factors which characterize the lake allover the year, have a great effect on the population of any species. The strength of any year class depends largely on the favorable conditions during the different stages of life. In case of mullet, the success of early developmental stages is determined in the sea at the breeding grounds. The survival of the fry and juveniles, which invade the lake, depends on many environmental factors such as water movement, water temperature, chlorsity and amount of food, among others.

9.3.2.3.1. Water movement

It has been observed, while collecting the fry at the lake-sea connection, that the amount of fry depends upon the direction of the water current. A large number of fry were collected when the water was streaming to the sea. The fry seems to prefer swimming against the current; beside, the fresh water flowing out attracts the fry to the interior of the lake (El-Maghraby *et al*. 1974 a & b).

The water in the lake is almost calm near the shores and in the vegetative pans, but it may be strongly agitated in the open parts even when wind of modern velocity blows. Due to the shallowness of the lake, the eastern wind drives the water from Baltim region to the north west leaving the whole area dry, this in turn forces all the mullet fry present to seek other places. The eastern area of the lake is not affected by such wind, on the contrary all the water mass rushes to it and rises the water level, and the mullet fry can be seen swimming among the weeds and reeds (*Phragmites australis*) growing near the shores. The vegetative areas decrease the effect of wind and create a suitable favorable shelter for the fry. Western winds never dry the western part of the lake because it is rather deep; however, large amounts of water are driven to the eastern sector of the Lake.

9.3.2.3.2. Water temperature

The temperature of water varies between 12.5°C and I5.5°C in winter and from 26.0°C to 29.0°C in summer. Owing to the shallowness of the lake, there is no thermal stratification except during very short spells in spring and autumn, when extremely calm weather takes place. The comparatively higher temperature in the lagoon and outlets of channels attracts the fry to survive. They seem to prefer warm shallow water, which are always in thermal equilibrium with the atmosphere. In addition, the higher water temperature of these areas stimulates the development of diatoms and other microorganisms needed as the basic supply for the fry and young mullet (Zambriborch 1949).

9.3.2.3.3. Chlorosity

The chlorosity of the Lake is greatly affected by the amount of seawater on one hand, and drain and fresh water on the other hand. The chlorosity of the different areas of the lake controls the distribution of the fry and even the adults.

The fry of euryhaline fishes like *L. ramada* and *M. cephalus* can invade the whole lake and are found in all areas, while the fry of *L. saliens* prefer areas with high chlorosity and does not leave the area of the lake-sea connection. *L. aurata* and *Chelon labrosus* were always found much closer to the sea, because of their stenohaline nature, but during the present survey no specimen has been obtained. El-Boughaz area, which is greatly affected by the seawater more than drain water, acts as a transition area between the seawater and brackish water of the lake. Huge amounts of fry rush into this area and they seem to stay for a while to acclimatize themselves before spreading in different sectors of the lake.

9.3.2.3.4. Amount of food

The mullet as a whole is a grazer, feeding on living organisms or organic material accumulated on the lake bottom. When observing the fry of *L. ramada* and *M. cephalus*, they were reported to descend to the bottom and gulp a portion of the sand or mud and then reject it after retaining the organic content in their special filtering apparatus present in the oesophagus. The amounts of organic materials (detritus) in Delta lakes are great, and the variety of plant and animal microorganisms living on their bottom provide a rich source of suitable food for the mullet.

9.3.2.3.5.Other factors

Many authors have discussed the effect of some other factors on the distribution of the mullet fry. De Angelies (1960) mentioned that dissolved oxygen, alkalinity, and the presence of dissolved nitrates were important factors affecting the biological productivity of lagoon waters and hence the abundance of mullet fry. Creutzberg (1961) during his experimental study on the migrating elvers of *Anguilla anguilla* and mullet, found that they are attracted to some organic compounds present in inland waters. It is suggested that the small inorganic and plant detritus sediment particles are richer than the coarser material that the mullet rejects.

9.3.3. Heavy Metals in Fish Organs

Moussa (2003) studied the spatial and temporal variations in concentration of heavy metals (Zn, Cu, Fe, Cd and Pb) in three cichlid species (*Oreochromis niloticus*, *Oreochromis aureus* and *Sarotherodon galilaeus*) in Lake Burullus. Tables 9.13, 9.14 and 9.15 showed the seasonal average concentrations of the estimated heavy metals in the different tissues of the three cichlid species collected from the three sectors of Lake Burullus. It is clear that, the concentrations of metals as a whole increase in fish organs in autumn and summer (average 45.32 and 42.45 µg g^{-1} dry wt., respectively) and decrease in winter and spring seasons (average 11.12 and 19.22 µg g^{-1}. dry wt., respectively).

Table 9.13. **Seasonal average of heavy metals concentration ((µg g^{-1} dry wt.) in tissues of some cichlid fish species collected from the eastern sector of lake Burullus during 2002 (Moussa 2003).**

Species	Metal	Winter			Spring			Summer			Autumn		
		Muscle	**Gill**	**Liver**	**Muscle**	**Gill**	**Liver**	**Muscle**	**Gill**	**Liver**	**Muscle**	**Gill**	**Liver**
Oreochmmis niloticus	**Zn**	3.53	9.62	10.47	4.32	18.00	13.60	15.20	58.90	48.40	16.40	23.90	68.20
	Cu	1.13	1.33	16.26	4.25	5.96	21.80	5.12	8.73	29.10	5.38	7.51	28.30
	Fe	11.8	50.10	74.69	13.90	71.90	109.0	20.60	146.0	287.0	33.20	172.0	301.0
	Cd	0.01	0.04	0.05	0.03	0.07	0.10	0.05	0.06	1.02	0.09	1.11	1.19
	Pb	1.58	5.17	4.78	1.45	3.62	7.65	1.87	6.94	10.60	1.92	5.69	9.94
	Mean	**3.62**	**13.25**	**21.25**	**4.80**	**19.91**	**30.44**	**8.58**	**44.19**	**75.19**	**11.38**	**42.07**	**81.81**
Oreochromis aureus	**Zn**	2.76	4.36	11.3	13.30	11.10	44.00	19.80	39.20	71.20	17.30	71.70	42.60
	Cu	2.83	3.26	13.1	4.25	6.32	24.10	7.91	21.10	34.50	5.31	6.67	29.30
	Fe	8.21	23.00	35.3	21.00	36.60	101.0	36.00	162.0	233.0	62.60	296.0	331.0
	Cd	0.11	0.36	0.42	0.14	0.46	1.06	0.09	0.54	1.25	0.19	0.63	1.12
	Pb	2.44	6.45	6.81	2.66	8.73	9.61	2.41	7.49	10.70	2.01	6.54	11.30
	Mean	**3.27**	**10.60**	**13.4**	**8.27**	**16.60**	**36.00**	**13.20**	**45.10**	**70.20**	**17.50**	**57.70**	**83.10**
Sarotherodon galilaeus	**Zn**	1.45	8.37	7.89	3.35	18.80	32.00	21.20	36.30	40.30	11.00	30.10	37.10
	Cu	1.56	3.92	8.33	6.11	7.22	18.20	4.56	6.11	20.10	7.03	8.28	19.30
	Fe	5.77	42.20	86.10	10.40	68.20	103.0	23.20	184.0	274.0	21.20	141.0	278.0
	Cd	0.01	0.03	0.06	0.02	0.07	0.07	0.04	0.08	0.09	0.10	0.15	0.23
	Pb	1.07	2.41	4.32	1.36	6.49	9.17	1.96	6.11	9.32	1.83	5.84	10.60
	Mean	**1.97**	**11.40**	**21.3**	**4.25**	**20.10**	**32.50**	**10.20**	**46.50**	**68.80**	**8.23**	**37.10**	**69.10**

Concerning the annual means of heavy metals in fish organs, Moussa (2003) obtained the following data:

9.3.3.1. Muscle tissues

In muscle tissues of the three cichlid fish species collected from the eastern sector, it is clear that there is no significant difference among the three fishes for Zn, Cu and Fe (Table 9.16 and Fig. 9.9). The highest values of Zn**,** Cu and Fe (13.28±3.75, 5.08±1.07 and 31.96±11.68 µg g^{-1}) were recorded in muscle tissues of *Oreochromis aureus*. The lowest values were observed in muscle tissues of *Sarotherodon galilaeus* with means of 9.24±4.48, 4.82±1.20 and 15.13±4.19 µg g^{-1}, respectively. On the other hand, for Cd and Pb there is significant difference between *Oreochromis aureus* (mean= 0.13±0.02 and 2.38±0.14 µg g^{-1}) from one side and *Oreochromis niloticus* (mean= 0.045±0.02 and 1.71 ±0.11 µg g^{-1}) and *Sarotherodon galilaeus* (mean= 0.042±0.02 and 1.56±0.21 µg g^{-1}) from the other side. No significant differences exist between *Oreochromis niloticus* and *Sarotherodon galilaeus.*

Table 9.14. **Seasonal average of heavy metals concentration ((µg g^{-1} dry wt.) in tissues of some cichlid fish species collected from the middle sector of lake Burullus during 2002 (after Moussa 2003).**

Species	Metal	Winter			Spring			Summer			Autumn		
		Muscle	Gills	Liver	Muscle	Gills	Liver	Muscle	Gills	Liver	Muscle	Gills	Liver
Oreochmmis niloticus	Zn	3.82	19.65	31.22	16.02	22.56	26.35	11.14	31.56	59.68	18.68	37.32	35.18
	Cu	1.68	6.11	10.42	3.12	7.02	15.26	5.16	8.64	29.18	7.22	11.34	31.02
	Fe	19.05	68.24	93.12	42.94	255.1	412.0	55.16	224.9	302.2	41.89	134.4	200.9
	Cd	0.02	0.26	0.32	0.04	0.37	0.23	0.03	0.61	0.77	0.03	0.53	1.32
	Pb	1.12	1.75	2.86	1.03	2.01	2.91	2.09	4.61	5.47	1.52	4.97	8.04
	Mean	**5.138**	**19.2**	**27.59**	**12.63**	**57.42**	**91.35**	**14.72**	**54.05**	**79.45**	**13.87**	**37.72**	**55.29**
Oreochromis aureus	Zn	4.15	10.38	25.67	17.02	41.26	33.12	26.81	41.53	77.16	27.91	78.39	120.4
	Cu	5.08	6.25	14.99	6.11	10.35	23.21	7.15	11.02	25.14	8.42	16.25	33.52
	Fe	13.42	118.4	155.8	18.30	106.3	272.0	61.93	126.2	351.3	54.22	177.5	321.3
	Cd	0.03	0.43	0.35	0.04	0.62	1.00	0.05	0.83	0.93	0.07	0.72	1.07
	Pb	1.55	3.22	10.06	2.21	9.23	13.2	3.08	8.63	9.41	3.63	9.73	7.85
	Mean	**4.85**	**27.74**	**41.37**	**8.74**	**33.56**	**68.51**	**19.80**	**37.64**	**92.78**	**18.85**	**56.52**	96.82
Sarotherodon galilaeus	Zn	3.76	11.82	14.57	4.22	25.18	33.27	11.35	29.22	40.25	13.69	43.37	46.31
	Cu	2.09	4.60	9.55	3.13	12.14	12.09	4.02	10.22	17.25	4.11	14.58	27.16
	Fe	17.35	43.25	79.73	32.70	121.4	270.9	27.30	113.3	366.5	46.17	127.1	341.0
	Cd	0.02	0.20	0.36	0.03	0.23	0.39	0.03	0.47	0.44	0.03	0.40	0.41
	Pb	1.37	2.63	3.43	1.03	2.01	8.57	2.09	4.61	8.47	2.01	2.97	13.04
	Mean	**4.92**	**12.5**	**21.53**	**8.22**	**32.2**	**65.05**	**8.96**	**31.55**	**86.57**	**13.20**	**37.69**	**85.59**

In the middle sector, there is no significant difference among the three species for Zn. For Cu, a significant difference was present between *O. aureus* (mean= 6.69±0.71 µg g^{-1}) and *S. galilaeus* (mean= 3.34±0.47 µg g^{-1}), but no significant difference between *O. niloticus* (mean= 4.30±1.21 (µg g^{-1}) and the other two fishes. However, no significant difference recorded among the three fishes for Fe. For Cd, there is a significant difference between *0. aureus* (mean= 0.046±0.008 µg g^{-1}*)* from one side and *O. niloticus* (mean= 0.029±0.003 µg g^{-1}) and *S. galilaeus* (mean= 0.027±0.002 µg g^{-1}) from the other side. No significant difference exists between *O. niloticus* and *S.. galilaeus.* Concerning Pb, there is a significant difference between *O. aureus (mean*= 2.62±0.46 µg g^{-1}) and *O. niloticus* (mean= 1.44±0.24 µg g^{-1}) but there is no significant difference between *S. galilaeus* (mean= 1.63±0.26 µg g^{-1}) and the other two fish species.

Table 9.15. **Seasonal average of heavy metals concentration ((µg g^{-1} dry wt.) in tissues of some cichlid fish species collected from the western sector of lake Burullus during 2002 (after Moussa 2003).**

Fish sp.	Metal	Winter			Spring			Summer			Autumn		
		Muscle	Gills	Liver	Muscle	Gills	Liver	Muscle	Gills	Liver	Muscle	Gills	Liver
Oreochmnis niloticus	Zn	5.21	19.32	26.11	15.04	36.28	42.10	25.03	67.29	66.47	22.86	51.27	84.48
	Cu	1.95	5.01	9.22	2.66	7.55	17.24	8.36	14.25	33.63	7.33	17.51	35.02
	Fe	14.13	22.17	106.1	44.02	93.11	621.6	56.15	87.21	542.1	42.05	401.8	693.2
	Cd	0.02	0.26	0.32	0.02	0.25	0.41	0.03	0.29	0.56	0.02	0.32	0.47
	Pb	0.95	1.44	2.35	0.98	1.92	3.66	1.46	2.25	6.21	1.54	2.13	7.02
	Mean	**4.45**	**9.64**	**28.82**	**12.54**	**27.82**	**137**	**18.21**	**34.26**	**17.9.8**	**14.76**	**94.61**	**164**
Oreochromis aureus	Zn	11.81	21.11	25.17	17.12	41.25	58.19	47.28	105.2	133.2	38.57	57.89	81.28
	Cu	4.37	6.35	17.23	4.91	7.17	35.2	6.42	17.35	29.11	9.11	17.01	32.18
	Fe	23.15	80.29	62.21	103.1	340.7	254.0	96.14	567.1	267.3	74.14	345.7	476.9
	Cd	0.02	0.19	0.41	0.03	0.27	0.55	0.05	0.39	0.54	0.04	0.44	0.43
	Pb	1.08	2.18	2.64	1.96	2.31	4.71	1.84	2.58	6.21	1.79	3.55	7.81
	Mean	**8.09**	**22.02**	**21.53**	**25.43**	**78.34**	**70.53**	**30.35**	**138.5**	**87.26**	**24.73**	**84.91**	**119.7**
Sarotherodon galilaeus	Zn	14.35	33.14	21.15	11.52	29.87	36.58	21.35	42.16	77.28	19.41	53.58	76.12
	Cu	1.44	9.25	10.77	5.16	10.44	17.25	3.11	16.35	31.12	6.35	12.58	29.14
	Fe	11.3	75.89	86.01	53.17	318.3	325.2	64.12	301.2	258.1	53.07	265.5	318.3
	Cd	0.01	0.11	0.29	0.02	0.21	0.25	0.02	0.29	0.31	0.02	0.31	0.30
	Pb	0.87	1.33	3.01	1.12	1.85	2.41	1.36	3.02	3.92	1.41	2.44	6.25
	Av.	**5.595**	**23.94**	**24.25**	**14.2**	**72.12**	**76.33**	**17.99**	**72.61**	**74.15**	**16.05**	**66.89**	**86.01**

Table 9.16 **Annual mean ± standard error of heavy metals concentrations (µg g^{-1} dry wt.) in muscle tissues of some cichlid fish species collected from the three sectors of lake Burullus during 2002 (after Moussa 2003). Capital letters in the exponent represent the difference among fishes in different sectors; small letters refer to difference among fish of the same sector.** ***On: Oreochromis niloticus, Oa: Oreochromis aureus, Sg: Sarotherodon galilaeus.***

Metal	Sector								
	Eastern sector			Middle sector			Western sector		
	On	*Oa*	*Sg*	*On*	*Oa*	*Sg*	*On*	*Oa*	*Sg*
Zn	9.86^{Aa} ±3.44	13.28^{Aa} ±3.75	9.24^{Aa} ±4.48	12.42^{Aa} ±3.26	18.97^{Aa} ±5.51	8.26^{Aa} ±2.51	17.04^{Aa} ±4.49	28.70^{Aa} ±8.48	16.66^{Aa} ±2.26
Cu	3.97^{Aa} ±0.98	5.08^{Aa} ±1.07	4.82^{Aa} ±1.20	4.30^{Aba} ±1.21	6.69^{Aa} ±0.71	3.34^{Ba} ±0.47	5.08^{Aa} ±1.62	6.20^{Aa} ±1.06	4.02^{Aa} ± 1.09
Fe	19.89^{Aa} ±4.81	31.96^{Aa} ±11.68	15.13^{Ab} ±4.19	39.76^{Aa} ±7.53	36.96^{Aa} ±12.33	30.88^{Ab} ±6.01	39.09^{Aa} ±8.88	74.14^{Aa} ±18.08	45.42^{Aa} ±11.66
Cd	0.045^{Ba} ±0.02	0.13^{Aa} ±0.02	0.042^{Ba} ±0.15	0.029^{Ba} ± 0.003	0.046^{Ab} ±0.008	0.027^{Ba} ± 0.002	0.019^{Aa} ±0.002	0.033^{Ab} ± 0.006	0.021^{Aa} ±0.003
Pb	1.71^{Ba} ±0.11	2.38^{Aa} ±0.14	1.56^{Ba} ±0.21	1.44^{Ba} ±0.24	2.62^{Aa} ±0.46	1.63^{Aba} ±0.26	$1\ 23^{Aa}$ ±0.16	1.67^{Aa} ±0.20	1.19^{Aa} ±0.12

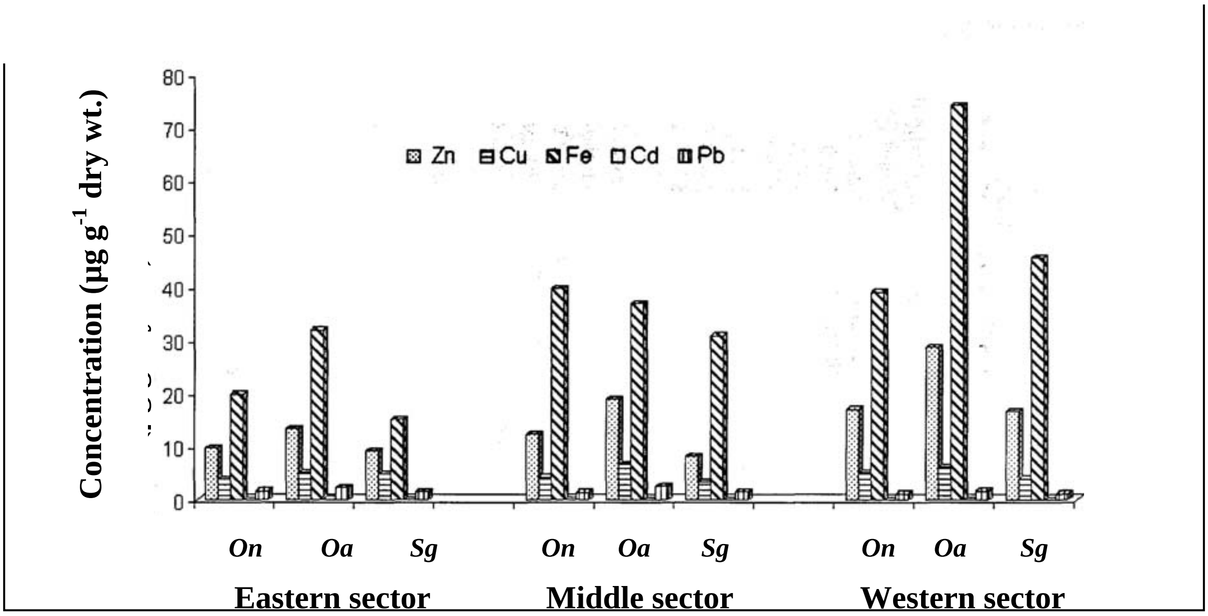


Fig. 9.9 **Annual mean of heavy metals concentration (µg g^{-1} dry wt.) in muscle tissues of some cichlid fish species collected from the three sectors of Lake Burullus during 2002 (after Moussa 2003)**

In the western sector, the accumulation of different heavy metals in the three fish species showed no significant difference. There is no significant difference between fishes collected from the three sectors for accumulation of Zn, Cu and Pb (Table 9.16). For Fe**,** there is no difference between fishes (*O. niloticus* and *O. aureus*) of the three sectors.

For the whole lake, metals in muscle tissues were accumulated in the order of Fe >Zn >Cu > Pb > Cd with an annual average of 37.03, 14.94, 4.83, 1.71 and 0.044 µg g^{-1} (Table 9.16). *O. aureus* accumulated metals more than the other two species. The annual average were 13.34, 11.40 and 10.39 µg g^{-1} for *O. aureus, S. galilaeus* and *O. niloticus,* respectively.

9.3.3.2. Gills tissues

The annual variations in heavy metals accumulation in gills tissues of different cichlid species collected from the three sectors of Lake Burullus are shown in Table 9.17 and Fig. 9.10.

In the eastern sector, the accumulation of different heavy metals in the three fish species showed no significant difference. The highest value of Zn, Cu, Fe, Cd and Pb were detected in gills of *O. aureus* with annual means of 31.58±15.36, 9.35±4.01, 129.49±63.80, 0.50±0.06 and 7.30±0.53 µg g^{-1}, respectively. The lowest values of Zn, Fe, Cd and Pb were recorded in *S. galilaeus*, with annual means of 23.39±6.18, 108.91±32.68, 0.08±0.025 and

5.21±0.94 µg g^{-1}, respectively. However, the minimum value of Cu was recorded in gills of *O. niloticus* (annual mean= 5.88±1.62 µg g^{-1}).

Table 9.17. **Annual mean ± standard error of heavy metals concentrations (µg g^{-1} dry wt.) in gills tissues of some cichlid fish species collected from the three sectors of lake Burullus during 2002 (Moussa 2003). Capital letters in the exponent represent the difference among fishes in different sectors; small letters refer to difference among fish of the same sector.** ***On: Oreochromis niloticus, Oa: Oreochromis aureus, Sg: Sarotherodon galilaeus.***

Metal	Sector								
	Eastern			Middle			Western		
	On	***Oa***	***Sg***	***On***	***Oa***	***Sg***	***On***	***Oa***	***Sg***
Zn	27.61^{Aa} ±10.83	31.58^{Aa} ±15.36	23.39^{Aa} ±6.18	27.77^{Aa} ±4.07	42.89^{Aa} ±13.91	*27A* ^{Aa} ±6.49	43.54^{Aa} ±10.26	56.36^{Aa} ±17.92	39.69^{Aa} ±5.31
Cu	5.88^{Aa} ±1.62	9.35^{Aa} ±4.01	6.38^{Ab} ±1.20	8.28^{Aa} ±1.15	10.97^{Aa} ±2.05	10.39^{Aab} ±2.12	11.08^{Aa} ±2.90	11.97^{Aa} ±3.01	12.16^{Aa} ±1.56
Fe	110.12^{Aa} ±29.19	129.49^{Aa} ±63.80	108.91^{Ab} ±32.68	170.67^{Aa} ±42.69	132.11^{Aa} ±15.68	101.26^{Ab} ±19.55	151.08^{Aa} ±85.12	333.99^{Aa} ±99.54	240.23^{Aa} ±55.87
Cd	0.32^{Aa} ±0.26	0.50^{Aab} ±0.06	0.080^{Ab} ±0.025	0.443^{Aba} ±0.079	0.65^{Aa} ±0.085	0.325^{Ba} ±0.065	0.280^{Aa} ±0.016	0.323^{Ab} ±0.057	0.230^{Aab} ±0.045
Pb	5.36^{Aa} ±0.69	7.30^{Aa} ±0.53	5.21^{Aa} ±0.94	3.34^{Bab} ±0.84	7.70^{Aa} ±1.51	3.06^{Ab} ±0.56	1.94^{Ab} ±0.18	2.66^{Ab} ±0.31	2.16^{Ab} ±0.37

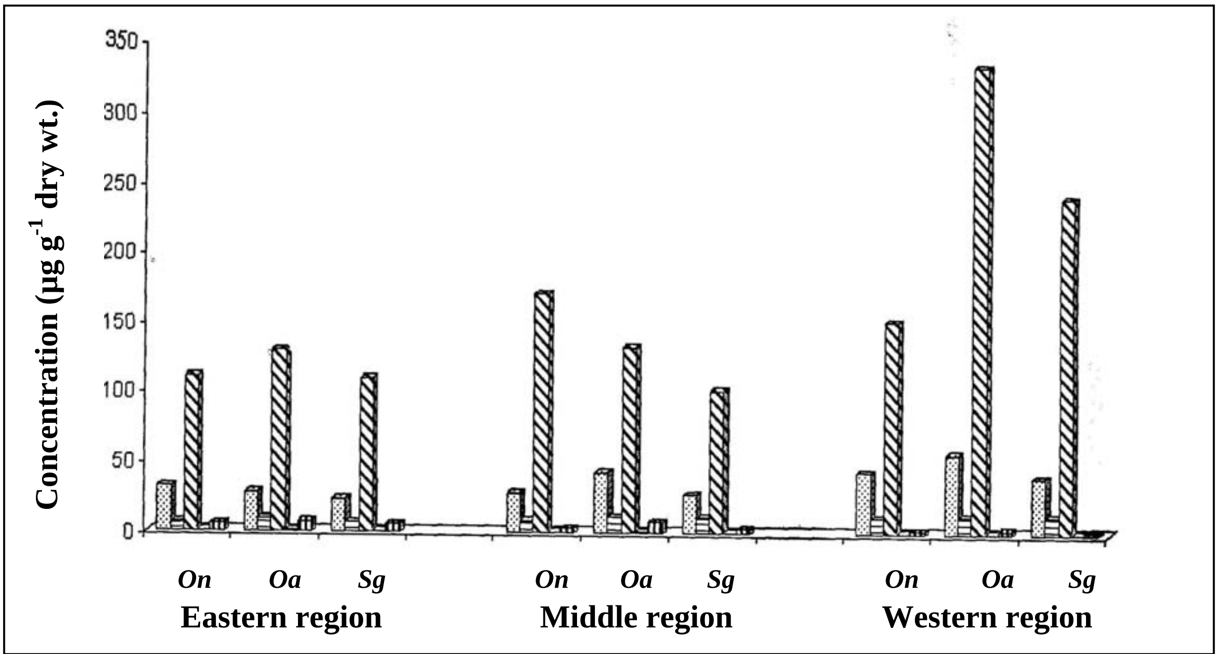


Fig. 9.10. **Annual mean of heavy metals concentration (µg g^{-1} dry wt.) in gills tissues of some cichlid fish spcies collected from the three sectors of Lake Burullus during 2002 (after Moussa 2003)**

In the middle sector, no significant differences exist between the three species for Zn, Cu, Fe and Cd. However, Pb accumulation showed significant difference between *O. aureus* (7.70±1.51 µg g^{-1}) and *S. galilaeus* (3.06±0.56 µg g^{-1}) on one side, and *O. niloticus* (3.34±0.84 µg g^{-1}) on the other one.

Metals accumulated in gills tissues of fish collected from the western sector showed no significant difference. The minimum values of Zn, Cd and Pb were detected in gills tissues of *S. galilaeus* with annual means of 39.69±5.31, 0.230±0.045 and 2.16±0.37 µg g^{-1}, respectively. However, the lowest values of Cu and Fe were recorded in *O. niloticus* with annual means of 11.08±2.90 and 151.08±85.12 µg g^{-1}, respectively. The maximum values of Zn, Cu, Fe, Cd and Pb were detected in gills tissues of *0. aureus* with annual means of 56.36± 17.92, 11.97±3.01, 333.99±99.54, 0.323±0.057 and 2.66±0.31 µg g^{-1}, respectively. There is no significant difference between fishes collected from the three sectors for accumulation of Zn, Cu (except *S. galilaeus* which exhibits significant difference between the west and east of the lake for Cu). For Fe, there is a significant difference between the western sector and both of other sectors. For Cd, *O. niloticus* showed no significant difference among the three sectors (Table 9.17). However, there is a significant difference between the middle sector on one side, and both of other sectors on the other side for *O. aureus* and *S. galilaeus*. For Pb, there is a significant difference between the eastern and western sector and no difference between the middle and both of the eastern and western sectors for *O. niloticus*. A significant difference also present between the eastern and middle sectors on one side, and the western sector on the other side for *O. aureus*. Regarding *S. galilaeus*, a significant difference was detected between the eastern sector and both of the middle and western sectors.

For the whole lake, metals in gills tissues were accumulated in the order of Fe >Zn >Cu > Pb > Cd with annual averages of 164.21, 35.85, 9.61, 14.30 and 0.35 µg g^{-1} (Table 9.17). *O. aureus* accumulated more metals than the other two species. The annual averages were 5.89, 3.55 and 3.48 µg/g for *O. aureus*, *O. niloticus* and *S. galilaeus*, respectively.

9.3.3.3. Liver tissues

The annual variations in heavy metals accumulation in liver tissues of different cichlid species collected from the three sectors of lake Burullus are shown in Table 9.18 and Figure 9.11.

In the eastern sector, the accumulation of different heavy metals in the three fish species showed no significant difference, except Cd which showed difference between *O. aureus* and *S. galilaeus*. The highest value of Zn, Cu, Fe, Cd and Pb were detected in liver tissue of *O. aureus* with annual means of 42.29±12.25, 25.26±4.57, 193.01±58.89, 0.96±0.19 and 9.60±0.99 µg g^{-1}, respectively. The lowest values of Zn, Cu and Cd were recorded in *S. galilaeus*, with annual means of 29.31±7.34, 1.6.49±2.75 and 0.113±0.039 µg g^{-1}, respectively. However, the minimum value of Fe and Pb were detected in liver tissue of *O. niloticus* (annual mean = 175.23±66.27 and 8.24±1.32 µg g^{-1}, respectively).

Table 9.18 **Annual mean ± standard error of heavy metals concentrations (µg g^{-1} dry wt.) in liver tissues of some cichlid fish species collected from the three sectors of lake Burullus during 2002 (Moussa 2003). Capital letters in the exponent represent the difference among fishes in different sectors; small letters refer to difference among fish of the same sector.** ***On: Oreochromis niloticus, Oa: Oreochromis aureus, Sg: Sarotherodon galilaeus.***

Metal	Sector								
	Eastern			Middle			Western		
	On	*Oa*	*Sg*	*On*	*Oa*	*Sg*	*On*	*Oa*	*Sg*
Zn	35.17 ^{Aa} ±13.97	42.29 ^{Aa} ± 12.25	29.31 ^{Aa} ±7.34	38.11 ^{Aa} ±7.41	64.09 ^{Aa} ±21.93	33.6 ^{Aa} ±6.88	54.79 ^{Aa} ±12.91	74.45 ^{Aa} ± 22.71	52.78 ^{Aa} ±14.17
Cu	23.84 ^{Aa} ±3.0	25.26 ^{Aa} ±4.57	16.49 ^{Aa} ±2.75	21.47 ^{Aa} ±5.09	24.22 ^{Aa} ±3.80	16.51 ^{Aa} ±3.89	23.78 ^{Aa} ±6.31	28.43 ^{Aa} ±3.93	22.07 ^{Aa} ±4.85
Fe	175.23 ^{Ab} ± 66.27	193.01 ^{Aa} ± 58.89	185.49 ^{Aa} 52.56	252.05 ^{Aa} ±68.29	275.08 ^{Aab} ±42.99	264.54 64.83 ^{Aa}	264.95 ^{Aa} ± 84.61	490.76 ^{Aa} ±131.88	246.9 ^{Aa} ± 55.70
Cd	0.59 ^{ABa} ±0.30	0.96 ^{Aa} ±0.19	0.113 ^{Bc} ±0.039	0.66 ^{Aa} ± 0.250	0.838 ^{Aa} ±0.165	0.400 ^{Aa} ±0.017	0.440 ^{Aa} ± 0.050	0.483 ^{Aa} ± 0.036	0.288 ^{Bb} ±0.013
Pb	8.24 ^{Aa} ±1.32	9.60 ^{Aa} ±0.99	8.35 ^{Aa} ±1.38	4.82 ^{Ba} ±1.23	10.13 ^{Aa} ±1.12	8.38 ^{ABb} ±1.96	4.81 ^{Aa} ±1.09	5.34 ^{Ab} ±1.10	3.90 ^{Aa} ±0.84

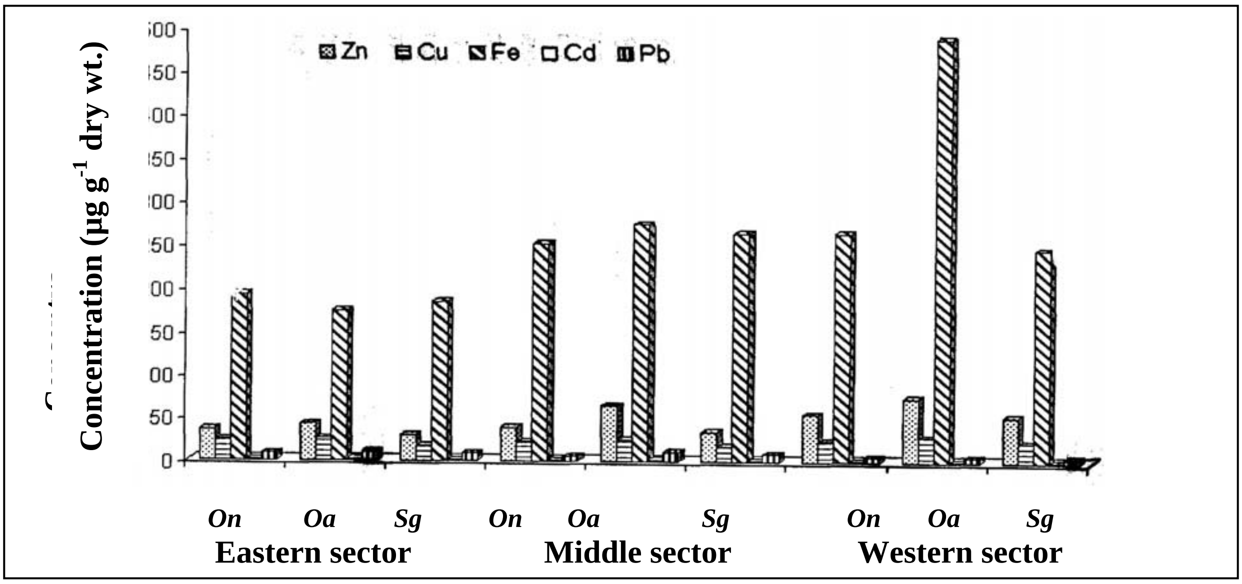


Fig. 9.11 **Annual means of heavy metals concentrations (µg g^{-1}dry wt.) in liver tissues of cichlid fish species collected from the three sectors of Lake Burullus during 2002 (Moussa 2003)**

Regarding the middle sector, no differences exist between the three species for Zn, Cu, Fe and Cd. However, Pb accumulation showed significant difference between *O. aureus* (10.13±1.12 µg g^{-1}) and *O. niloticus* (4.82±1.23 µg g^{-1}), but no significant differences exist between *S. galilaeus* (8.3 8± 1.96 µg g^{-1}) and the other two species.

Concerning metals accumulation in liver tissues of fish collected from the western sector, no significant difference was present among different fishes except Cd, where it showed a difference between *O. niloticus* and *O. aureus* on one side, and *S. galilaeus* on the other side. The minimum values of Zn, Cu, Fe, Cd and Pb were detected in liver tissue of *S. galilaeus*, with annual means of 52.78±14.17, 22.07±4.85, 246.9±55.7, 0.228±0.013 and 3.90±0.84 µg g^{-1}, respectively. However, the maximum values of these metals were determined in *O. aureus* with annual means of 74.45±22.71, 28.43±3.93, 470.76±131.88, 0.483±0.036 and 5.34±1.10 µg g^{-1}, respectively. From Table 9.18, it is clear that *O. niloticus* showed no significant differences among the three sectors for all metals, whereas *O. aureus* showed significant difference between the eastern and middle sectors on one side, and the western sector sectors on the other side for Zn, Cu and Fe. However, there is a significant difference between the middle sector and both of the eastern and western sectors, and between the western and eastern sectors for Cd. *S. galilaeus* also showed a significant difference for Pb between the eastern and western sectors on one side, and the middle sector on the other side.

For the whole lake, metals in liver tissues were accumulated in the order of Fe> Zn >Cu > Pb > Cd with an annual average of 260.89, 47.18, 22.45, 7.06 and 0.53 µg g^{-1} (Table 9.18). *0. aureus* accumulated more metals than the other two species. The annual average was 81.81, 61.78 and 59.28 µg g^{-1} for *0. aureus, 0. niloticus* and *S. galilaeus*, respectively.

9.3.4. Fishing Effort Analyses

According to the statistical data, it is clear that the number of licensed fishing boats and fishermen had remained relatively constant during the past period up to 1984. Starting with 1985 and the following years, the fishing efforts have been considerably increased in order to coincide with the considerable increase in fish yields obtained during these last years. The number of fishermen has increased from about 9000 men in 1963 to about 21660 men in 1993, then to about 28000 in 2002. The number of boats has increased from 2438 boats in 1963, to about 7277 in 1993, and to 10489 boats in 2000. The annual catch per fisherman has been nearly doubled from about 0.8 ton in 1963 to about 2.0 ton in 1993 then decreased to about 0.9 ton in 2000. Likewise, the catch per boat has been doubled from about 3 ton in 1963 to about 6 ton in 1993 then decreased to about 5.3 ton in 2000.

Statistical analysis of production functions, revealed that the total catch of the lake is positively correlated with the total number of boats and fishermen. This interdependence, between catch and fishing effort, is largely responsible for the variations in fish yields from year to year. This can be explained as follows: when the fishing intensity increases, the fish population begins to deteriorate, fish yields decline and fishermen respond by decreasing their effort until the fish stocks are built up again. As the fish stocks increase, an increase in fishing effort follows, which after certain period again reduces fish stocks, fish catch, and returns of fishing. This oscillating behavior of fishing effort and fish catch indicate that the intensive fishing effort is over-exploiting the fisheries, reducing the actual yields below the optimum sustainable yields. That what happened during 1970's; land reclamation have forced the same number of fishermen to intensify fishing effort on the remaining lake area, that led to depletion in fish stocks of the lake, followed by reducing its annual yield. Therefore, regular surveys should be made in order to follow further variation in the fishing effort and its effect on the fish stocks.

9.3.5. Fishing Gears and Techniques

El-Maghraby *et al.* (1977) described the fishing gears in Lake Burullus and classified them according to their way of capturing the fish. The gears given here are only the most popular types, which are of common use in Lake Burullus and other Northern Delta Lakes.

I. Entangling Gears:

1. Gill net
2. Trammel net (Nasha and Takem)
3. Stationary trammel net (Saksook)

II- Encircling Gears:

1. El-Gafsha
2. El-Ganeb

III- Trawl Gears (Dragged gears).

1. Lawat
2. Lokkafa
3. Kerba

IV- Seine nets:

1. Eshalta

V- Set nets:

1. Shrimp set net
2. Mullet set net

VI- Traps:

1. Wire basket trap

2. Fyke nets
3. Clarias trap

VII- Hook and line Gears:

1. Baited and unbaited hooks

VIII- Cast nets:

1. Torraiha

IX- Hosha

9.3.5.1. Entangling Gears:

9.3.5.1.1. Gill net

The gill net is designed to capture fish by entangling them in the meshes. The size of the mesh is such as to allow the passage of the head but not the body of the fish. The fish is usually caught behind the gill covers (operculum). The size of the mesh varies according to the fish species desired to catch. By this means it is possible to allow for escapement of the under-sized fish.

The gill net is used to catch *Lates niloticus*, sometimes fishes of family mugilidae or tilapia. Fishing operation is carried out usually by night. The gill nets are usually manufactured of cotton twines No. 80/6 or nylon twines Td 210/3. Gill nets without floats and leads are mostly used to build weirs, fastened to bamboo sticks, mainly during migrations of mullets. They are also used for other special methods of fishing. The length of a part of gill nets varies between 10-20 meters; the height between 30 and 160 cm, and the number of meshes per 50 cm varies from 14 to 26.

9.3.5.1.2. Trammel net

This is the most common net in Lake Burullus, and is used to catch various fish species including tilapia, mullets and others. A trammel net consists of three layered walls of webbing. These are hanged from a single cork and lead line. The two outer walls are made of cotton twines (No 80/6) or nylon twines (Td 2l0/3 or 110/3). The inner wall having smaller stretched mesh made of cotton twines (No 120/6) or nylon twines (Td 210/3 or 110/2). The mesh size of both the inner and outer walls depends on the species and size of fish to be caught.

Fish are captured by passing between the large meshes of the outer wall, then pushing the small meshes of the inner wall into a pocket between the large meshes of the wall on the opposite side of the net. When the trammel net is hung, care in taken to make the inside web quite sufficient, so that there will be a plenty of webbing to trap the fish. The stretched length of the central wall equals usually from 1.5 to 2.0 times the stretched length of the outer wall. Three meshes of the central wall are usually connected with one mesh of the outer layer in the longitudinal direction. If the inside wall of webbing is not hung properly, after few fish are captured the netting will be drawn so tight that it has no room for others to be entangled. The lead rope is longer than the cork rope, so that the pockets are easily formed.

This gear is used with difficulty in some areas and seasons because of the prevalence of crabs or aquatic plants (*Ceratophyllum demersum*) which entangle the net and render it difficult to remove. The local name given by the native fishermen to the trammel nets used in Lake Burullus is E1-Naama. This net is used in different ways. The basic part of the net is some 25 meters long, 75cm height. These basic parts can be fused to make a net of the desired length.

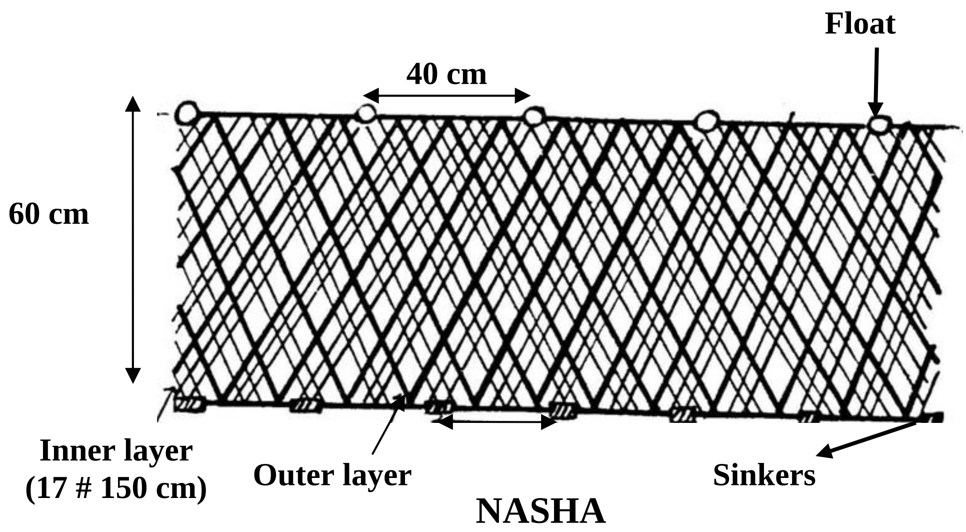
When a likely fishing spot has been found, the boat is anchored. Two boats usually operate for fishing with this net. In operation of the set, the fishermen join their nets and row away from each other, allowing the net to fall. The nets are set so that they form a closed oblong pattern or any number of other patterns in the water, which enclose the major portion of the school and prevent the fish from escaping. The fishermen strike the water on the bottom of the boat repeatedly to enforce the fish to enter into the nets. After a short period of time, depending on the school of fish, length of the net and other conditions, the gear is picked up and the catch is removed from the net. This fishing operation may take few hours if the catch is large.

Trammel net is used as an entangling floating net, when set from a boat in the littoral part of the lake among the vegetation. The nets are marked with buoys and also flags on bamboo poles, so as to be visible from quite a distance. The net is set overnight; the fish caught in the net are removed several times while the net is left setting. A common type of this net is called locally by fishermen as “Takem” which is adopted for use in deeper water (Fig. 9.12). It is some 1.25 meter in height and is set from a boat. It is used in the deeper western part of the lake. Another type called Nasha is specially used to catch *Tilapia* spp. In this net, the length of the basic part is some 20 meters, the height is 60 cm, the outer layer has 10-14 meshes per 50 cm, while the inner one has 14 to 20 meshes per 50 cm.

Nets of various colours are used according to the water turbidity and season of the year. Nets are usually treated by various colouring materials to suit the water turbidity and fishing time of the day (Fig. 9.13).

9.3.5.1.3. Stationary trammel nets (Saksook)

Saksook (Fig. 9.14) is a modified type of trammel nets used in Lake Burullus The net consists of three layers, usually manufactured of nylon similar to those used for making the ordinary trammel net.This net is designed so as to increase the catch ability of the net. Dry bamboo sticks are fixed to the upper rope of the net at regular distances. This keeps the net suspended in the upper 40 cm of the lake water. It is well known that this type of framed net is called beamed trammel net; that is more efficient than the ordinary gill or trammel nets. The height of the net hardly reaches 50 cm where lead pieces are attached to the lower rope and several pieces of the net are joined together constituting a set of 400 meters long. The net is usually set at right angles to the shore or in a strait between two islands. This net is used mainly in Lake Burullus to catch mullet, therefore its use is confined to the season of mullet spawning migration. One can find several nets of this type set in the area at lake-sea connection. It is interesting to mention that the catch can be removed several times, while the net is left setting.



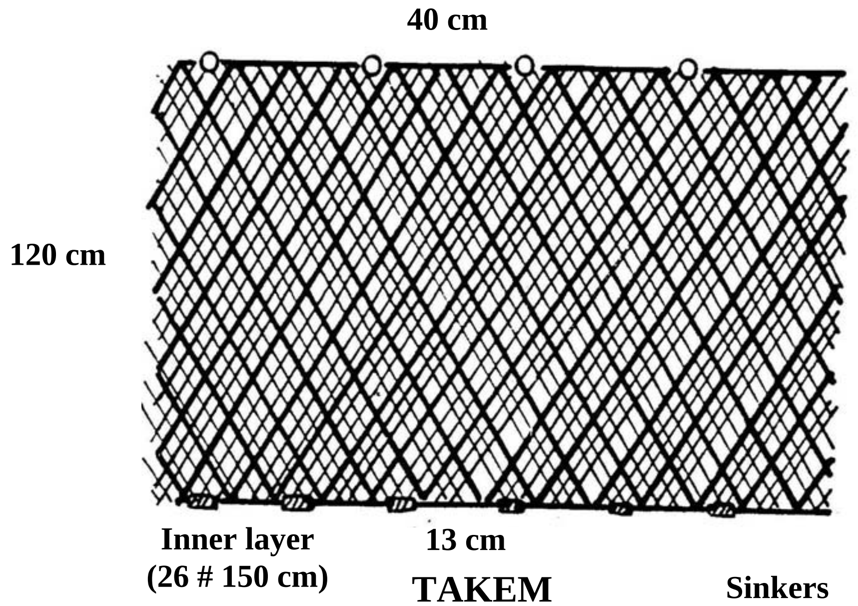


***Fig. 9.12*. The two common types of trammel nets used in Lake Burullus (El-Maghraby *et al.* 1977)**

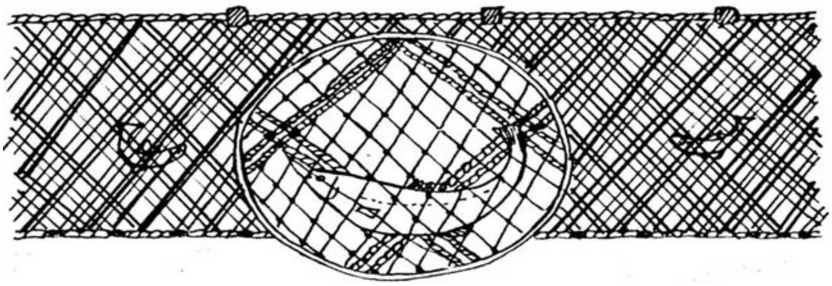


Fig. 9.13. **A section of trammel net showing the pocket formed by trapped fish (El-Maghraby *et al.* 1977)**

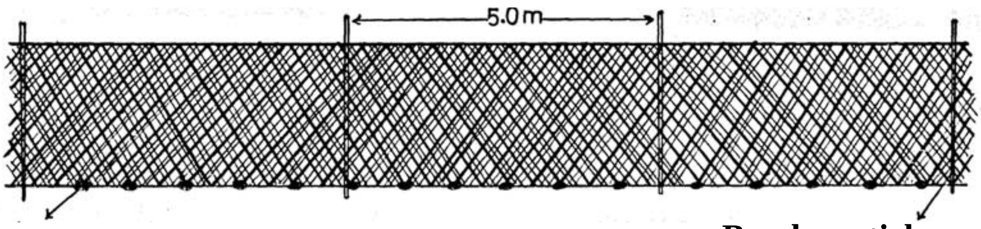


Fig. 9.14. **Fixed trammel net (Saksook) (El-Maghraby *et al.* 1977)**

9.3.5.2. Encircling gears

9.3.5.2.1. El-Gafsha (Shebak El-Habl)

El-Gafsha is the largest of all nets used in Lake Burullus. The net is about 500 to 1000 meters long, 4 meters height, without floats and weights. The net is usually manufactured of cotton twines No. 20/4. The webbing is treated sometimes with traditional preservative against rotting. It has 30 mesh bars per 50 cm at the middle portion of the net, which decreases to 26 towards the ends. Such a net requires about 30 persons to operate. Each man holds a length of 6 to 10 meters, these being joined together to form the complete net.

This sort of net is used in shallow waters; and is coiled up in the stern of a large fishing-boat in two equal portions, each resting on small rafts, generally made of dried stalks of reed bound together. When the boat is in position, the rafts are floated out at the stern, one at each side, and the net which is attached to the boat by a strong cord, is payed out in a semi-circle. The upper edge of the net is kept 60 cm above the water, by boys, who hold the net with short stalks of bamboo. The lower edge is kept touching the bottom by their feet.

In this way, the encircled fish (specially mullets which are excellent jumpers) are prevented from escaping either by jumping the upper head rope or by running under the lower edge of the net. When about half of the net has been payed out, several boats, which have taken up their position some distance behind the chief boat, begin working towards the net, while shouting and beating the water in order to drive the fish in front of them. The fishermen operating the net also keep up shouting, while their chief is directing the operations from the large boat. When the net is all payed out, the two ends are gradually brought together, the large boat being pulled ahead to keep the top edge of the net fairly tight. Directly after the two ends are closed, the boys holding up the net meet in the middle line and keep the two edges close together, preventing the fish from jumping out. The net is then hauled on the large boat, and after the contents have been shaken out into the hold, it is carefully coiled back onto the rafts ready for use again. One fishing operation takes about one hour. This net is operated in summer to catch mainly mullet; while fishing is carried out on day time. Sailing for fishing starts at sunrise, while the boats return at sunset.

9.3.5.2.2. El-Ganeb

The complete net is made up of sections, each of about 15 meters long and 1.5 meters wide attached together. The webbing is manufactured of cotton twines No 20/4. The upper and lower ropes are not furnished with floats or sinkers. Two or three small boats operated with about 8 fishermen are engaged in fishing by this net. Fishing is carried out in shallow areas covered with aquatic vegetation. A well trained fisherman goes around to beat the water with bamboo stalk. Movement of fish in the area is then observed, indicating the size of fish shoals. Once a considerable shoal of fish is detected, a fishing spot is fixed.

The fishing operation starts by setting the net, fixed by stalks surrounding the aquatic plants; a small part of the net is left opened. When the net has been set out, several men start from some distance off and advance towards the opening, shouting and beating the water so as to drive fish to the surrounding area, to ensure a better catch. Shouting is usually more efficient in areas of clear water. The next step is to enclose completely the aquatic plants by closing the opening. Four or five fishermen drive inside the enclosed area, cutting and removing the plants out from it, meanwhile closing the net gradually. Step by step the fish are traped inside the net and are then removed out from it. El-Ganeb net is operated usually for fishing *Clarias* fish.

9.3.5.3. Trawl gears (Dragged gears)

9.3.5.3.1. Lawat

Lawat (Fig. 9.15) is a big trawl net used in Lake Burullus. This net consists of 180 to 200 meters netting, 8 meters height at the middle decreasing to 4 meters at the ends of the net. The net has 35 mesh bars per 50 cm at the middle portion, decreasing to 30 at the wings. The netting is manufactured of cotton twines No 20/4 or No 50/9, treated with cutch for preservation. Cork pieces are hung to the upper rope while lead is hung to the foot rope.

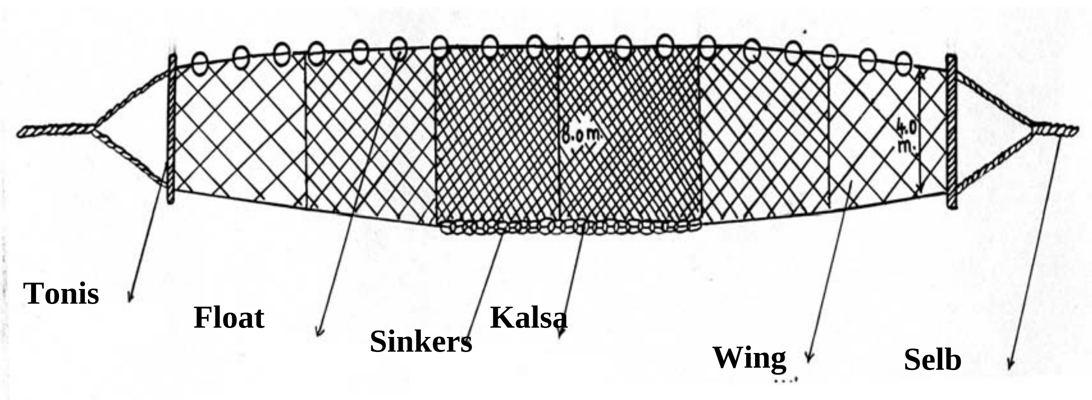


***Fig. 9.15*. Sketch of Lawat or Wannan net (El-Maghraby *et al.* 1977).**

The net is towed by two boats, each carries half the net. When the fishing operation starts, the two parts are joined. The center of the net is dragged on the bottom by a pole burdened by a rock or heavy iron chain. It is important to keep the bottom line close to the ground so as to prevent the escape of fish. The time of trawling depends on both the speed of wind and abundance of fish. The net is more or less dragged for about one km distance. The trawling is only possible when the wind is satisfactorily strong. After trawling, the net is lifted on the two boats and catch is removed. Once a fishing operation is completed, the two boats sail to a next fishing spot. Fishing with this net is usually carried out at day time; starting by sunrise and returning at sunset. All types of abundant fish are caught by this net.

9.3.5.3.2. Lokkafa

Lokkafa (Fig. 9.16) is a sac-like funnel shaped net, some 8 meters long, fastened to a wooden frame shaped like a reversed “V”. It is manufactured from cotton twines No 20/9 and sometimes of nylon twines Td 210/8. The wooden frame is made from a couple of curved wooden stalks, each measures about 3 meters long, and fastened together to form a “V” shape. A wire of about 120 cm. long is fastened between the ends of the two wooden pieces, forming the base of the triangle. The netting has 30 mesh bars per 50 cm. at the edges of the sack. The number of meshes diminishes gradually towards the ends of the funnel, reaching 80 meshes.

This net is tied to the side of the boat and is thrust nearly vertically into the water, and dragged by the boat, consequently any fish that may be enclosed falls back into the net. The net is lifted usually after half hour trawling. More catch is obtained at dark stormy nights. Lokkafa is not selective for certain fish species.

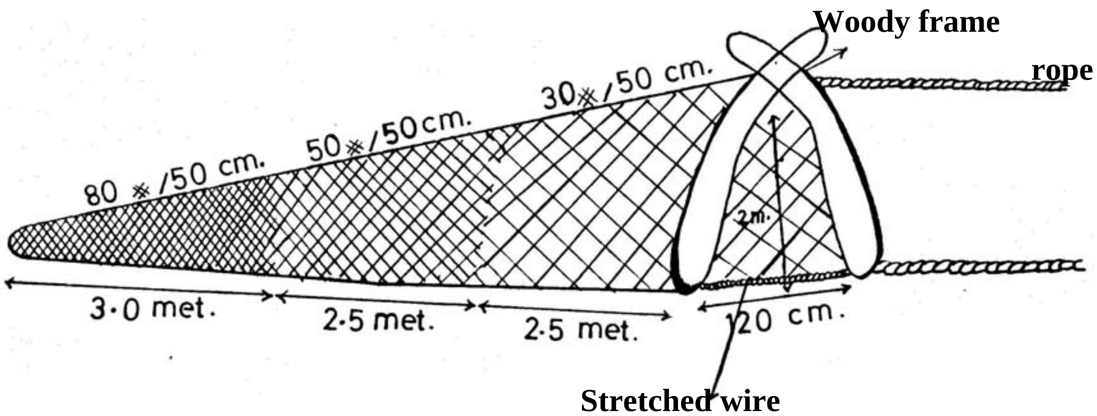


***Fig. 9.16*. Small trawl net (Lokkafa) (El-Maghraby *et al.* 1977).**

9.3.5.3.3. E1-Kerba

This net (Fig. 9.17) is more or less similar to Lokkafa, but smaller in size, with a modified wooden frame. The wooden frame is triangular in shape. A sharp iron plate 90 cm. long, constitutes the edge of the base of the frame. The "V" shaped piece is strengthened by cross bars. To the frame, a funnel shaped webbing about 6 meters long is attached. The funnel webbing is usually manufactured of nylon twines Td 210/6 or 210/9.

El-Kerba is tied to the side of the fishing boat with a strong rope. Fishing with this net is carried out in areas where aquatic plants are spreading. When trawling, the net is held by the fishermen themselves, where they push the wooden frame downward, cutting the plants by the sharp edges of the frame. Consequently, these plants as well as all fish living within the plants fall back into the funnel of the net. The net is then lifted on the boat where the catch is removed and plants thrown away. Fishing with this net is carried out at night; stormy nights are occasionally preferred, when more catch of various fish species is obtained.

9.3.5.4. Seine net (El -Shalta)

E1-Shalta is of the common type of seine nets used in the lake. The length of the net is around 10 meters. The upper rope is furnished by cork pieces as floats; the lower rope carries pieces of lead. The webbing is manufactured of cotton twines No 20/4, usually treated with seed oil as net preservative. The webbing has 40 meshes per 50 cm. There are poles tied to the ends of the net. This net is commonly used for hauling towards beaches. Two or more fishermen usually haul with this net.

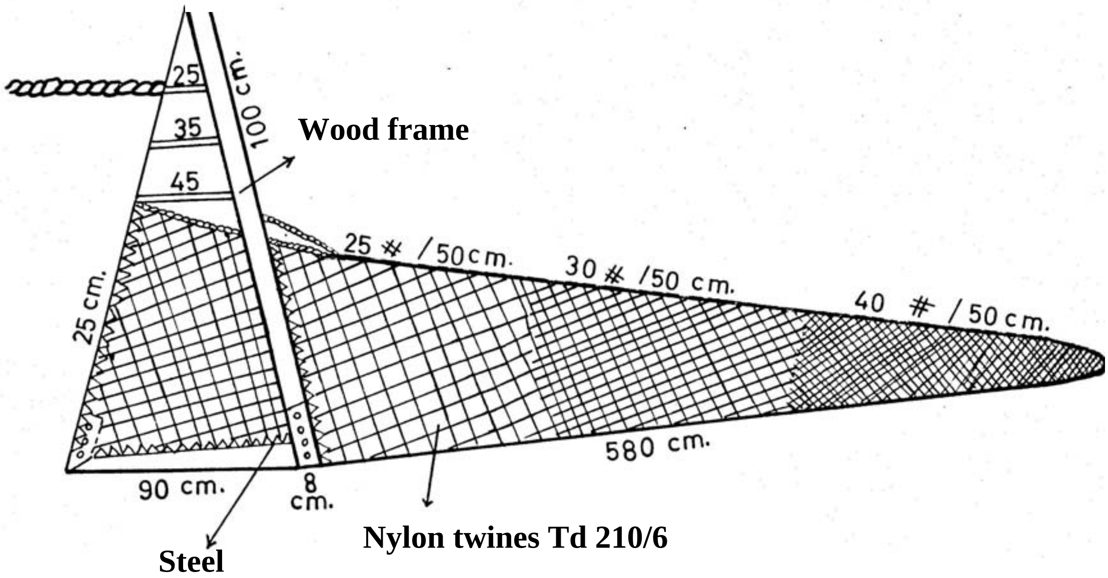


Fig. 9.17. **El-Kerba net (El-Maghraby *et al.* 1977)**

9.3.5.5. Set nets

9.3.5.5.1. Shrimp set net

Shrimp set net consists of two parts, a weir (fence) and a catching box. The weir is formed by three to four sections, some 20 to 30 meters long, each of one meter deep, 35 mesh bars per 50 cm. The net is fixed on bamboo stalks. The catching box is placed at the end of the weir. It is 10 to 15 meters long, 1.25 meter deep and has 45 meshes per 50 cm. It has a semicircle or semiellipse shape. The weir ends in the middle of the catching box. The ends of the semicircle turn back and lead close to the weir into the middle of the box. In such a way, two narrow slit entrances are formed on both sides of the weir. In one setting, usua11y three weirs and six catching boxes are present.

9.3.5.5.2. Set net for mullet

This type is used in the lake-sea connection area, mainly at the time of mullets migration. The net has two parts; the weir as that described in shrimp set net and the catching box composed of trammel net which is spirally turned. Another trammel net is fixed just outside the labyrinth above the water surface to capture those fish which try to jump over the wall of the box.

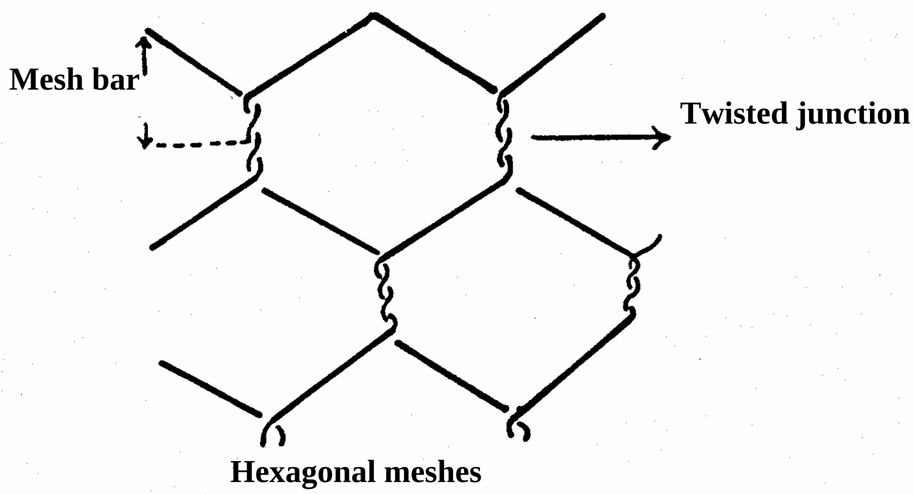
9.3.5.5.3. Mugil capito set net

This type is used during the spawning migration of *Mugil capito* towards the sea (October till December) in the lake-sea connection area. It is formed of a weir fastened to bamboo stalks. The height of the net is 175cm, the webbing has 35 mesh bars per 50 cm. The weir ends in spiral like turnings (three full turnings) of the catching box. In the middle of the labyrinth, there is a catching chamber. Besides, the box is provided with three to four back wings.

9.3.5.6. Traps

9.3.5.6.1. Wire basket traps

The wire traps (Fig. 9.18) used in the Egyptian Delta lakes are of non return basket type, made of galvanized wire webbing 0.8 mm diameter. A typical trap has one hoop, horizontally elliptical, 100 cm long and 50-60 cm in diameter. The meshes are hexagonal and the weirs are tripple twisted at the junctions. The cone at one end of the trap has an elongated and vertical opening for the passage of fish. The blind end has no hoop and the catch is removed through an opening which is closed by a clasp.



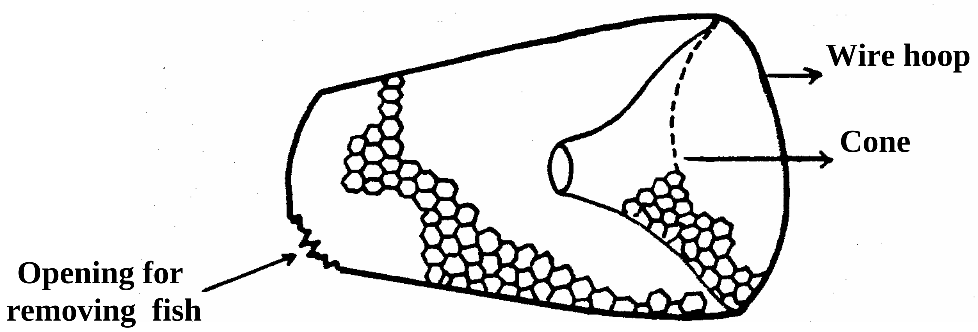


Fig. 9.18 **Wire basket trap (El-Zarka *et al.* 1970)**

These traps are usually set among aquatic vegetation, such as *Phragmites, Potamogeton* and. *Ceratophyllum* beds. In open water free from vegetation, the traps are either fixed to the bottom by bamboo sticks or in rows among an artificially made barrier. The barrier is usually made from bamboo sticks with gaps at intervals into which the traps are placed.

The traps which are very commonly used to catch mainly *Tilapia*, may also catch mullet fishes. The mesh bars of the traps usually range from 14 to 30 meshes in 50 cm. On the other hand, the traps are used to catch fishes which are traped behind an artificial muddy barrier. Traps with relatively narrow meshes are set in openings through the muddy barrier.

9.3.5.6.2. Clarias traps

Clarias traps (Fig. 9.19) are used to catch *Clarias* fishes, during their spawning season. This net is considered to be a complicated mode of fishing methods. The whole net consists of three traps joined together and the net is set between two banks of a freshwater stream; traversing the water flow. It is well known to the fishermen in Lake Burullus that *Clarias* fish move towards the fresh water during the spawning season. They usually prefer swimming near the banks of the stream.

The webbing is made from cotton twines No 20/8. The wings of the traps are fixed by dry bamboo sticks, about one meter height. Each trap is fixed also between two sticks. The number of sticks used depends on the velocity of water flowing. Before setting up the net, the muddy bottom is piled up in the form of a dune. The sticks are fixed in this muddy dune in a way that the dune, touches the mouths of the three traps. This dune serves as an underline for the mouth of the trap. The fishes while moving on the muddy bottom enter through the mouth of the trap to the cone.

Fishing with this net is carried out during night, where the net is fixed daily just before sunset and the catch is removed before sunrise. The net is left up for removing the catch, cleaning and drying during day time.

9.3.5.7. Hook and line gears

Line fishing is carried out at Lake Burullus, using baited or unbaited hooks; the hooks are made of iron. The first type is represented by a line carrying small hooks that are attached to the line by means of a 50 cm long cord, at distances of about 5 cm. Small fishes serve as bait. A line has some 500 to 600 hooks. Another type of line is provided with bigger hooks which are unbaited. This type in adapted for fishing on softly-bodied fishes like *Bagrus bajad* and *Clarias* sp. The lines are usually laid down at sunset and picked up again at sunrise, when they are dried by being coiled on pools.

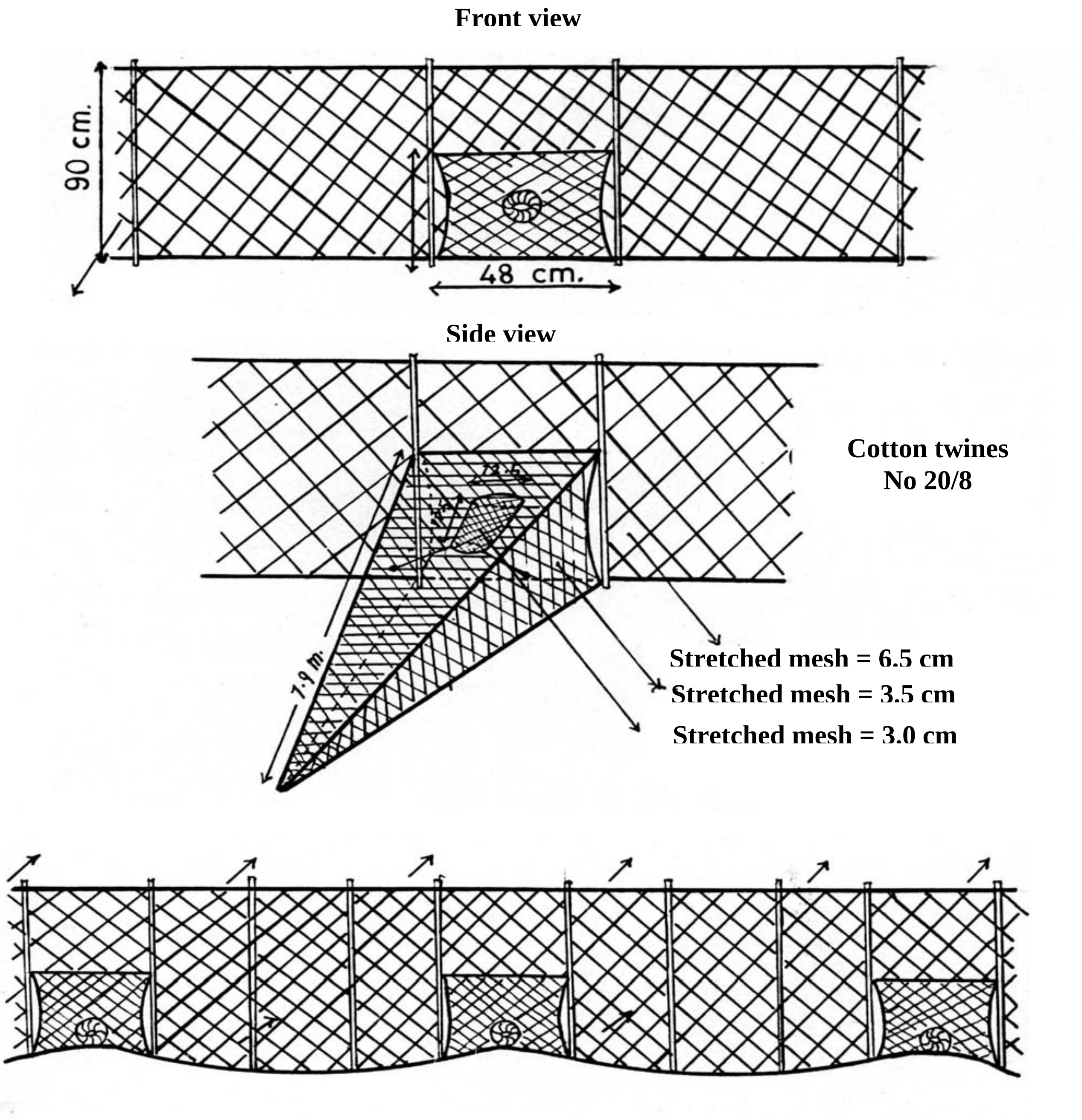


Fig. 9.19 **Clarias trap (El-Maghraby *et al.* 1977).**

9.3.5.8. Cast nets (Torraha or Shabka)

Torraha is a circular throwing-out, with an average circumference of about 15 feet and has about 30 mesh bars in 50 cm. The net webbing is manufactured of cotton twines No 20/9, sometimes of Nylon twines Td 210/6. A strong cord is attached to the middle of the net and a thin cord runs around the circumference. To the latter cord leads are attached about 8 cm apart and it is looped up at each 50 cm to the inside of the net, at a height of about 15 cm, thus forming a series of pockets in which the fish otherwise entangled in the meshes get caught. Fishes with the exception of very large ones, rarely escape under the edge of the net.

The net is used in the following manner; the cord and the middle portion of the net to which it is attached, is gathered up in the right hand, half the net now hanging down in front of the fisherman. The fisherman is now ready to make a cast, and firmly planting his feet on the ground he turns the upper part of his body away from water and then swings smartly back again, releasing the net from his left hand.

If the net is properly thrown, it should fall on the surface of water in more or less complete circle. The net is now allowed to sink on the bottom and is then carefully drawn in, the fishes are taken out and the water squeezed out of the net, which is gathered up for a fresh cast. Before casting, the fishermen sometimes throw in a large stone or strikes the water with a stick, this often has the effect of attracting fish to the spot, on which casting is carried out.

9.3.5.9. Hosha

It is an enclosure located within the lake area (mostly at the southern shores of the lake, as well as around some islands). It is a pond represented by shallow water basin built by erecting low dykes made of mud and straws. It has one or more narrow openings connecting it with the lake. Fish swim into the Hosha through these openings, which are periodically closed. Then the Hosha is pumped dry and the fish are harvested. This fishing method may be repeated several times during the year, the bulk of the yield consists of small, low value cichlid species.

In 1982, there were 171 licensed Hosha in Lake Burullus (i.e. presumably modified with fish culture practices). Hosha operations occupy 12,689 ha (28,838 feddan). Of these, 45% were 1-42 ha in size , 28% were 42-84 ha, and a further 12% were 84 -126 ha. The remaining 15% were of operations 126-420 ha in size. Interestingly, Lake Burullus Area Development Study found that, in addition to the 171 licensed Hosha, there were an estimated 1,079 unlicensed or illegal Hosha in lake Burullus. Together the total estimated Hosha area amounted to 17,522 ha (39,822 Feddan), i.e 38% more than that officially licensed. While the officially licensed Hosha averaged more than 74 ha in size, the unlicensed Hosha average only 4-5 ha. It is estimated that Hosha operations with fish farms occupy an area nearly 1/3 the size of the open water area .

The studies revealed also that Hosha yields per ha are much higher than yields per ha from open lake fishing. On the average, Hosha produces nearly two times the yield per ha produced in the open lake (0.970 ton per ha as compared with 0.541 ton per ha).

The fishermen consider Hosha as a negative factor, focusing on the competition for the same stock of fish and the competition for fishing areas. Furthermore, fishermen believe that Hosha reduces the production potential of the lake, primarily because it harvests all age groups. Some Hosha. particularly in the tilapia grounds of Lake Burullus's southern sector, produce small-sized fish (less than 6 cm) which are used for production of poultry meal. The proportion of small fish in the Hosha harvest ranges from 15% to 30%.

The long standing arguments against Hosha that it reduces important inshore breeding grounds and that it indiscriminately harvests fish of all sizes and thus (harmfully) removes juveniles from the potential breeding population may have had some validity prior to the construction of the Aswan High Dam. However, the change to a more freshwater environment has weakened both criticisms. First, the new water regime has resulted in aquatic vegetation and the accompanying tilapia breeding areas spreading throughout the lakes. Thus the preservation of these inshore areas is now less important. Furthermore, the spread of aquatic vegetation has rendered much of the shallow shoreline unsuitable for open water fishing gears. Second, the change to a higher yielding fishery much dominated by tilapia, means that increased fishing pressure and thinning of juveniles may help diminish the problems of over-recruitment of tilapia. In addition, it is likely that Hosha's periodic drying of the bottom sediments will stimulate the recycling of nutrients, thus contributing to the overall productivity of the fisheries. This has been confirmed by many reports by algal blooms in newly flooded Hosha .

9.4. MAIN THREATS TO FISHERIES OF LAKE BURULLUS

1- Neglecting of clearing and dredging the lake-inlet to the Mediterranean is the first complaint of fishermen. The only remaining Burullus inlet near Burg El-Burullus is not dredged at regular basis. Decreasing of salinity levels have damaged the fish habitat and nursery of some marine high – valued fish.
2- Hosha, an illegal method of fish catching is widely practiced in lake Burullus, that harvests all sizes of fish that certainly affects the fish production of the lake.
3- Illegal capture of small fishes and fry directly from the only existing inlet by illegal operating gangs to provide fish farms established on the southern shore of the lake.
4- Using illegal fishing gears with small meshes leads to catching non-commercial sizes, which are finally dried up and used in feed industry. This certainly affects negatively upon the net fish production of the lake.

5- Hydrological and water balance studies revealed that the drainage water has dominated the lake ecosystem, and the water inflows into the lake are always greater than outflows. That means water in the lake is in a continuous movement toward the sea, and salinity has been reduced in the lake, which undoubtedly is reflected upon the disappearance of marine fish species from the lake.

6- Pollution and waste disposal:

Agricultural drainage. Agricultural drainage water with increasing quantities of fertilizer and pesticide loads are being released into Burullus, contributing significantly to the eutrophication and pollution of the lake.

Municipal wastewater. Untreated wastewater from Baltim and the villages outskirting Lake Burullus is directly released into the Lake. This has led to the rapid eutrophication of parts of the Lake and further promoted the extensive growth of *Phragmites australis* beds. Also, the drainage of toxic and industrial wastes into the lagoon eradicated some sensitive fish stocks and tainted the water; even some of the fishermen suffered from skin diseases.

Solid waste dumping. Solid waste is one of the main sources of environmental pollution associated with human settlements in Egypt today. Currently, there are no mechanisms or facilities to deal with solid waste in the sector.

7- The low awareness of fishermen about environmental issues as well as management plans and their importance, combined with limited understanding of the role of protected areas and their value (at both local and national levels) are some of the basic factors, which hinder the proper fisheries management of Lake Burullus and threaten their integrity in the long run.

9.5. RECOMMENDATIONS FOR FISHERIES MANAGEMENT

1- Economically, the main activity in Lake Burullus Protectorate is fish production, where the population majority declared that their income source comes from fishing. Therefore, fisheries activities must have priority in developing the population standards because this is the first step for sustainability.

2- It is essential for the preparation of the fisheries management plan that it includes the interests of Governmental (The local branch of the General Authority for the Development of Fisheries Resources: GADFR/Ministry of Agriculture) as well as other national agencies (Conservation Organizations and Development Agencies. A supplementary participation of local people in management efforts is needed, because when the local inhabitants feel part of development and progression, then the conservation organizations can be sure that the protection and management of the wetland is guaranteed. Therefore, wide steps should be taken to promote the public awareness towards understanding the management and protection of natural resources.

3- At the initial stage of the management and monitoring process, a baseline data need to be established, to serve as a starting point, with which subsequent monitoring results are compared. Some of the results of the current site studies could be used as a basis for the Burullus baseline data.

4- Obtaining regular data on fisheries from local fisheries authorities (High priority). It is particularly important to collect accurate information on the economic value of the fisheries and fish production in the Protected Area. This information will be very useful in determining and evaluating fisheries management options in the Protected Area.

5- The water inflow of the agricultural drainage canals into the lake should be examined regularly to control polluted water inflow into the lake.

6- Removal of solid wastes from lakeside; either by re-allocation of these wastes away from lake water to a more environmentally acceptable area or constructing a plant for recycling these wastes; in addition to raising public awareness to discourage littering.

7- Restoring the natural status of the lake by addressing Baltim's sewage waste problem, by liaising with the National Agency for Drinking Water and Sanitary Wastes to construct the sewage treatment plant through the local advisory committee.

8- Monitoring the lake water level and salinity through an adequate management program to control the quantity of drainage water inflow into the lake.

9- Fish farming is becoming a prominent activity along shores of Lake Burullus, occupying increasingly large areas, and their total production in 2000 was about 115,335 tones, i.e. more than twice of open water production. They are often attracting large numbers of waterbirds and other wildlife. There is a need to assess the ecological value of aquacultures in the region as alternative wetland habitats, and the effect that various management procedures applied have on that value. The study should propose ways which maximize benefits to both fisheries and wildlife.

10- Illegal fishery practices should be banned, such as capture of fry and small fishes from the sea inlet area, "Hosha" fishing procedure, and using illegal fishing gears with small meshes.

11- Fishery management of cichlid species must be based on the criterion of gaining extra fish weight, because the mean size of cichlid species in the catch of Lake Burullus does not affect their breeding activities, i.e. first maturity is usually attained at small sizes. By this procedure, the total catch of cichlid species from the lake is expected to increase two or three times than that available today. It is suggested that the most effective method to attain such gain is the regulation of the mesh of fishing gears. So, it is recommended that the stretched mesh size of the trammel nets should not be less than 2.86 cm (or mesh number 17) to catch cichlid fishes of 15.0 cm mean selection length for either *Oreochromis niloticus* or *T. zillii*. For traps, it is advised that the mesh size of wire traps should not be less than 25 mm (mesh bar) to give a mean selection length of 16 cm for *0. niloticus*, 15.5 cm for *T. zillii* and 15 cm for *S. galilaeus*.

Based on the above, it is recommended that the minimum catchable size should be 15 cm, instead of the present legal size 10 cm. Consequently, this will increase the average weight of individual fish from 40 to 60 gm and hence the total fish yield.

12- Fishery management of mullet fishes is based on raising salinity of Lake water and regulating of a closed fishing season from December 20th to January 20th; the peak period of migration of juvenile mullets from the Mediterranean into the Lake.

9.6. SUMMARY

The occurrence of brackish and saline waters in Lake Burullus during seventies and early eighties of the last century, has resulted in a large variety of fish species inhabiting the Lake; approximately 32 species were recorded in the Lake during these periods. Decreasing of salinity and dominating of drainage water in the lake during the last two decades has led to change in species composition and biodiversity of fishes and other organisms. The field survey during 2000 – 2002 period showed that the diversity of fishes in Lake Burullus has declined from 32 to 25 species. All the species which have disappeared are of marine affinity. On the other hand, the total production of the lake has increased gradually from 7349 ton in 1963 to its maximum of 59000 ton in 2002. In the course of these forty years, a sharp decline in the total yield was recorded, especially in the middle of seventies, where the production declined to 4556 and 4875 ton in 1973 and 1974, respectively. Higher yields were regained in 1976 (6573 ton).

As far as the main groups of fishes are concerned, a gradual decrease in the mullet catch was recorded from about 44.7% in 1963 to 17% in 2000 of the total catch. This was accompanied by an increase of tilapia production from 42.8% in 1963 to 72% in 1992, and then decreased to about 67.8% in 2003. The shift was more pronounced during the eighties of the last centurry. On the other hand, the annual production of certain freshwater fish species has gradually increased, especially during the last five years. This relates to two species; *Clarias gariepinus* and *Bagrus bajad*, where their production increased from 188 and 220 ton in 1963 to 2150 and 744 ton in 2003, respectively. The production of marine fishes, such as *Johnius hololepidotus* and *Dicenlrarchus labrax* was greatly decreased. All these changes confirm an increased predominance of freshwater components in the fish stock of the lake, reflecting the changes that the lake underwent in the water supply, mostly from drains, and reducing chlorosity of water, especially in the eastern part of the lake in association with the huge drains newely constructed at that area.

Cichlids are represented in Lake Burullus by four main species which are *Tilapia zillii, Sarotherodon galilaeus*, *Oreochromis niloticus* and *O. aureus*. Besides, there are two species of cichlids, namely *Hemichromis bimaculatus* and *Haplochromis bloyeti* but these are of little economic importance due to their small sizes. It was found that *Oreochromis niloticus* was the most abundant species in the 2002 catch, constituting more than 40.5 % of the total catch, followed by *Oreochromis aureus* (34.7 %), while *Sarotherodon galilaeus* was the least frequent species contributing 24.8 %. In the eastern sector, *Oreochromis aureus* is the most commonly distributed one (38.5 %) followed by *Sarotherodon galilaeus* (31.5 %), then *Oreochromis niloticus* (30.1 %). In the middle and western sector, *Oreochromis niloticus* is the major one with 39.8% and 53.6 %, respectively. *Oreochromis aureus* represents 35.7 and 28.9 %, whereas *Sarotherodon galilaeus* is the minorly distributed with 24.5 and 17.5 % in the two sectors, respectively.

On the other hand, five species of mullets are present in Lake Burullus namely: *Mugil cephalus, Liza ramada*, *Liza aurata*, *Liza saliens* and *Chelon labrosus*. *Liza ramada* is the most dominant species of the mullet catch throughout the year. Its accessibility in the nets operating in the lake greatly increases during November and December, when the fish is sexually ripe. *M. cephalus* production ranks next to that of *L. ramada.* Its maximum yield is attained during summer, representing maturation period. The fishery of *Liza saliens* whose production comes next to that of *M. cephalus* extends from late spring to the beginning of autumn. The maximum fishing of this species is recorded in September, during which the fish leaves the area of the lake-sea connection, where it is localized and migrates to the sea.

According to the statistical data, the number of fishermen has increased from about 9000 men in 1963 to about 21660 men in 1993, then to about 28,000 in 2002. The number of boats has increased from 2438 boats in 1963 to about 7277 in 1993 to 10489 boats in 2000. The annual catch per fisherman has been nearly doubled from about 0.8 ton in 1963 to about 2.0 ton in 1993, then decreased to about 0.9 ton in 2000. Likewise, the catch per boat has been doubled from about 3 ton in 1963 to about 6 ton in 1993, then decreased to about 5.3 ton in 2000. Statistical analysis of production functions revealed that the total catch of the lake is positively correlated with the total number of boats and fishermen. This interdependence, between catch and fishing effort, is largely responsible for the variations in fish yields from year to year.

9.7. REFERENCES

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9.8. PLATES OF FISHES (9.1 – 9.15)

(after Bishai & Khalil 1997, Website: www.fishbase.org 2000)

Plate 9.1
Tilapia zillii
Oreochmmis niloticus niloticus

Plate 9.2
Oreochromis aureus
Sarotherodon galilaeus

Plate 9.3
Clarias gariepinus
Lates niloticus

Plate 9.4
Mugil cephalus
Liza ramado

Plate 9.5
Dicentrarchus punctatus
Bagrus bajad

Plate 9.6
Anguilla anguilla
Liza saliens

Plate 9.7
Disentrarchus labrax
Sparus aurata

Plate 9.8
Solea solea
Atherina boyeri

Plate 9.9
Labeo niIoitcus
Hydrocynus forskalii

Plate 9.10
Gambusia affinis
Barbus prince

Plate 9.11
Barbus bynni bynni
Aphanius fasciatus

Plate 9.12
Pomatoschistus microps
Haplochromis bloyeti

Plate 9.13
Hemichromis bimaculatus
Engraulis encrasicholus

Plate 9.14
Belone belone
Liza aurata

Plate 9.15
Chelon labrosus
Pomatoschistus minutus