Chapter 9
Fisheries

Assessment of Lake Nasser fisheries is required for better development and management of the resources on which the fishing is based. This requires a certain preliminary assessment of the level of exploitation of the fishery relative to its potential. Furthermore, details of the biological and ecological constraints to the resource are needed for the effective management and monitoring.

As a matter of fact, remarkable changes both in environment and fishery have been occurring in Lake Nasser since the construction of the High Dam. Unfortunately, there is a lack of adequate scientific knowledge and data on the present fish stocks, under the changing environmental conditions. Lake Nasser was originally a multispecies fishery during the first period of impoundment (1966-1975). At present, fish stocks are dominated by *Sarotherodon galilaeus* and *Oreochromis niloticus.* The remaining fish species have either declined to insignificant levels or almost in their way to disappear from the Lake. There has been no continuous information on the fish stocks in offshore and inshore waters of the Lake. Recently, Mekkawy (1998) carried out a study on fish stock assessment of Lake Nasser, with emphasis on those of *0. niloticus* and *S. galilaeus,* based on previous data collected by various investigators (Abdel-Azim 1974, Latif & Khallaf 1987, Yamaguchi *et al.* 1990, Vanden - Bossche & Bernacesk 1991, Adam 1994, Ahmad 1994, Mekkawy *et al,* 1994 & Mekkawy & Mohamed 1995).

IMPORTANT FISHING SITES AND KHORS

The presence of side extensions known as khors is an important feature of Lake Nasser. Fig. 2 shows the important fishing sites and khors of the Lake. The six major fishing areas of the Lake are shown in Fig. 149. The length of shoreline of khors is 969.9 km, the length of shores of eastern and western khors are 576.33 and 393.57 km respectively. The number of important khors is 85 of which 48 are located on the eastern side, and 37 on the western side (Fig. 2). The dimensions of some khors are shown in Table 101.

Table 101 **Dimensions of some khors of Lake Nasser***

Name of khor	Position in the Lake	Distance from the HD km	Length (km)		Area (km^2)		Perimeter (km)		Depth (m) at 160m level	Water volume (million m^3)	
			at 180 m level	at 160 m level	at 180 m level	at 160 m level	at 180 m level	at 160 m level		From 160-180 m level	From bottom to 160 m level
Kendy	East	0.5	4.0	3.2	2.5	1.4	10	7	30	0.039000	0.042000
Wadi Kurkur	West	11.0	25.72	4.5	101.2	8.4	284	29	20	1.096000	0.168000
Wadi Dihmit	East	35.0	20.50	6.0	56.8	6.3	226	11.5	20	0.631000	0.126000
Wadi Kalabsha	West	46.0	47.20	22.0	620.0	54.0	517	85	40	6.740000	2.160000
Rahma	East	48.0	23.58	21.0	95.2	42.4	232	42	40	1.376000	1.696000
Wadi Abyad	East	68.0	18.30	14.0	48.7	9.60	184	31	20	0.583000	0.192000
Wadi Mariya	East	70.0	17.42	11.0	80.7	58.5	184	46	20	1.392000	1.170000
Wadi Abesco	East	185.0	18.56	16.0	139.8	41.20	79	46	20	1.810000	0.824000
Wadi El-Allaqi	East	100.0	54.83	30.5	490.8	64.7	510	100	40	5.555000	2.588000
El-Meharraka	East	125.0	8.7	6.5	99.25	14.4	53	15	20	1.136500	0.288000
Shaturma	East	160.0	19.0	10.2	25.96	11.3	211	27	30	0.372600	0.339000
Korosko	East	177.0	22.56	10.7	83.6	23.4	253	34	30	1.070000	0.702000
El-Genena	East	239.0	13.54	7.0	48.2	15.80	103	20	10	0.640000	0.158000
Tushka (East)	East	245.0	15.2	9.4	66.9	28.7	117	25	20	0.956000	0.574000
Tushka (West)	West	245.0	33.35	24.1	366.8	49.10	127	89	20	4.159000	0.982000
Wadi Hamido	East	254.0	15.0	4.8	100.0	27.10	55	19	20	1.271000	0.542000
Wadi Or	East	285.0	19.23	6.3	52.4	11.3	110	19	20	0.637000	0.226000
Adindan	East	304.0	8.7	4.8	10.5	6.8	16	9	20	0.173000	0.136000
Sourah	West	312.0	21.05	15.0	122.4	24.40	60	42	20	1.468000	0.488000

***Source : Survey Department, High Dam Lake Development Authority, Aswan.**

According to the perimeter, the important khors are in the following order: Khor Kalabsha, Wadi El-Allaqi, Kurkur, Korosko, Khor El-Birba (El-Ramla), Rahma, Dihmit, Shaturma, Wadi Abyad, Mariya, Masmas, Tushka and Or which have perimeters more than 100 km at 180 m level. This factor seems to be important from the aspect of fish production as open water fishing has not yet been taken up. Surface area at this stage of fishery development is relatively less important (Latif 1974b).

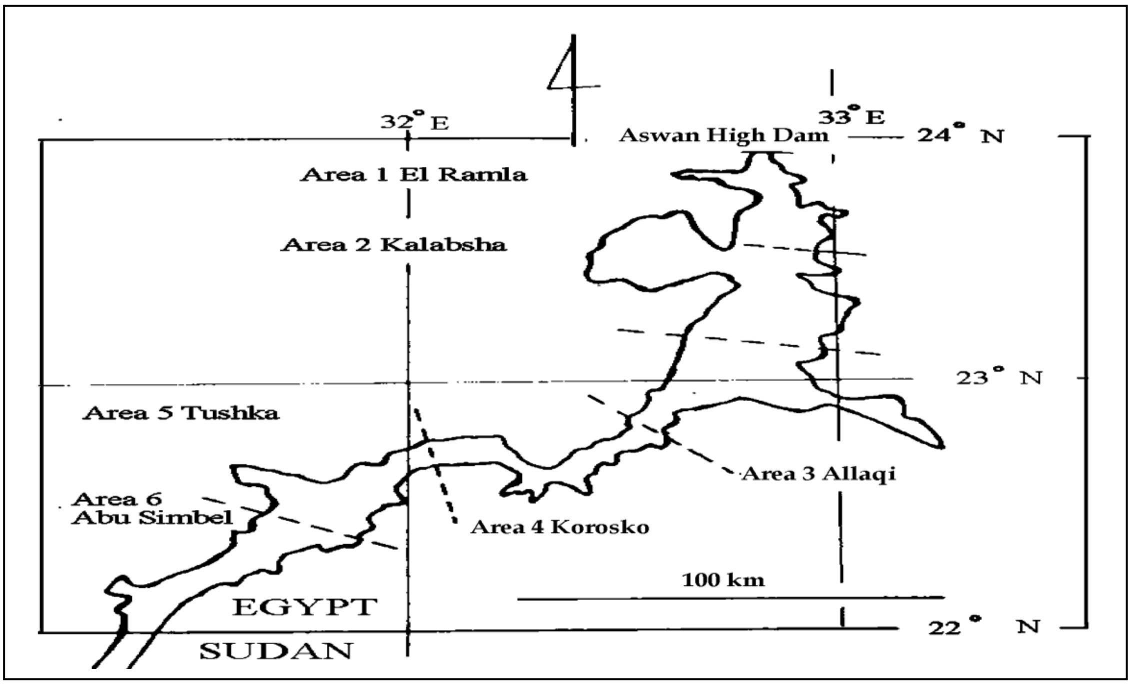


Fig. 149 Fishing areas of Lake Nasser.

FISH PRODUCTION

A list of commercial fishes from Lake Nasser is presented in Table 102. The pre-dominant marketable fresh fishes are *Sarotherodon galilaeus, Oreochromis niloticus, Lates niloticus, Labeo* spp., *Bagrus* spp. and *Synodontis* spp., while the salted fishes are mostly *Hydrocynus forskalii, Alestes* spp. and *Schilbe (Eutropius) niloticus* (Latif 1974a and b and 1977).

Fish are usually landed either fresh or salted. The amount of salted fish was considerable and formed from 44.73 to 56.72% with an average of 51.75% during the first period (1966-1968). During the second period (1969-1978), the percentage of salted fish decreased and ranged between 21.44 and 40.63% with an average of 32.72% (Tables 103 and 104). A sharp decline in the salted fish was noticed during the last period (1979-1996), since the percentage of salted fish in the landings ranged between 3.88 and 16.18% only with an average of 10.30% (Tables 103 and 104).

Table 102 **List of the commercial fishes of Lake Nasser.**

Family	Species	Local name	
Cichlidae	*Oreochromis niloticus*	Bolti Nili	بلطى نيلى
	Sarotherodon galilaeus	Bolti Galilae	بلطى جاليلى
Centropomidae	*Lates niloticus*	Samoos, Ishr-Bayad	ساموس - قشر بياض
Bagridae	*Bagrus bajad*	Bayad	بياض
	Bagrus docmak	Docmak	دقماق
Cyprinidae	*Labeo niloticus*	Lebeis abyad	لبيس أبيض
	Labeo coubie	Lebeis aswad	لبيس أسود
	Labeo horie	Lebeis aswad	لبيس أسود
	Barbus bynni	Benni	بنى
Clariidae	*Clarias anguillaris*	Karmout Zaflout	قرموط زفلوط
	Clarias gariepinus	Karmout Lazeer	قرموط لازير
	Heterobranchus bidorsalis	Karkour Hela	كركور حالا
	Heterobranchus longifilis	Karkour Asli	كركور أصلى
Characidae	*Hydrocynus forskalii*	Kalb-el-samak	كلب السمك
	Brycinus nurse	Sardina	سردينه
	Alestes dentex	Raya, Omaya	رايه
	Alestes baremoze	Raya, Omaya	رايه
Mormyridae	*Mormyrus kannume*	Boweza, Anooma	بويز - أنومه
	Mormyrus caschive	Boweza, Anooma	بويز - أنومه
Schilbeidae	*Schilbe (Eutropius) niloticus*	Schilba	شلبه
	Schilbe (Sehilbe) mystus	Schilba	شلبه
	Schilbe uranoscopus	Schilba-Arabi	شلبه عربى
Synodontidae	*Synodontis spp.*	Schall.	شال

Commercial fish species according to their feeding habits

The commercial fishes are classified by Latif *et al.* (1979), according to their feeding habits in the following groups:

1. Periphyton-plankton feeders including *Sarotherodon galilaeus* and *Oreochromis niloticus.*

2. Zooplankton-insect feeders represented by *Alestes* spp.

3. Omnivorous fish feeding mostly from the bottom and or between stones, including mainly *Barbus* sp., *Labeo* sp., synodontids, shilbeids and mormyrids.

4. Carnivorous fish including *Bagrus* spp., *Lates* sp., *Hydrocynus* spp., *Clarias* spp. and *Heterobranchus* spp.

Table 103 **Commercial fish landings from Lake Nasser (1966-1999) in relation to water level and number of fishing boats. [Data from: Statistical Department, Central Managment Fisheries Resources, Lake Nasser Development Authority, Aswan.**

Year	Total landings (ton)	Fish landings (ton)				Water level (m above sea level)			No. of fishing boats
		Fresh fish		Salted fish		Maximum	Minimum	Average	
		ton	%	ton	%				
1966	751	347	46.21	404	53.79	141.32	119.20	130.17	200
67	1415	782	55.27	633	44.73	151.08	133.48	142.28	350
68	2662	1152	43.28	1510	56.72	156.55	145.29	150.92	500
69	4670	2802	60.00	1868	40.00	161.29	150.80	156.05	599
1970	5676	3370	59.37	2306	40.63	164.88	153.81	159.35	816
71	6819	4316	63.29	2503	36.71	167.64	159.65	163.65	1039
72	8343	5303	63.56	3040	36.44	165.30	162.49	163.90	1135
73	10587	8027	75.82	2560	24.18	166.32	158.20	162.26	1440
74	12255	8030	56.52	4225	34.48	170.64	161.00	165.82	1540
75	14635	10384	70.95	4251	29.05	175.71	165.60	170.66	1630
76	15791	10929	69.21	4862	30.79	176.55	172.42	174.49	1680
77	18471	12279	6648	6192	33.52	177.21	171.69	174.45	1690
78	22725	17852	78.56	4873	21.44	177.49	172.44	174.97	1700
79	27021	22649	83.82	4372	16.18	175.95	173.03	174.49	1613
1980	30216	26344	87.19	3872	12.81	176.22	171.18	173.70	1570
81	34206	31295	91.49	2911	8.51	175.96	171.13	173.55	1500
82	28667	25979	90.62	2688	9.38	172.63	170.18	171.41	1450
83	31282	28885	92.34	2397	7.66	169.86	165.64	167.75	1388
84	24534	22069	89.95	2465	10.05	169.42	162.97	166.20	1385
85	26450	24975	94.42	1475	5.58	164.34	156.15	160.25	1382
86	16315	15.023	92.08	1292	7.92	163.61	156.14	160.38	1379
87	16815	15287	90.91	15.28	9.09	161.66	154.50	158.08	1379
88	15888	14579	91.76	1309	8.24	168.82	150.62	159.72	1244
89	15650	14031	89.65	1619	10.35	169.79	164.30	167.05	1175
1990	21882	20129	91.99	1753	8.01	169.50	163.72	166.61	1915
91	30838	29642	96.12	1196	3.88	169.35	162.23	165.79	1927
92	26219	24721	94.29	1498	5.71	170.75	163.84	167.30	1961
93	17931	16723	93.26	1208	6.74	174.32	167.24	170.78	1900
94	22074	20491	92.83	1583	7.17	177.28	169.51	173.40	2304
95	22058	19692	89.27	2366	10.73	176.93	172.32	174.62	2200
1996	20541	18160	88.41	2381	11.59	178.55	172.28	175.41	2200
97	20601	16644	80.79	3957	19.21	178.52	175.40	177.38	2200
98	19203	15013	78.18	4190	21.82	181.30	174.66	178.13	2200
1999	13983	9876	70.63	4107	29.37	181.60	175.66	178.92	2200

Table 104 **Percentage of fresh and salted fish landings from Lake Nasser during different periods (1966-1996).**

	Percentage of fresh fish landings		Percentage of salted fish landings	
	Range	Average	Range	Average
1966-1968	43.28-55.27	48.25	44.73-56.72	51.75
1969-1978	59.37-78.56	67.28	21.44-40.63	32.72
1979-1996	83.82-96.12	89.70	3.88-16.18	10.30

The percentages by weight of fishes with different feeding habits during the period from 1966 to 1996 are shown in Table 105. Also, the average percentage by weight of fishes with different feeding habits during three successive periods (1966-1972, 1973-1978, and 1979-1996) are shown in Table 106 and Fig. 150. From the aforementioned results it is obvious that the composition of fish landings is in favour of periphyton-plankton feeders. Thus, during the first period (1966-1972) the average percentage of the annual catch of periphyton-plankton feeders was 39.92%. This percentage increased gradually during the following periods, being 66.27 and 88.27% during the second (1973-1978) and third (1979-1996) periods (Table 106 Fig. 150). On the other hand, the average percentage of the annual catch of carnivorous and zooplankton-insect feeders was 42.04% during the first period (1966-1972), which decreased gradually to 32.96 and 10.76% during the second and third periods respectively. Furthermore, the average percentage of the annual catch of omnivorous fishes was 18.04% during the first period (1966-1972), followed by a sharp decrease to 0.77 and 0.97% during the second and third periods respectively (Table 106 and Fig. 150).

Evolution and trends of total fish catch

The total fish catch during 1966 -1999 is presented in Table 103 which shows a catch ranging from 751 to 34,206 ton with an average annual catch of 17.85 x 10^3 ton. The differences between the annual catch and the average annual yield (i.e. 17.85 x 10^3 ton) are presented in Fig. 151. It is obvious that a remarkable decrease from the average annual yield was recorded during the first period (1966-1976) (Fig. 151). On the other hand, the annual catch values were higher than the average annual yield during the second period (i.e. 1977-1985). It is worthy to mention that the drought period was from 1984 to 1988.

Table 105 **Percentage by weight of fishes with different feeding habits during the period from 1966 to 1996.**

Year	Percentage by weight of fishes (%)		
	Feeding habit		
	Periphyton-plankton feeders	**Carnivorous and zooplankton - insect feeders**	**Omnivorous feeders**
1966	37.06	45.07	17.87
7	33.33	44.80	21.87
8	28.73	43.07	28.20
9	42.30	37.30	20.40
1970	42.00	43.61	14.39
1	46.30	40.00	13.70
2	49.70	40.40	9.90
3	67.15	30.87	1.98
4	59.11	40.22	0.67
5	66.00	33.97	0.03
6	67.14	32.86	-
7	60.55	37.49	1.96
8	77.65	22.35	-
9	82.90	15.87	1.23
1980	84.16	14.60	1.24
1	89.25	9.49	1.26
2	82.72	16.21	1.07
3	90.43	8.93	0.64
4	93.21	5.90	0.89
5	93.22	6.14	0.64
6	90.34	7.29	2.37
7	86.37	11.00	2.63
8	86.21	11.51	2.28
9	83.12	14.88	2.00
1990	89.41	10.19	0.40
1	95.29	4.69	0.02
2	92.06	7.94	-
3	90.30	9.70	-
4	90.00	10.00	-
5	85.80	14.20	-
6	84.01	15.09	-

(-) not recorded

Table 106 **Average percentage by weight of fishes with different feeding habits during three successive periods.**

Period	**Average percentage by weight of fishes (%)**		
	Feeding habit		
	Periphyton-plankton feeders (1)	**Carnivorous and zoo-plankton - insect feeders (2)**	**Omnivorous fishes (3)**
1966-1972	39.92	42.04	18.04
1973-1978	66.27	32.96	0.77
1979-1996	88.27	10.76	0.97

(1) *Sarotherodon galilaeus* and *Oreochromis niloticus.*
(2) *Hydrocynus forskalii, Lates niloticus, Bagrus bajad, B. docmak, Brycinus nurse, A. dentex* and *A. baremoze.*
(3) *Labeo* spp., *Barbus* spp., synodontids, shilbeids and mormyrids

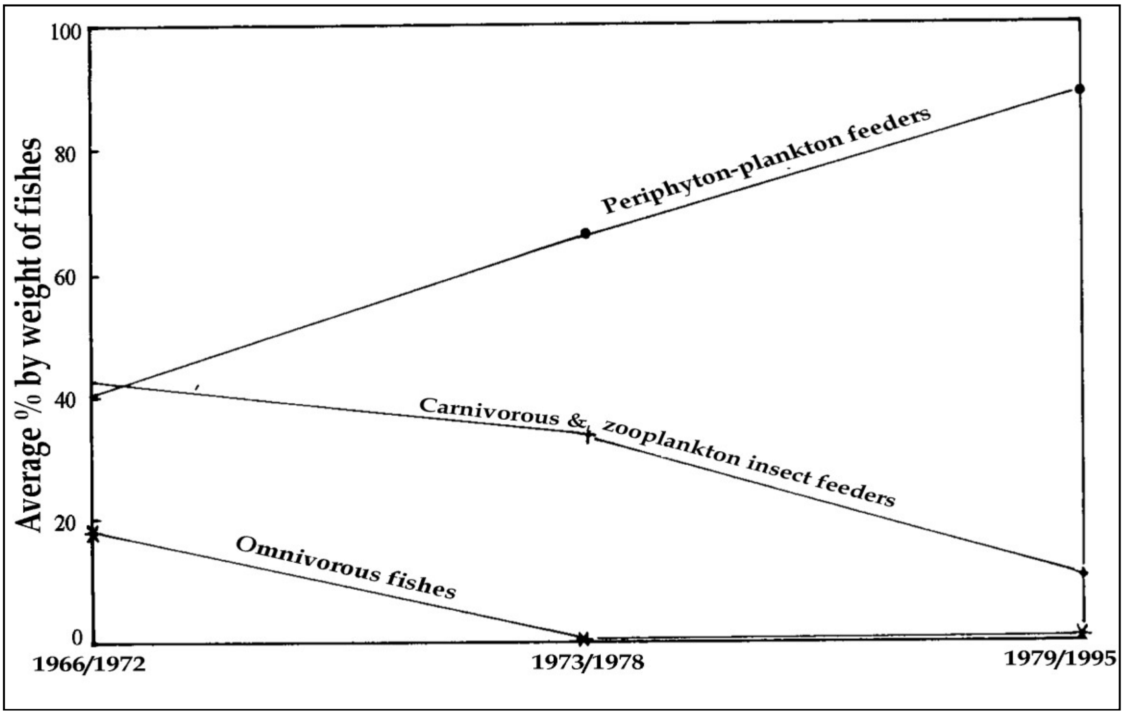


Fig. 150 **Average percentage by weight of fishes with different feeding habits during different periods.**

During the third period (1986 -1989) following the drought period a slight decrease from the average annual yield was observed followed by a sharp increase from the average value recorded during the last period (1990-1996) (Fig. 151).

Evolution and trends of different fish group catches

The evolution and historical trends of different fish group catches of Lake Nasser have been worked out by different investigators (Belal *et al.* 1992 Agaypi, 1993 a-d and Mekkawy 1996). Agaypi (1993d) and Mekkawy (1996) studied in detail the correlations between the catch of the major fish group *(Tilapia* spp.) and those of the other fish groups in the lake.

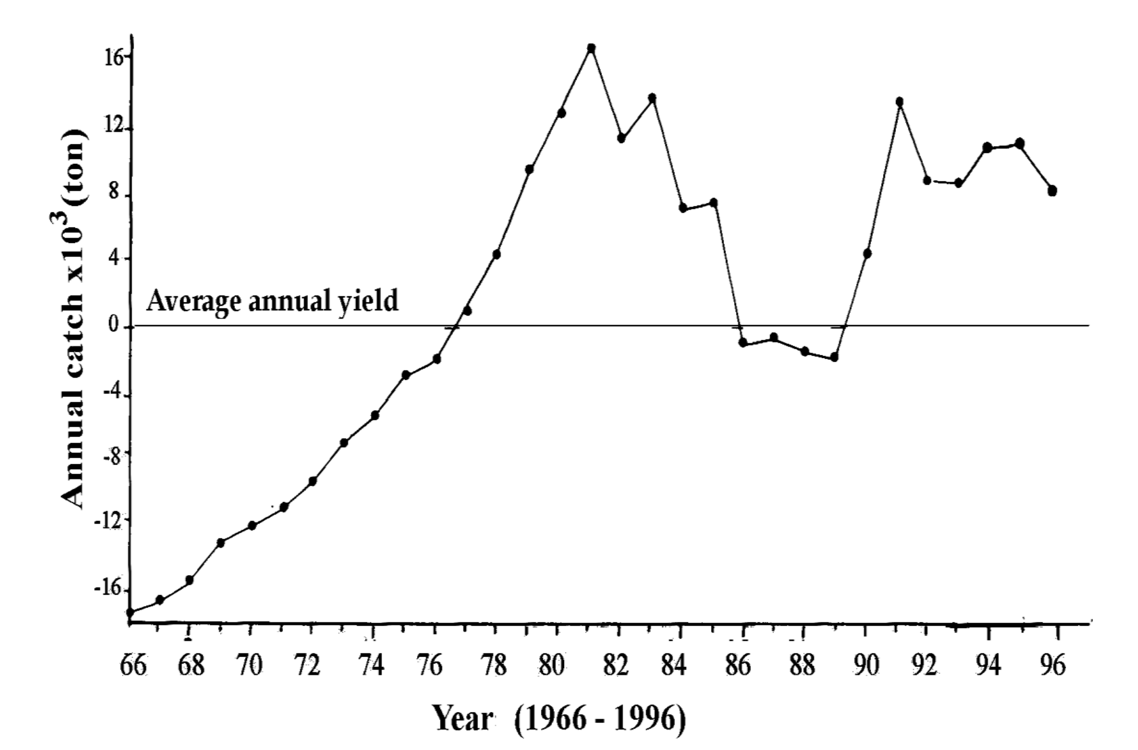
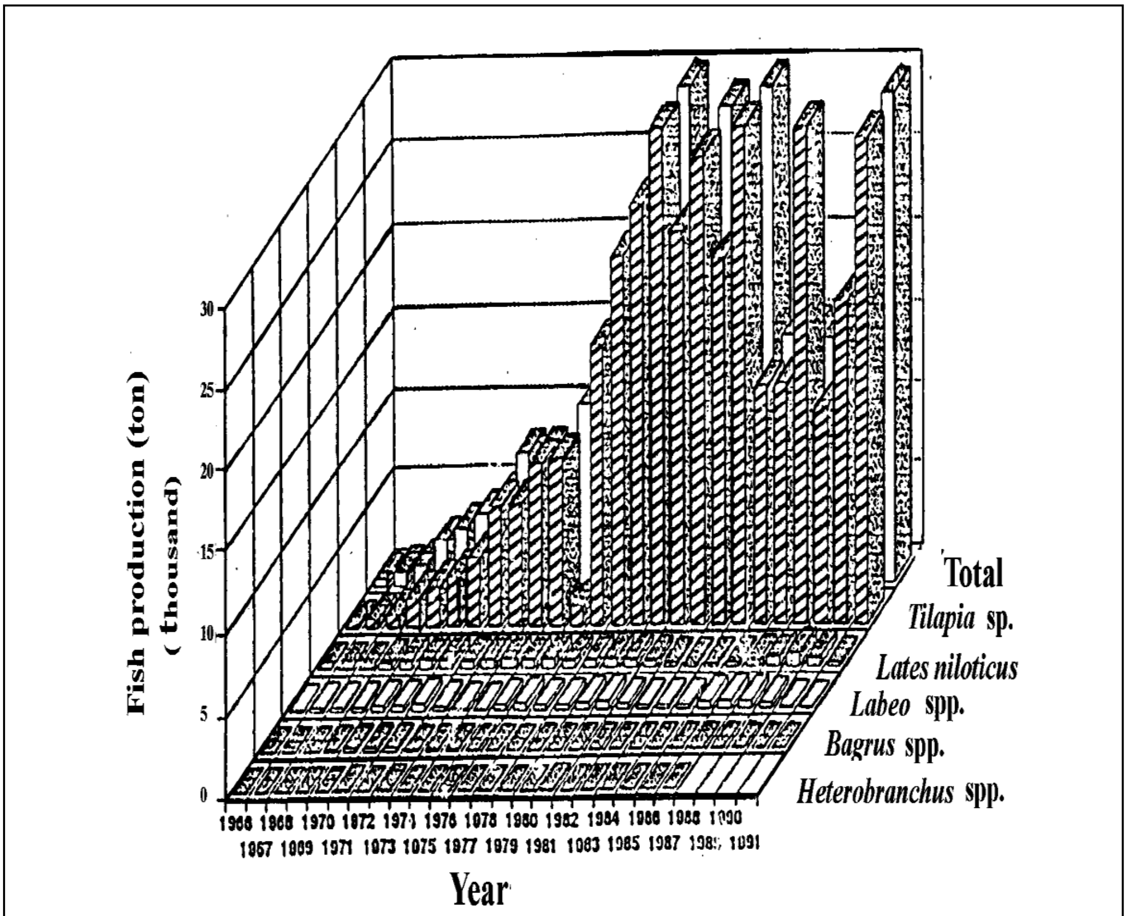


Fig. 151 **Difference between the annual fish production and the average annual yield (17.85 x 10^3).**

Lake Nasser is a huge reservoir, and as mentioned before, there are many kinds of fish species inhabiting the Lake. Among them tilapiine species mainly *Sarotherodon galilaeus* and *Oreochromis niloticus* (periphyton-plankton feeders) are the most dominant fish species (Figs. 152-154) particularly during the period 1979-1996, as their percentage by weight was high and ranged between 82.72 and 95.29% with an average of 88.27% (Tables 105 and 106). *Tilapia* species catches increased from 278 ton in 1966 to its maximum (i.e. 30,527 ton) in 1981. Afterwards, the tilapia catch decreased to about 13,000 ton in 1989, and this decrease was mainly due to the decline in the water level from 1984 to 1988 (the drought period) (Table 107 and Fig. 155), which led to a decrease in the length of the shoreline and its slope together with a decrease in the fishing grounds. As aforementioned, the length of the shoreline and its slope are important factors for the development of periphyton and littoral fauna, the main food of *Tilapia* species as well as the littoral areas provide tilapias with suitable breeding and nursery grounds. Furthermore, tilapia catch increased from 13,008 ton in 1989 to 19,563 and 29,383 ton in 1990 and 1991 respectively. At the same time, there was a progressive decrease in the mean water level from 167.75 m in 1983 to 165.79 m in 1991. Tilapia catch decreased progressively from 29.383 ton in 1991 to 8606 ton in 1999. Simultaneously, the mean water level increased progressively during the same period (1991 – 1999) from 165.79 m in 1991 to 178.92 m in 1999. This indicates that there is a reverse relationship between the annual tilapia catch and the mean water level during the period 1991 - 1999. This may be attributed to that a large portion of tilapia catch is sold illegally in the black market, and hence not recorded in the official catches which do not represent the actual annual tilapia catch. Buhukaswan (1976) found a reverse relationship between annual water level fluctuation and commercial catch in Ubolratana Reservoir in Thailand. Also, Braimah (1995) observed a reverse relationship between the fish catch and the water level in Lake Volta, Ghana.



F*ig. 152* **Fresh fish production of Lake Nasser (1966-1991) (Belal *et al.,* 1992).**

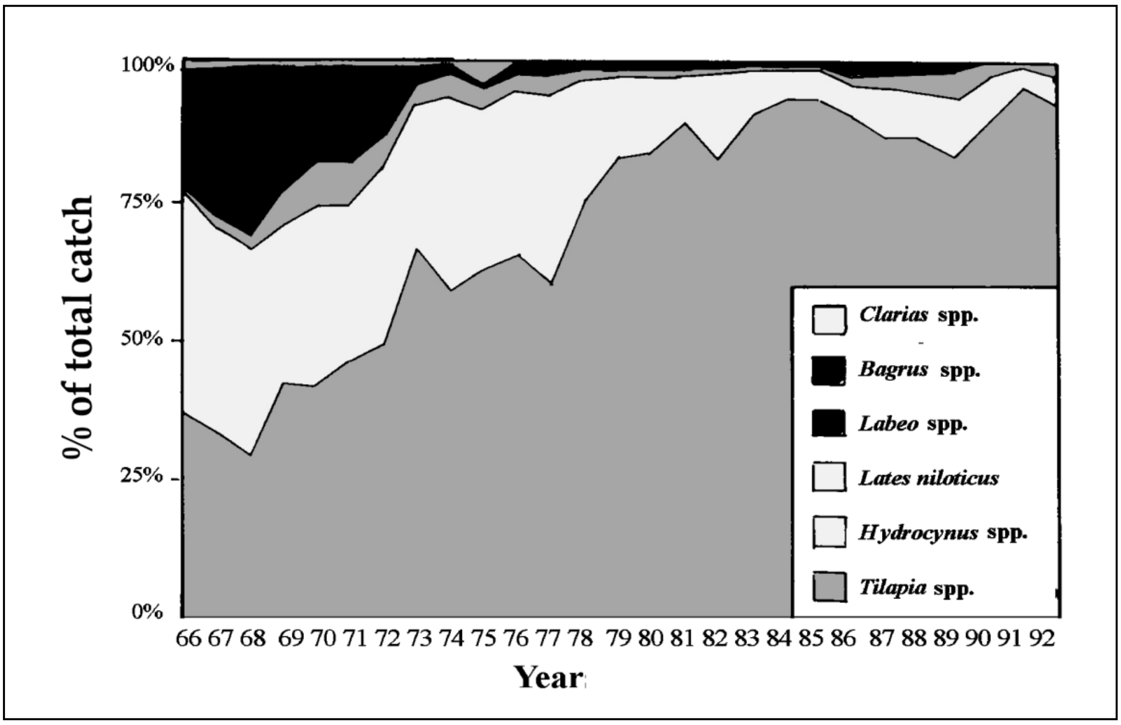


Fig. 153 **The evolution of different fish group catches in percentage of the total catch of Lake Nasser in 1966-1992 (Mekkawy 1996).**

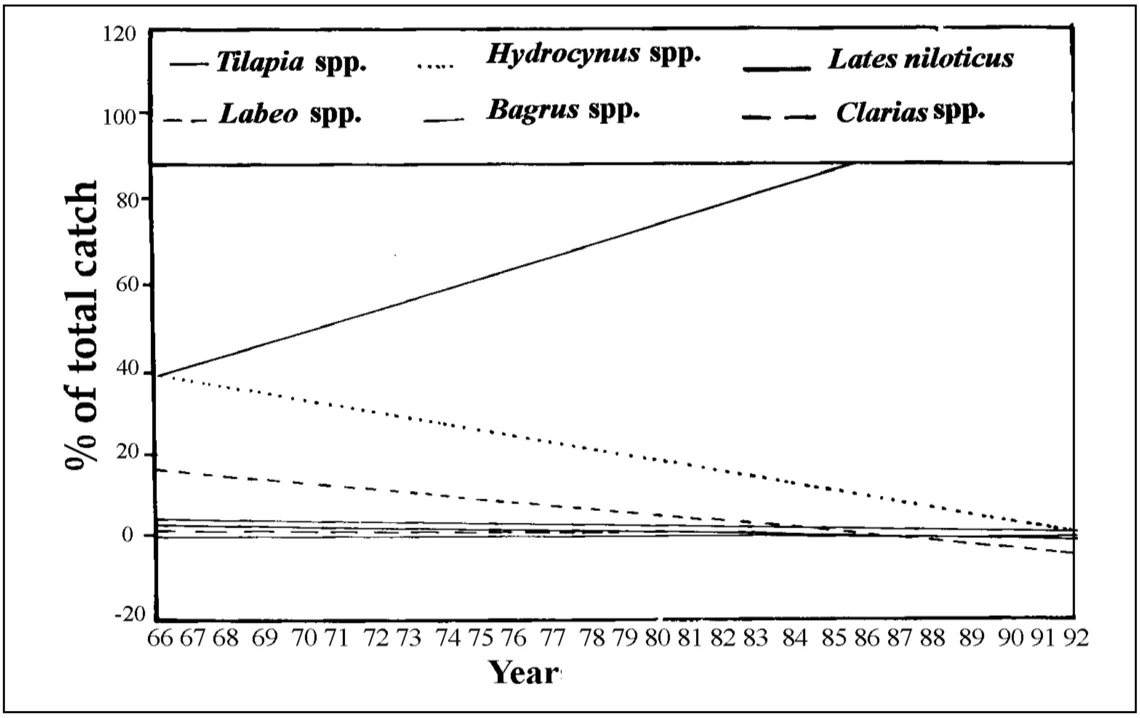


Fig. 154 **The trends of different fish group catches in percentage of the total catch of Lake Nasser in 1966-1992 (Mekkawy 1996).**

Table 107 **Annual catch (x10^3 ton) of the main fish species in Lake Nasser during 1996 - 1996. [Data from: Statistical Department , Central Management Fisheries Resources, Lake Nasser Development Authority Aswan].**

Species	Year															
	1966	**67**	**68**	**69**	**1970**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**1980**	**81**
***Tilapia* spp.**	0.278	0.471	0.713	1.978	2.384	3.157	4.146	7.179	7.244	9.660	10.519	11.200	16.931	22.347	25.440	30.527
Hydrocynus forskalii	0.308	0.537	0.939	1.343	1.848	1.965	2.660	2.744	4.312	4.326	4.657	6.304	4.873	3.868	3.949	2.825
Lates niloticus	0.005	0.027	0.071	0.289	0.451	0.517	0.451	0.394	0.490	0.525	0.416	0.564	--	0.371	0.433	0.399
***Labeo* spp.**	0.134	0.309	0.700	0.954	0.817	0.934	0.826	0.212	0.083	0.004	--	0.362	--	0.331	0.376	0.433
***Bagrus* spp.**	0.025	0.069	0.059	0.112	0.176	0.245	0.258	0.162	0.127	0.121	0.075	0.066	--	0.045	0.031	0.021
Total	**0.750**	**1.413**	**2.482**	**4.676**	**5.676**	**6.818**	**8.341**	**10.691**	**12.256**	**14.636**	**15.667**	**18.496**	**21.804**	**26.957**	**30.229**	**34.205**
Mean water level (m)	130.17	142.28	150.92	156.05	159.35	163.65	163.90	162.26	165.82	170.66	174.49	174.45	174.97	174.49	173.70	173.55

	Year														
	1982	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**
***Tilapia* spp.**	23.712	28.220	22.862	23.267	14.930	14.548	13.897	13.008	19.563	29.383	24.136	16.189	19.874	18.953	17.257
Hydrocynus forskalii	4.361	2.524	1.309	1.403	0.952	1.544	1.308	1.620	1.753	1.195	1.497	1.208	1.583	2.366	2.382
Lates niloticus	0.274	0.256	0.134	0.129	0.250	0.307	0.547	0.709	0.476	0.251	0.584	0.534	0.617	0.739	0.902
***Labeo* spp.**	0.308	0.200	0.218	0.159	0.393	0.443	0.367	0.312	0.089	0.007	--	--	--	--	--
***Bagrus* spp.**	0.011	0.006	0.004	0.002	0.002	0.001	0.001	0.000	0.000	0.000	--	--	--	--	--
Total	**28.666**	**31.206**	**24.527**	**24.969**	**16.527**	**16.843**	**16.120**	**15.649**	**21.881**	**30.836**	**26.217**	**17931**	**22074**	**22058**	**20541**
Mean water level (m)	171.41	167.75	166.20	160.25	160.38	158.08	159.72	167.05	166.61	165.79	167.30	170.78	173.40	174.62	175.41

The annual catch of *Hydrocynus forskalii* increased gradually from 308 ton in 1966 to 6,304 ton in 1977, followed by a sharp decrease to 952 ton in 1986 (Table 107 and Fig. 155). From 1987 to 1994, the catch was around 1,500 ton annually, ranging between 4.06 and 12.45 % with an average of 8.61% of the total annual catch (Table 107 and Fig. 155). During 1995 and 1996, the catch increased and reached 2,366 and 2,382 ton respectively (Table 107).

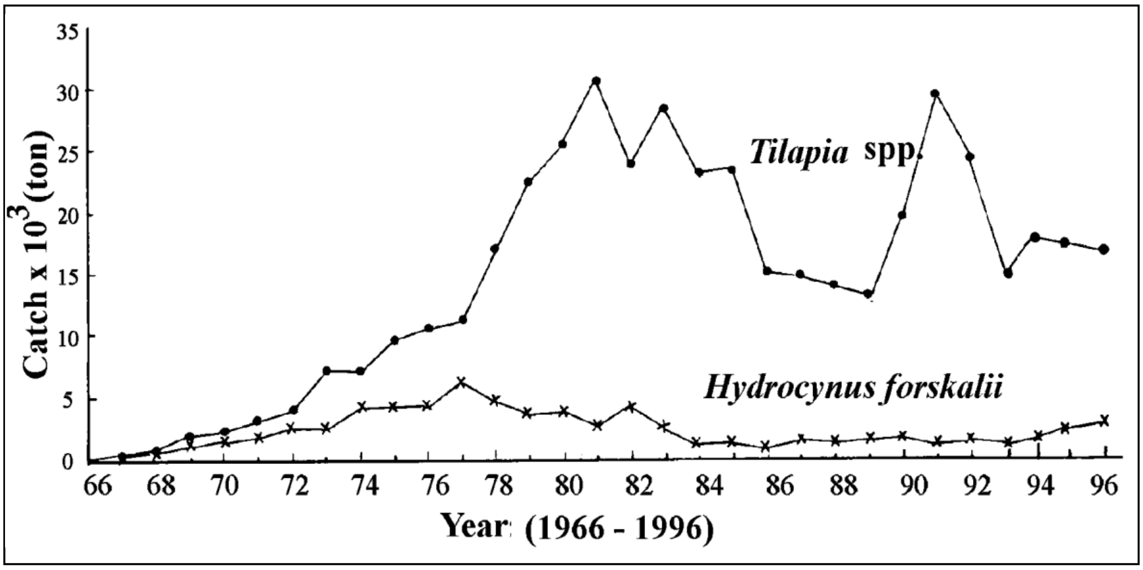


Fig. 155 **Annual catch of the main fish species: *Tilapia* species and H*ydrocynus forskalii* from Lake Nasser (1966-1996).**

Lates niloticus catch increased from only five ton in 1966 to 564 ton in 1977. Then, the catch fluctuated greatly from no landings in 1978 to 902 ton (4.39 % of the total annual fish catch) in 1996 (Table 107 and Fig. 156), and 400.4 ton (4.05% of the annual fresh fish catch) in 1999.

Labeo species catch increased rapidly from 134 ton in 1966 to attain its maximum (i.e. 954 ton) in 1969.Then the catch fluctuated greatly between no landings in 1976, 1978 and 1992-1996, and 934 ton (13.7% of the total annual fish catch) in 1971 (Table 107 and Fig. 156). During 1985-1991, the catch fluctuated between 443 ton during 1987 and 7 ton in 1991. It is obvious that no landings were recorded between 1992 and 1996. In 1999 a remarkable increase to 869.5 ton (about 8.8% of the annual fresh fish production) was recorded.

Bagrus species catch increased from 25 ton in 1966 to 258 ton (3.09 of the total annual fish catch) in 1972, and thereafter the catch decreased and no fish were landed from 1989 to 1996 (Table 107 and Fig. 156).

As aforementioned, there are many kinds of fish species inhabiting Lake Nasser, and among them *Tilapia* species have been the dominant species. Therefore, the production of *Tilapia* species may affect the production of other fish species. Agaypi (1993d) examined the relationship between *Tilapia* species catch and other fishes catch (Figs. 157-160), and his results are summerized as follows:

1. The relation between *Tilapia* species catch and that of *Hydrocynus forskalii* looks like a roughly dome shaped curve (Fig. 157). *H. forskalii* catch increased gradually from 1966 to 1977 and the catch of *Tilapia* species reached 10,000 ton in 1977. After 1979 *Tilapia* species catch reached 20,000 ton, then *H. forskalii* catch decreased. Therefore, when *Tilapia* species production reached more than 15,000 ton, then the production of *H. forskalii* may be affected by *Tilapia* species yield. Agaypi (1993d) examined the correlation by comparing two periods, one from 1966 to 1977 and the other from 1979 to 1992. The value of correlation coefficient in the former was 0.964 and *H. forskalii* catch increased without any obstacle. While in the latter it was without any relation and this suggested that increasing of *Tilapia* species production might affect the yield of *H. forskalii* and the critical catch of *Tilapia* species might be more than 15,000 ton.

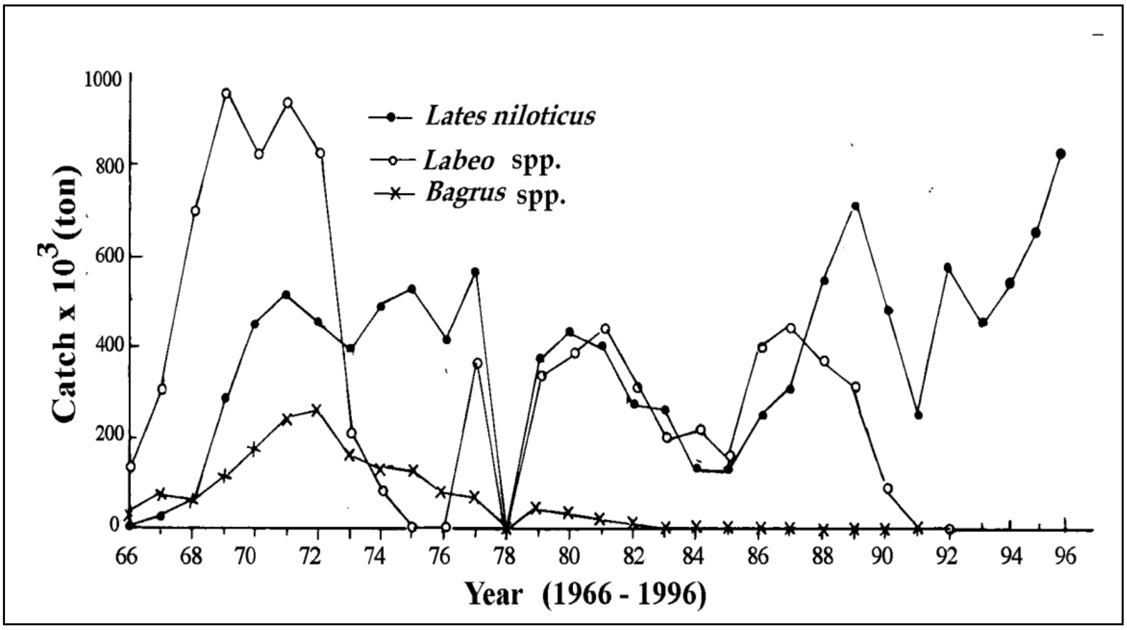


***Fig. 156* Annual catch of *Lates niloticus, Labeo* species and *Bagrus* species from Lake Nasser (1966-1996).**

2. The relation between *Tilapia* species catch and that of *Lates niloticus* catch (Fig. 158) shows that the catch of the latter species increased gradually until 1974, while *Tilapia* species catch reached 7,000 ton during this year. After 1975 *Tilapia* species production increased parallel with a decrease of *Lates niloticus* catch as a general tendency. Therefore, *L. niloticus* catch may be affected by the amount of *Tilapia* species catch of more than 15,000 ton. Agaypi (1993d) calculated the correlation coefficient, comparing the two periods, one from 1966 to 1974 and the other from 1975 to 1992. The value of correlation coefficient in the former

was 0.745 and *L. niloticus* catch increased without any obstacle. While, in the latter period the value of correlation coefficient was without any relation and this suggested that a catch more than 15,000 ton of *Tilapia* species might affect the catch of *Lates niloticus.*

3. The relation between *Tilapia* species catch and that of *Labeo* species showed a sharp increase until 1969, but after 1973 the catch decreased rapidly (Fig. 159). The catch of *Tilapia* species in 1973 reached 7,000 ton. It seems that *Labeo* species catch may be affected by the catch of *Tilapia* species when it reaches more than 10,000 ton. Agaypi (1993d) found that the correlation coefficient was 0.753 from 1966 to 1972, while from 1973 to 1992 there was no relation. This suggests that when *Tilapia* species catch attains more than 10,000 ton, it may affect the catch *of Labeo* species.

4. The relation between *Tilapia* species catch and that of *Bagrus* species (Fig. 160) shows that the catch of *Bagrus* species increased gradually until 1972, after 1973, it showed a gradual decrease corresponding to the increase of *Tilapia* species catch. In 1972 the catch of *Tilapia* species was 5,000 ton. It seems that *Bagrus* species catch may be affected by the catch of *Tilapia* species, when it is more than 5,000 ton. *Bagrus* species catch decreased after 1972 with a simultaneous increase of *Tilapia* species catch. The correlation coefficient from 1966 to 1972 was 0.973 and from 1973 to 1992 was 0.664 (Agaypi 1993d). This suggests that more than 5,000 ton of *Tilapia* species catch might affect the catch of *Bagrus* species leading to its decrease.

It is concluded from Agaypi's results that:

a. The annual catch of *H. forskalii* and *Lates. niloticus* may be affected by *Tilapia* species catch when it is more than 15,000 ton thus leading to a decrease in the annual production of the former two species.

b. The annual catch of *Labeo* species and *Bagrus* species shows a decrease, when *Tilapia* species catch is more than 10,000 and 5,000 ton respectively.

The statistical analysis of the commercial catch of Lake Nasser fisheries showed significant relationships between the catch of the predominant group, the tilapiines and the catch of others (Table 108 - Mekkawy 1998). The negative high correlations between tilapiine catch and those of *Hydrocynus, Labeo* and *Bagrus* were due to the pre-drought period (1966 - 1983). These correlations remained high for *Hydrocynus* and relatively high for *Labeo* in the post-drought period (1989 - 1992). *Lates niloticus* and *Clarias* spp. exhibited low negative correlations due to the post-drought period for the first species and due to the whole period for the second. Mekkawy (1998) summarized the aforementioned patterns of relationships by the cluster analysis which discriminated the commercial catch into two main clusters: tilapiine cluster and the cluster of other fish groups (Fig. 161).

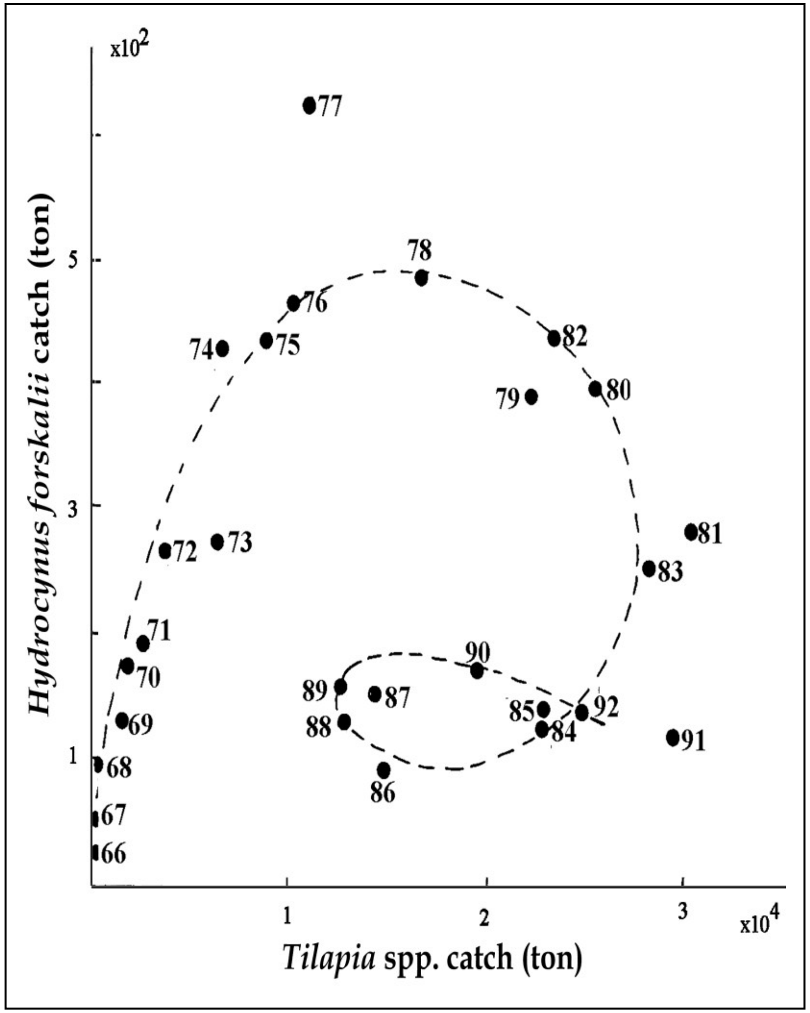


Fig. 157 **Relation between *Tilapia* species catch and that of *Hydrocynus forskalii* (Agaypi 1993d).**

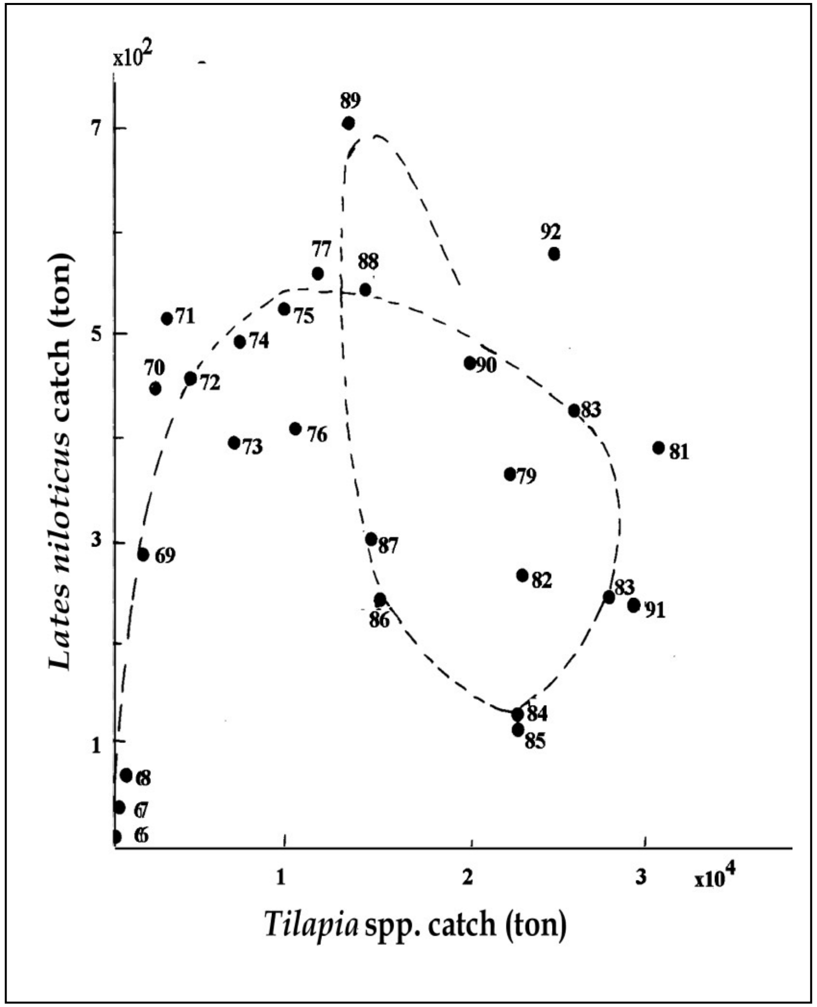


Fig. 158 **Relation between *Tilapia* species catch and that of *Lates niloticus* (Agaypi 1993d).**

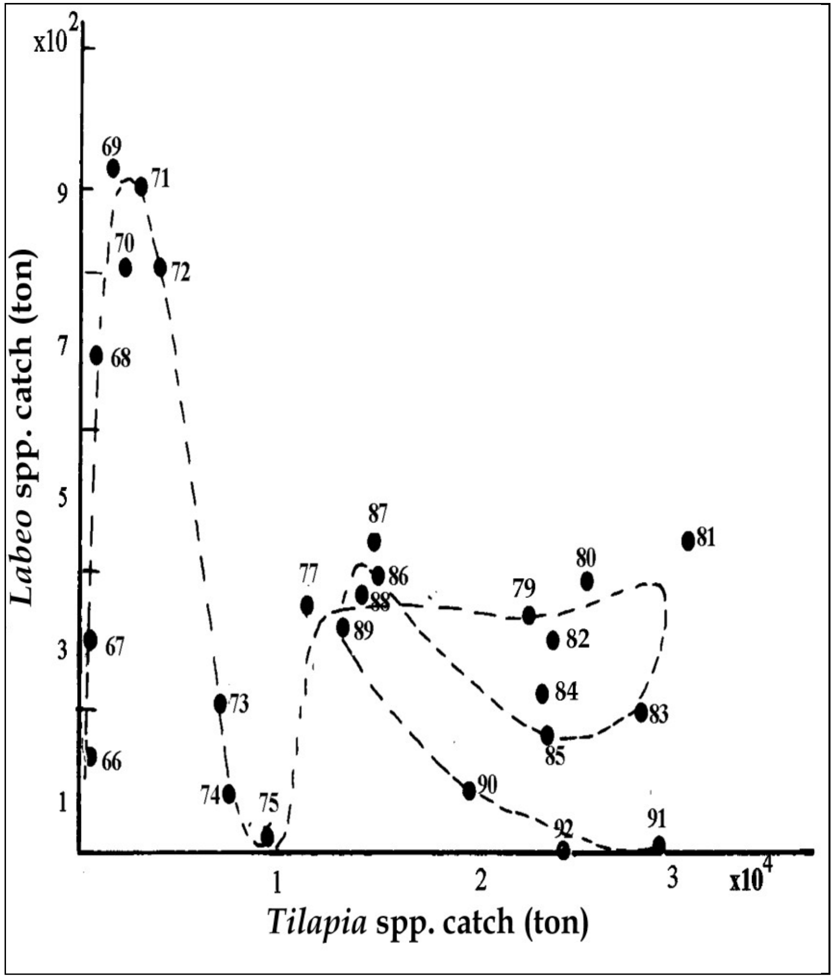


Fig. 159 **Relation between *Tilapia* species catch and that of *Labeo* spp. (Agaypi 1993d).**

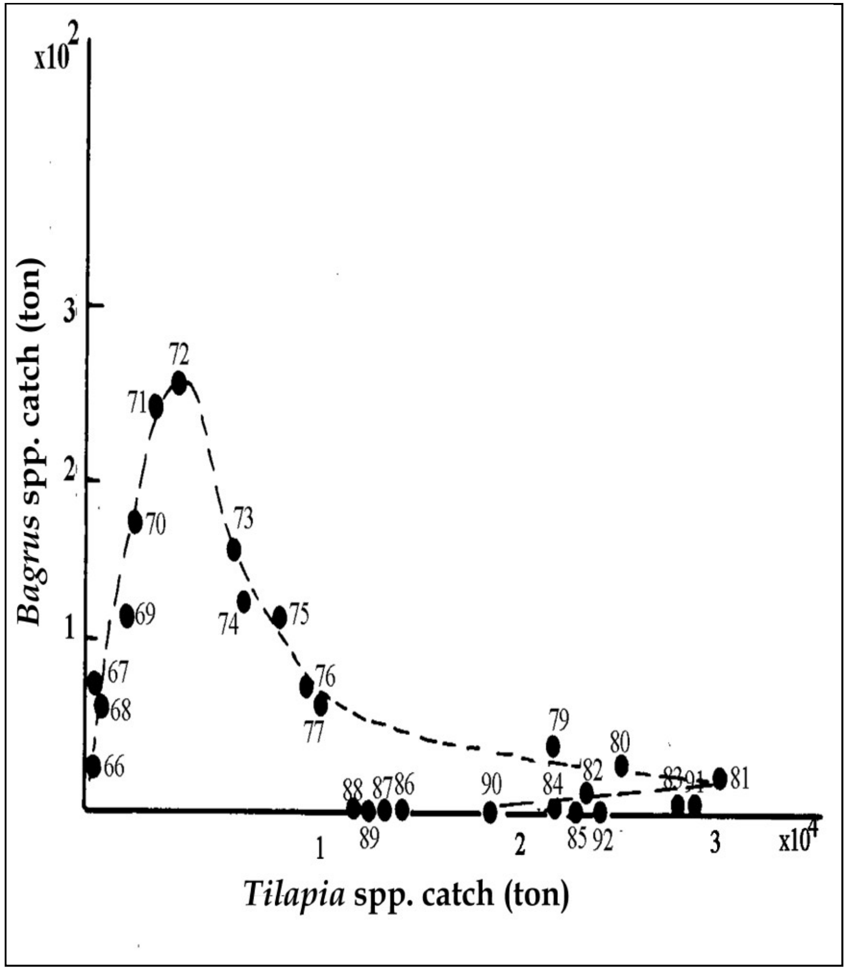


Fig. 160 **Relation between *Tilapia* species catch and that of *Bagrus* spp. (Agaypi 1993d).**

Table 108 **Significant relationships between *Tilapia* spp. catch and the catch of other fish groups of Lake Nasser, in terms of their regression coefficients (b), Y-intercepts (a) and correlation coefficients (R) (Mekkawy 1998).**

Fish species	R	a	b
	1966 - 1992		
Hydrocynus sp.	-0.946**	57.86	0.543
Lates niloticus	-0.560**	6.48	0.053
Labeo spp.	-0.865**	28.01	-0.319
Bagrus spp.	-0.900**	5.20	-0.059
Clarias spp.	-0.563**	2.45	-0.025
	1966 – 1980		
Hydrocynus sp.	-0.857**	50.41	- 0.385
Labeo spp.	-0.899**	35.51	- 0.478
Bagrus spp.	-0.858**	5.86	- 0.073
	1981- 1992		
Hydrocynus sp.	-0.906**	68.12	-0.677
Lates niloticus	-0.583**	17.65	-0.179
Labeo spp.	- 0.617**	13.89	-0.143

** highly significant at 0.01

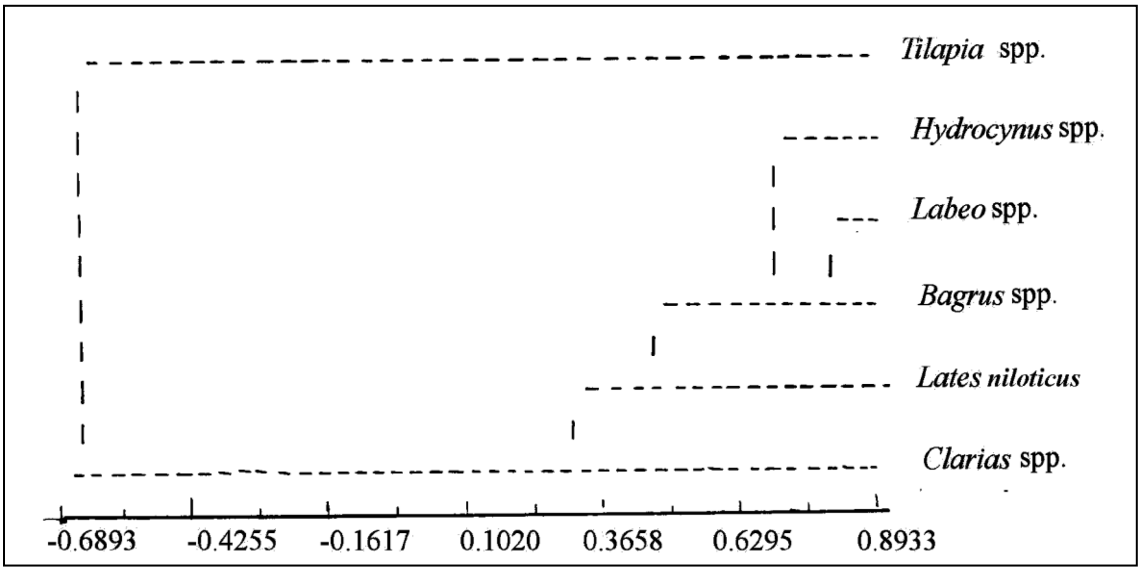


Fig. 161 **Clustering (weighted pair group method) of Lake Nasser (1966-1992) fish species based on the intercorrelation matrix of their annual catch (% weight of the total catch) (based on data by Agaypi 1993d and Ahmed 1994) (Mekkawy 1998).**

The rates of change, towards increase or decrease, of commercial fish groups are given in Table 109. Tilapiine group showed a positive annual rate of change over 1966 - 1992, whereas other species showed negative rates. The rate of change of the total catch also exhibited yearly variations (Table 110 - Mekkawy 1998).

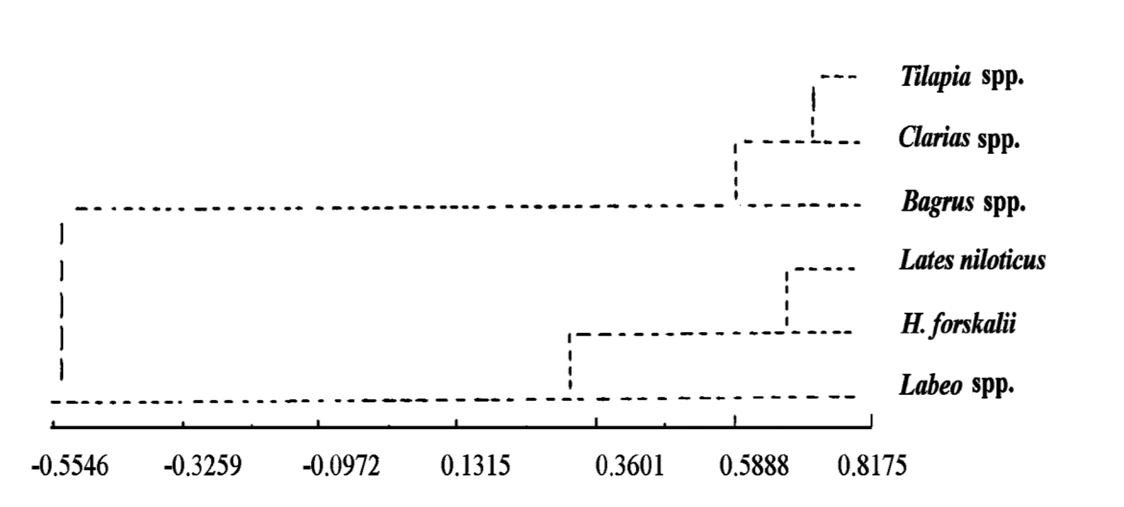


Fig. 162 **Clustering (weighted pair group method) of Lake Nasser (1983-1991) fish species based on the intercorrelation matrix of their annual catch (% weight of the total catch) (based on data by Agaypi 1993d and Ahmad, 1994). (Mekkawy 1996).**

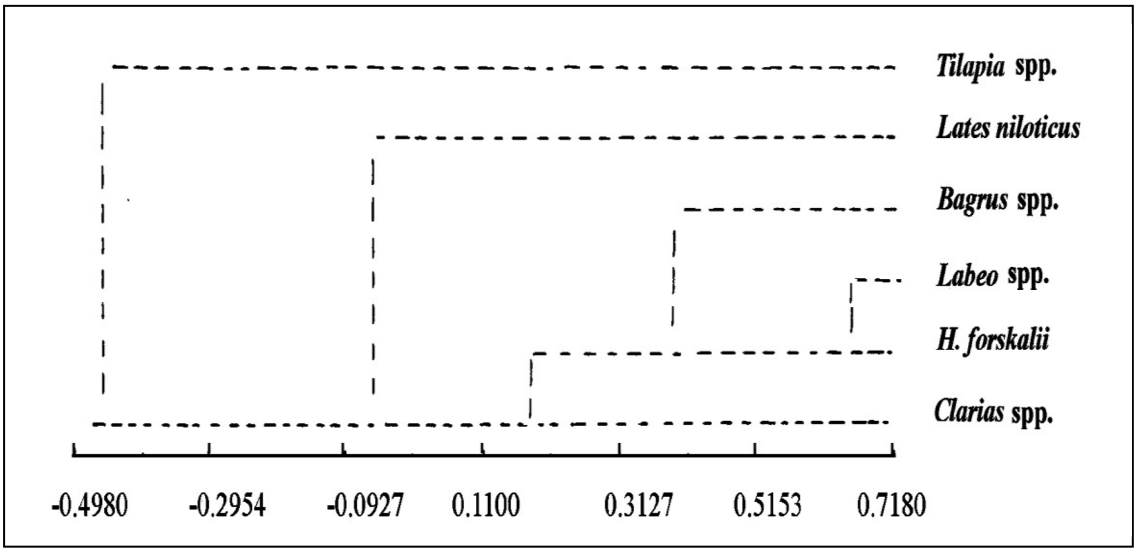


Fig. 163 **Clustering (weighted pair group method) of Lake Nasser (1983) fish species based on the intercorrelation matrix of their annual catch (% weight of the total catch) (based on data by Agaypi 1993d). (Mekkawy 1996).**

Table 109 **The significant trend analysis parameters of different fish groups catch of Lake Nasser through 1966-1992 period (Mekkawy 1998).**

Fish species	**General mean**	**R**	**a**	**b**	**Rate of change (%)**
***Tilapia* spp.**	70.4419	0.925	35.1651	2.5197	3.58
***Hydrocynus* sp.**	19.6120	- 0.920	39.7959	- 1.4381	-7.33
Lates niloticus	2.7411	- 0.434	4.3101	-0.1121	-4.09
***Labeo* spp.**	5.533	-0.744	16.0041	- 0.7479	- 13.52
***Bagrus* spp.**	1.0078	- 0.834	3.1089	- 0.1501	- 14.89
***Clarias* spp.**	0.6644	- 0.584	1.6659	- 0.0715	- 10.76

Refer to Table 108 for abbreviations.

Table 110 **Trend analysis parameters of the total catch of different khors of fish groups of Lake Nasser through August and December 1988-1992 (Mekkawy 1998).**

Month / year	**Mean**	**R[1]**	**a[1]**	**b[1]**	**Rate of change (%)**
Aug.1988	21635.23	0.362**	122274.96	234.007	1.08**
Dec. 1988	12981.53	-0.170	15513.65	- 63.303	-0.49
Aug.1989	13344.43	- 0.395**	19803.02	- 161.463	- 1.21**
Dec. 1989	14395.87	-0.149	17027.62	- 65.794	-0.46
Aug. 1990	29339.01	- 0.031	30211.84	-21.821	-0.07
Dec. 1990	29853.54	0.117	26426.31	85.681	0.29
Aug.1991	42902.36	0.260**	33706.51	229.896	0.54**
Dec. 1991	44901.62	0.128	34864.01	250.940	0.56
Aug. 1992	29691.27	0.483**	11845.50	466.144	1.57**
Dec. 1992	27204.03	0.375**	17356.94	246.177	0.90**

1, Refer to Table 108 for abbreviations. **** highly significant at 0.01.**

Fish species composition of experimental catches

Table 111 and Fig. 164 show the fish species composition of High Dam Lake. Floating and sinking gill nets were used in experimental fishing in the reservoir during October 1978 and July 1979 (Latif *et al.* 1979). The results are summarized in the following:

1. In Lake Nasser, *Sarotherodon galilaeus, Lates niloticus, Hydrocynus forskalii* and *Mormyrus* spp. were more in the northern third than elsewhere in the Lake. *Oreochromis niloticus,* on the contrary, is much more frequent in the middle third. *Alestes baremoze* and A. *dentex* are mainly concentrated in the southern third where cyprinids are more frequent.

2. In Lake Nubia, *Tilapia* spp. are less frequent than in Lake Nasser. High percentage of *Sarotherodon galilaeus* prevailed in the southern third of Lake Nubia. *Alestes baremoze* and *A. dentex* appeared only in the northern third of Lake Nubia but to a much less extent than in the southern part of Lake Nasser. *Schilbe uranoscopus* is an important component (6-7%) in the middle and southern thirds. Cyprinids form numerically more than 50% of the catch in these two sections, thus exhibiting much higher values than in Lake Nasser.

3. *Hydrocynus* spp. show an increasing pattern from the southern third of Lake Nubia northwards till the northern section of Lake Nasser. *Barbus bynni* is concentrated in the middle third of the whole reservoir.

EFFECT OF DIFFERENT WATER LEVELS AND EFFORT ON FISH PRODUCTION

The number of fishing boats operating in Lake Nasser during the period from 1966 to 1999 is presented in Table 103 and Fig. 166. It started with 200 boats in 1966 and gradually increased to 1700 in 1978, while from 1979 to 1989, it gradually decreased from 1613 to 1175. The number of fishing boats was stable (about 1900) during 1990 to 1993, increased thereafter to about 2300 in 1994 and 2200 in 1995, 1996 and 1999.

It is beleived that there is a relationship between the total annual fish production of the Lake and the water level, which shows remarkable fluctuations from year to year. The highest percentage of fish (83-95.3%) is composed of *Tilapia* spp. (viz., *S. galilaeus* and *0. niloticus*) which inhabit shallow inshore waters, the area of which is profoundly affected by the water level. Hence consideration of the water level and total fish production since the filling of the Lake till now is important. Table 103 and Fig. 165 show the maximum, minimum and mean water levels, while Figs. 167 and 168 show the fluctuations in the total annual catch in relation to water level. From these data the following is observed:

***Table 111* Percentage number of different fish species among catch by floating and sinking gill-nets in different sections of high Dam Reservoir (Latif *et al.* 1979).**

Species	**Lake Nasser**			**Lake Nubia**		
	Northern	**Middle**	**Southern**	**Northern**	**Middle**	**Southern**
Oreochromis niloticus	0.22	33.6	--	0.53	0.56	--
Sarotherodon galilaeus	18.50	8.16	0.87	7.27	2.38	29.7
Lates niloticus	18.60	13.10	3.54	13.17	11.95	4.5
***Hydrocynus* spp.**	54.13	34.87	27.00	9.75	7.31	1.2
***Bagrus* spp.**	0.44	--	--	4.69	1.3	1.4
***Alestes* spp.**	1.94	4.15	23.1	1.06	--	1.4
Schilbe uranoscopus	--	--	--	--	5.85	6.83
Schilbe (Schilbe) mystus	--	--	--	--	0.79	--
Eutropius niloticus	--	--	0.79	3.52	4.07	6.0
***Synodontis* spp.**	1.29	2.6	3.13	24.5	9.63	25.4
***Mormyrus* spp.**	6.68	3.37	0.14	2.99	1.36	1.67
Labeo niloticus	--	--	1.23	23.74	49.00	17.7
Labeo coubie	--	--	0.39	33.15	2.38	1.4
Labeo horie	--	--	0.53	1.59	--	0.7
Barbus bynni	--	0.15	4.67	4.69	2.82	2.16

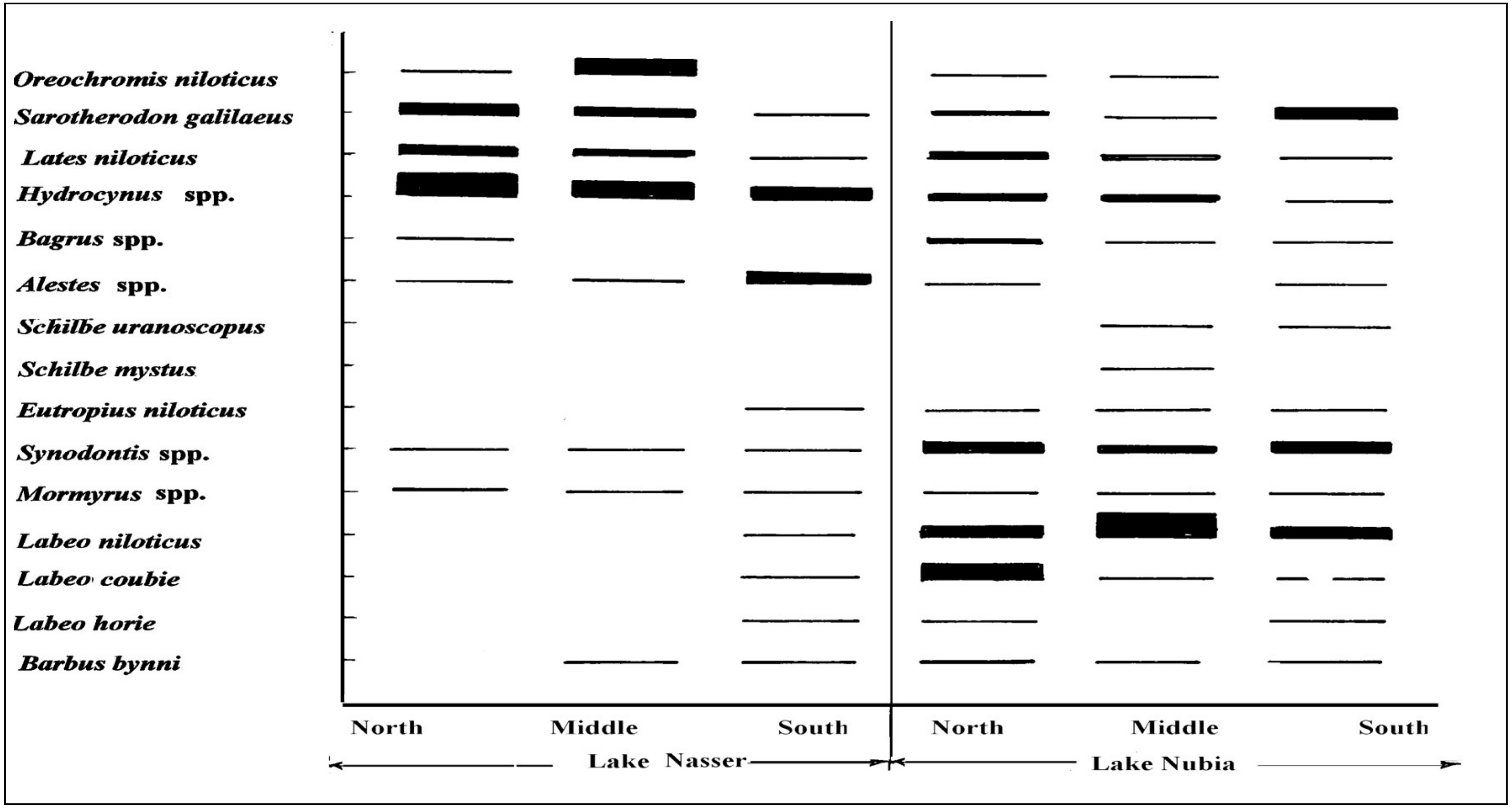


Fig. 164 **Diagram of species composition of different sectors of high Dam Reservoir based on experimental fishing. (Latif *et al.* 1979).**

1. From 1966 to 1976, the total catch increased and reached about 16,000 ton in 1976 with the increase of water level and number of fishing boats.

2. From 1976 to 1981, the total catch increased from about 16,000 to 34,000 ton. At that period, the mean water level attained was kept at about 174 m and the fishing effort was constant (1600 fishing boats). Thus, the water level was relatively high and so, very suitable for tilapia reproduction during this period. Mohamed & Adam (1995) pointed out that during the period from 1976 to 1982, the water level in Lake Nasser was about 174 m, and the total catch reached 34,000 ton in 1981, while in 1982 the catch decreased to 28,700 ton (Figs. 167 and 168). The latter authors considered the catch of 34,000 ton as overfishing at that low water level, and they estimated the tentative sustainable yield as the mean catch of 1980 and 1982, or (30,200 + 28,700) /2 = 29,450 ton at the low water level of about 172 m.

3. From 1982 to 1988, - including the drought period - the total catch decreased from 29,000 to 16,000 ton (i.e. about 50%) and there was a decrease in the mean water level from 171 m to 160 m (Figs. 167 and 168).

4. During 1989 to 1992, the low water level was nearly 164 m and the total catch reached 30,800 ton in 1991, but in 1992, the catch decreased to 26.000 ton (Figs. 167 and 168). Mohamed & Adam (1995) estimated the tentative sustainable yield as the mean value of the catches in 1990 and 1992 or (21,900 + 26,200)/2 = 24,050 ton, at the low water level of about 164 m.

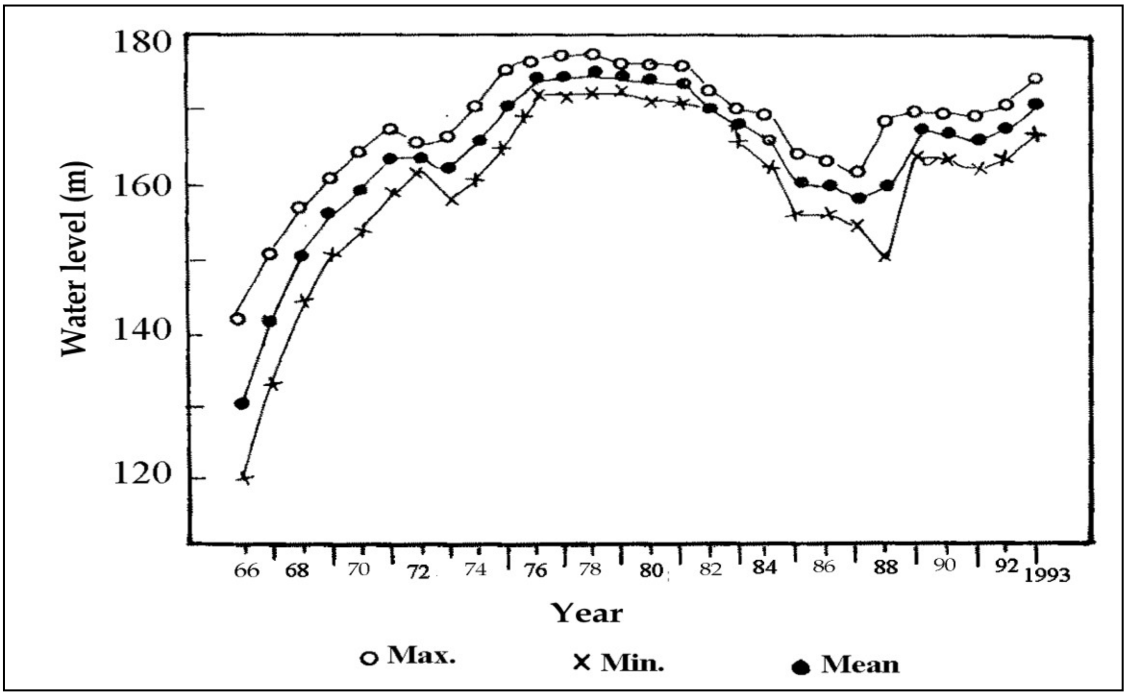


Fig. 165 **Maximum, minimum and mean water level of Lake Nasser (1966-1993) (Agaypi 1995b).**

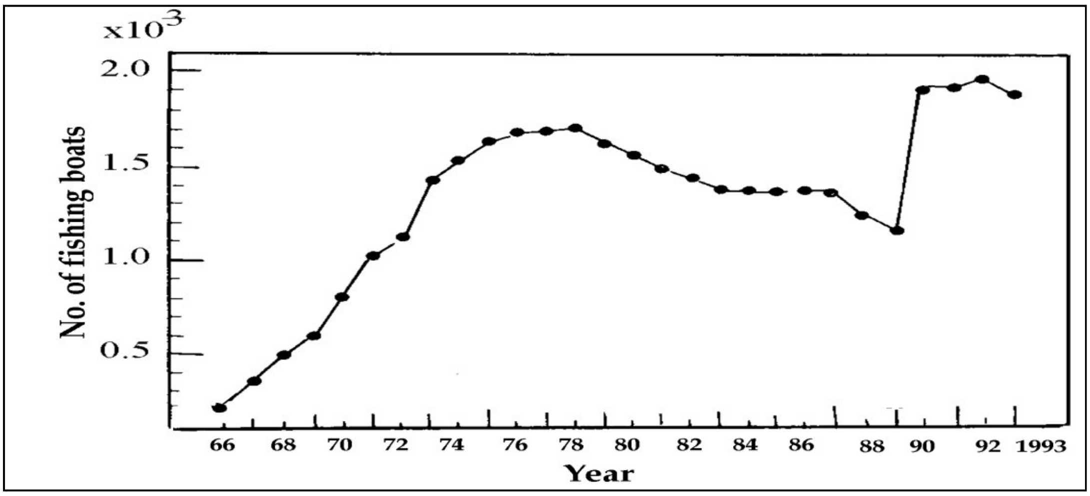


Fig. 166 **Number of fishing boats in Lake Nasser (1966-1993) (Agaypi 1995 b).**

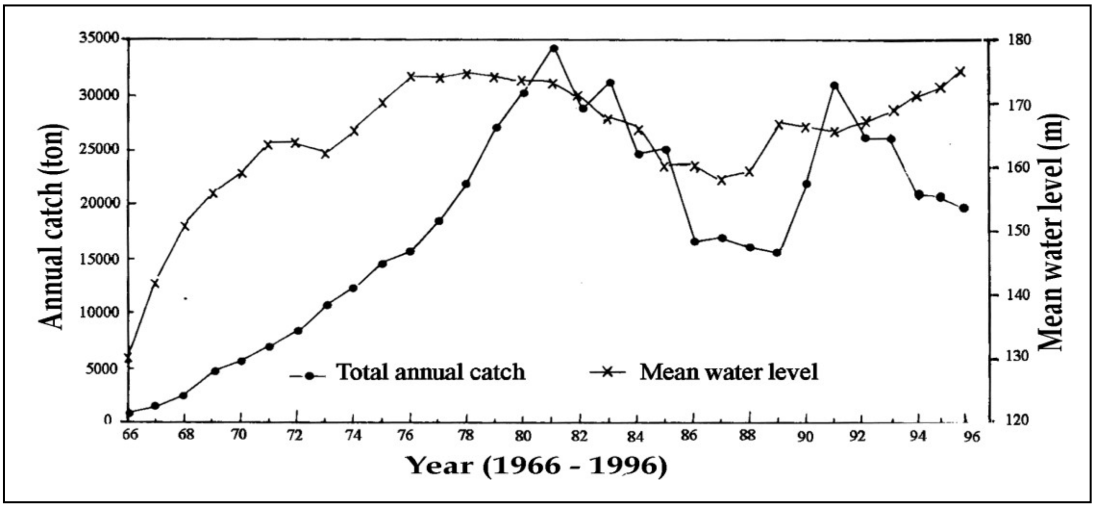


Fig. 167 **Fluctuation of the total annual catch in relation to the mean water level.**

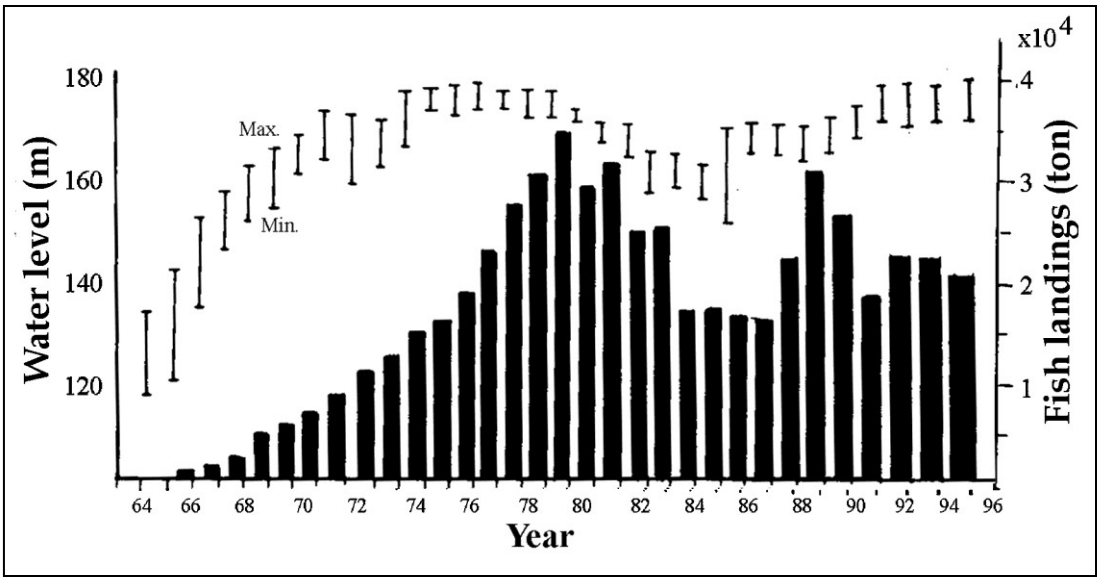


Fig. 168 **Variation of water level and fish landings at Lake Nasser (1964-1996) (Agaypi 1995 b).**

As a matter of fact, fish production in Lake Nasser is affected by many factors including prohibiting of fishing from 15th March to 15th May, which started from 1990. Agaypi (1995b) attributed the decrease in the total catch from 34,000 ton in 1981 to 29,000 ton in 1982 to overfishing, because the mean water level was high during previous years (about 174 m), showing favourable environmental conditions for fish production. Similarly, the total catch decreased from 30,838 ton in 1991 to 26,219 ton in 1992 and 17,931 ton in 1993, followed by an increase to 22,074, 22,058, 20,541 and 20,601 ton in 1994,1995, 1996 and 1997 respectively. Then, the total catch decreased to 19,203 and 13,983 ton in 1998 and 1999 respectively.

The catch is considered a dependent variable, while both water level and effort, represented by the number of fishing boats per year and number of fishermen per year, are independent variables. Using the multiple linear regression, Mekkawy (1998) presented the relations as follows :

Total catch (Multiple R = 0.94885, P < 0.0001) = - 189029.7664** - 411.3143 WL1 + 762.0031 WL2 + 777.9169 WL3* - 42.6486 WL4 + 34.6586 WL5 - 12.2834 WL6 + 11.3704 boat** + 0.5496 fisherman

Tilapiine catch (Multiple R = 0.944, P < 0.0001) = - 186212.43** - 292.1281 WL1 + 638.0132 WL2 + 806.2936 WL3* - 152.6959 WL4 + 240.1809 WL5 - 68.0935 WL6 + 11.1222 Boat** + 0.8626 fisherman.

***Hydrocynus* catch** (Multiple R = 0.891, P < 0.003) = - 13879.41 + 170.0945 WL1* + 63.9416 WL2 - 81.6443 WL3 - 26.2004 WL4 - 69.4056 WL5 + 60.9031 WL6 - 0.8624 Boat - 0.2870 fisherman.

***Lates* catch** (Multiple R = 0.853, P < 0.01) = 2553.66 + 11.7921 WL1 - 9.5386 WL2- 9.3175 WL3 + 7.4938 WL4 - 30.6562 WL5* + 17.6134 WL6* + 0.12056 Boat - 0.0320 fisherman

***Bagrus* catch** (Multiple R = 0.949, P < 0.0001) = 1056.41** + 0.4917 WL1 - 0.8188 WL2 - 0.5188 WL3 + 0.0868 WL4 + 6.2542 WL5 - 10.1625 WL6** - 0.0221 Boat - 0.0040 fisherman

N.B. (1) * or ** means that the parameter is significant at 0.05 or highly significant at 0.01.

(2) WL1 - WL6 = previous water levels from 1 to 6 years.

Table 112 shows the relationships between the commercial catch of fish groups of 1972 - 1992 and both efforts (boat / year and fisherman / year) and combination of flood histories in terms of maximum water levels (WL) of the six years preceding the catch - year (Mekkawy 1998). Using the correlation coefficients, the latter author concluded from that table the following:

1- Significant correlations between tilapiine catch and WL2 to WL6, insignificant correlation with effort.

2- Significant correlations between *Hydrocynus* spp. catch and WL1, WL2 and effort (only fisherman / year).

3- Significant correlation between *Lates* sp. catch and WL5, insignificant correlation with effort.

4- Significant correlation between *Labeo* spp. catch and effort (only boat / year), insignificant correlations with water levels.

5- Significant correlation between *Bagrus* spp. catch and WL4 to WL6, insignificant correlation with effort.

6- Insignificant correlation between *Clarias* spp. catch and water levels and effort.

7- Significant correlations between total catch and WL2 to WL6 and insignificant correlations with effort; a case similar to that of tilapiine catch .

***Table 112* Simple correlation coefficients between fish species catch of Lake Nasser and water levels of the six preceding years and efforts (boats and fishermen (Mekkawy, 1998).**

	Correlation **coefficients**							
	WL1	**WL2**	**WL3**	**WL4**	**WL5**	**WL6**	**Boats**	**Fishermen**
***Tilapia* spp.**	0.34	0.58*	0.67*	0.62*	0.61*	0.63*	0.45	0.38
***Hydrocynus* spp.**	0.69**	0.51*	0.25	0.07	-0.09	-0.23	-0.36	-0.69**
Lates niloticus	0.05	-0.36	-0.47	-0.47	-0.56*	-0.42	0.18	-0.17
***Labeo* spp.**	0.05	-0.00	-0.01	-0.02	-0.00	-0.13	-0.55*	-0.41
***Bagrus* spp.**	-0.03	-0.18	-0.35	-0.53*	-0.68**	-0.87**	-0.48	-0.49
***Clarias* spp.**	0.13	0.03	-0.07	0.02	-0.08	-0.18	-0.02	-0.23
Total	**0.44**	**0.68****	**0.74****	**0.65****	**0.59***	**0.59***	**0.39**	**0.27**

*** Significant at 0.05, ** highly significant at 0.01. WL1-WL6 = previous water levels from one to six years.**

The multiple linear model, represented by these equations, treated simultaneously the most important factors : fishermen, boats and water levels, that control Lake Nasser catch.

Mekkawy (1998) mentioned that the total catch standardized by effort (CPUE) for 1972 - 1992 varied with variation of water levels (WL1 - WL6). The CPUE-WL relationships were described by the following equations (*, ** significant at 0.05 and 0.01 respectively).

Catch/boat	= 54.85 + 0.399 WL1,	r =0.490*
Catch /fisherman	=39.71 + 0.259 WL1,	r= 0.535**
Catch / boat	= - 94.42 + 0.632 WL2	r = 0.794**
Catch/fisherman	= - 49.06 + 0.310 WL2	r= 0.667**
Catch / boat	= - 99.24 + 0.662 WL 3	r = 0.876**
Catch / fisherman	= - 45.18 + 0.288 WL3	r = 0.652**
Catch/boat	= - 73.23 + 0.511 WL 4	r= 0.752**
Catch / fisherman	= - 33.56 + 0.220 WL 4	r = 0.555**
Catch / boat	= - 49.05 + 0.369 WL 5	r = 0.632**
Catch / fisherman	- = -21.65 + 0.151 WL 5	r = 0.441*
Catch / boat	= - 30.06 + 258 WL6	r = 0.544**
Catch / fisherman	= - 8.61 + 0.073 WL6	r = 0.265

The correlation coefficients of CPUE-WL relationships were significant, but relatively low except for catch / fisherman-WL

The picture obtained by Mekkawy (1998) using the multiple linear regression, makes it possible to predict the allowable catch considering the water level and effort.

Williams (1972) pointed out that the relation between annual water level fluctuation and catch per unit effort (CPUE) presents a predictive hypothesis, which has an important value in the management of fisheries. The latter author recorded a positive correlation between water level and the catch per unit effort in Mweru Lake in Zambia, and he referred this positive correlation to the effect of water level fluctuations on the spawning grounds of some fish species as *Tilapia macrochir*, which has certain limited depths for spawning.

A different picture is observed in Lake Nasser particularly during 1991 – 1999. One can notice a negative correlation between water level and tilapiine catch, which represents about 90% of the total fish catch. Thus, the mean water level increased progressively from 165.79 m in 1991 to 178.92 m in 1999; while tilapiine catch sharply decreased from 29,383 ton in 1991 to 8606 ton in 1999. This is mainly attributed to that, a large portion of the catch is sold illegally in the black market at high prices, and hence not recorded in the official catches, which thus do not represent the true annual tilapiine catch from the Lake.

The increase in the catch of commercial fishes may be reversely related to the increase in water level, taking into consideration that this increase is not correlated with the growth of plankton. Fig. 169 shows the relationship between annual water level fluctuation and commercial catch in Ubolratana Reservoir in Thailand (Buhukaswan, 1976). It is obvious that the catch fluctuates monthly. It increases during the dry season, when the water level decreases, while the catch decreases during the period of high water level. The fishermen can easily catch fish during the dry season, when the water level is low and the fish concentrates in smaller areas (Buhukaswan, 1976). Varikol (1980) pointed out that the catch effort increases generally during the period when fishermen are free from culturing rice. Also, Braimah (1995) recorded a reverse relation between the catch and water level in Volta Lake in Ghana (Fig. 170). The latter author mentioned that tilapia catch was low, when the water level was high and vice versa. Furthermore tilapias are rarely found during water floods.

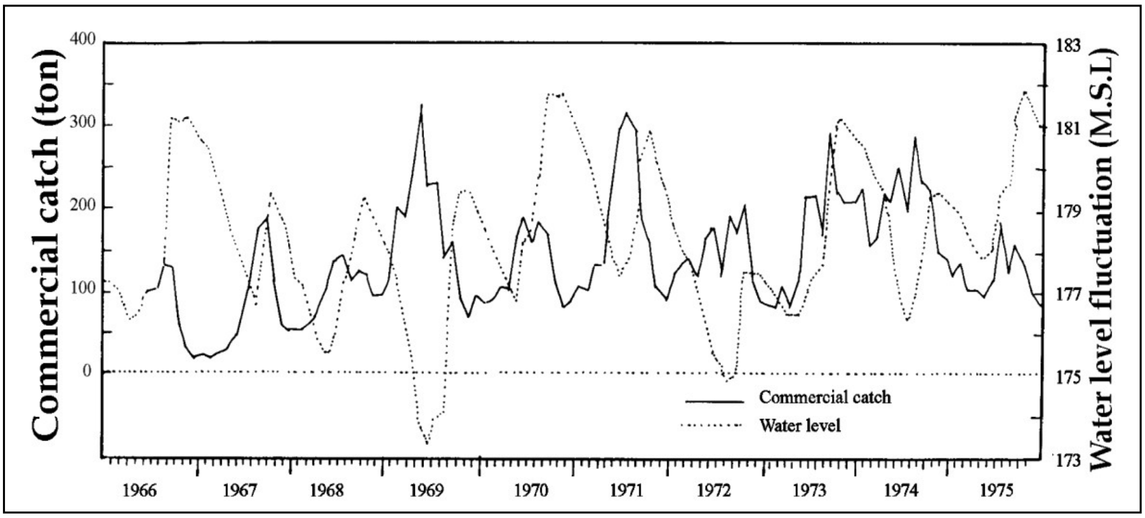


Fig. 169 **The relationship between annual water level fluctuation and commercial catch in the Ubolratana Reservoir, Khon Kaen, Thailand, July 1966 - December 1975 (Buhukaswan 1976).**

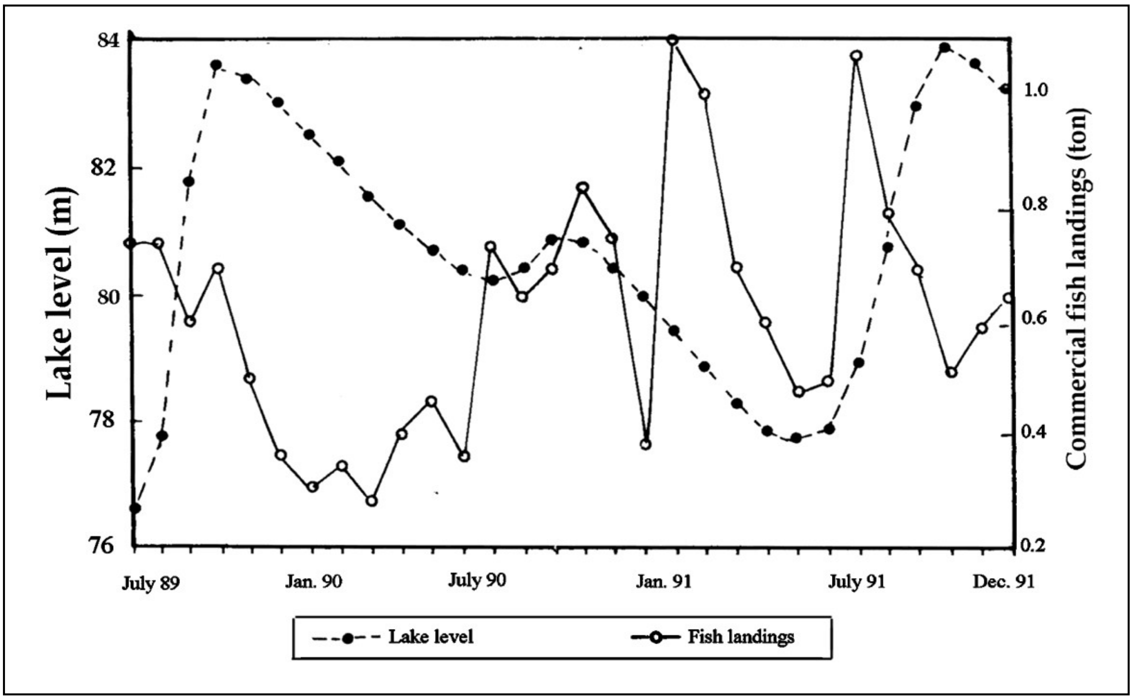


Fig. 170 **Water level and commercial catch of Volta Lake, Ghana in July 1989-December 1991 (Braimah 1995).**

EFFECT OF CHANGEABLE SHORELINE LENGTH ON FISH PRODUCTION

Yamaguchi *et al* (1996) used the following cubic equation for measuring the relationship between water level (H) and shoreline length (L).

$$L = LO + a\,(H\text{-}Ho) + b\,(H\text{-}Ho)^2 + c\,(H\text{-}Ho)^3 + e \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where : a, b and c are constants, e is an error, and Ho and Lo are water level and shoreline length before High Dam construction . The constants a , b and c were obtained by the least square method. After calculation, the latter authors obtained the following equation:

$$L = 625 + 177.8\,(H - 112) - 5.054\,(H - 112)^2 + 0.0587\,(H - 112)^3 \ldots\ldots. (2)$$

The mean water level in Lake Nasser, during the period 1966-1996 was calculated, and then the calculated mean length of shoreline, during the same period, was obtained by using equation (2) (Table 113).

Relation between total fish production and calculated length of shoreline of Lake Nasser

The mean length of shoreline (km) of Lake Nasser during 1966 -1996 is calculated, as shown in Table 113, using the mean water level (m) in different years applying equation (2).

It is obvious that the total fish production is affected (3 years afterwards) with the increase or decrease of the shoreline length of Lake Nasser (Table 113 and Fig. 171). Thus, there was a progressive increase in the calculated mean length of the shoreline from 2539 km in 1966 to 6438 km in 1978, and accordingly there was a successive increase in the total fish production from 4,670 in 1969 to 34,206 ton in 1981 (Table 113 and Fig. 171). So, it may be said that the total fish production increases (3 years afterwards) with the increase of shoreline length of the Lake. It is worth mentioning that there is a progressive increase in the shoreline length of Lake Nasser from 4702 km in 1991 to 7482 km in 1999 (Table 113), as a result of the continuous increase in he mean water level from 165.79 m in 1991 to 178.92 m in 1999 (Table 113). Accordingly, it is expected that the total fish catch, particularly tilapiines, should increase greatly during 1991 - 1999. However, a reverse picture is observed. Thus, tilapiine catch decreased sharply from 29,383 ton in 1991 to only 8606 ton in 1999. This observation is mainly attributed to that a high percentage of the catch is sold in the black market illegally at high prices. Hence, it is obvious that the official catches - which is taken in consideration in the present study - do not represent the true annual fish catch.

RELATIONSHIP BETWEEN CATCH AND GONAD INDEX

Monthly variations of gonad index of *O. niloticus* and *S. galilaeus* are shown in Table 114. For both tilapiine species, two major peaks were observed (Figs. 172 and 173). The monthly catch of both fish species exhibited two or three major peaks. However, the catch peaks do not coincide with those of gonad index (Figs. 172 and 173).

Table 113 **Relation between total fish production and calculated length of the shoreline of Lake Nasser during 1966-1999.**

Year	Mean Water Level (m)	Calculated * length of shoreline (mean, km)	Total fish** production (ton) (Actual)
1966	130.17	2539	751
7	142.28	3005	1415
8	150.92	3350	2662
9	156.05	3668	4670
1970	159.35	3944	5676
1	163.65	4414	6819
2	163.90	4445	8343
3	162.26	4247	10587
4	165.82	4706	12255
5	170.66	5512	14635
6	174.49	6324	15791
7	174.45	6315	18471
8	174.97	6438	22725
9	174.49	6324	27021
1980	173.70	6143	30216
1	173.55	6109	34206
2	171.41	5659	28667
3	167.75	5000	31282
4	166.20	4761	24534
5	160.25	4032	26450
6	160.38	4045	16315
7	158.08	3830	16815
8	159.72	3979	15888
9	167.05	4890	15650
1990	166.61	4822	21882
1	165.79	4702	30838
2	167.30	4929	26219
3	170.78	5535	17931
4	173.40	6076	22074
5	174.62	6355	22058
6	175.41	6544	20541
7	177.38	7051	20601
8	178.13	7257	19203
9	178.92	7482	13983

*** Mean length of the shoreline of Lake Nasser is calculated using the equation:**

[$L = 625 + 177.8 (H - 112) - 5.054 (H - 112)^2 + 0.0587 (H - 112)^3$ .... Yamaguchi *et al.* (1996)] (where, L = length of shoreline, H = water level).

****Total fish production is affected (at 3 year after) with the increase or decrease of calculated shoreline length.**

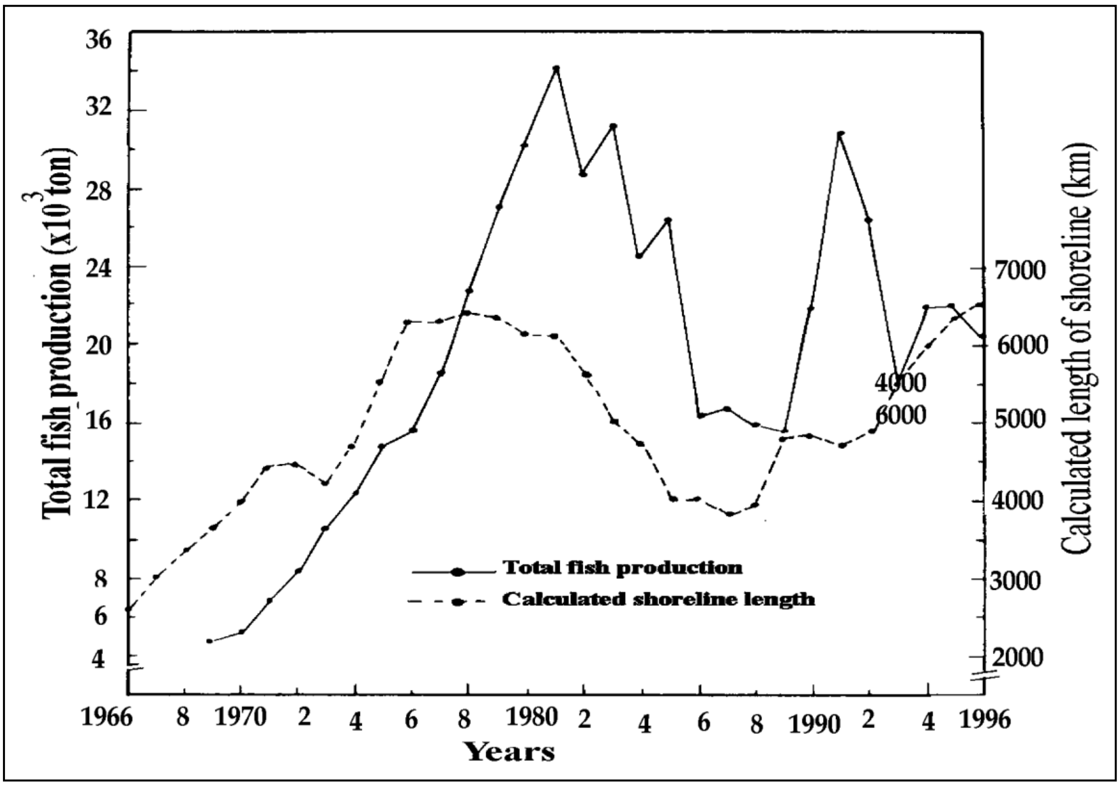


Fig. 171 **Relation between total fish production and calculated mean length of shoreline of Lake Nasser.**

Table 114 **Months of the main peaks in the catch and gonad index (GI) of *0 . niloticus* and *S. galilaeus* . (Mekkawy 1998).**

Catch & gonad index (GI)	Peak no. 1	2	3
Peaks in catch of year (Ahmad 1994)			
1983	March	August	
1984	March	August	November
1985	March	July	November
1989	March	September	December
1990	March	August	December
Peaks in GI of *O. niloticus* (Latif & Rashid 1972)			
Males	March	August	December
Females	April	September	
Peaks in GI of *S. galilaeus* (Abdel-Azim 1974)			
Males	April	September	
Females	February	June	
Peaks in GI of *O. niloticus* (Adam 1994, 1995a and b)			
Males	April	September	December
Females	April	September	

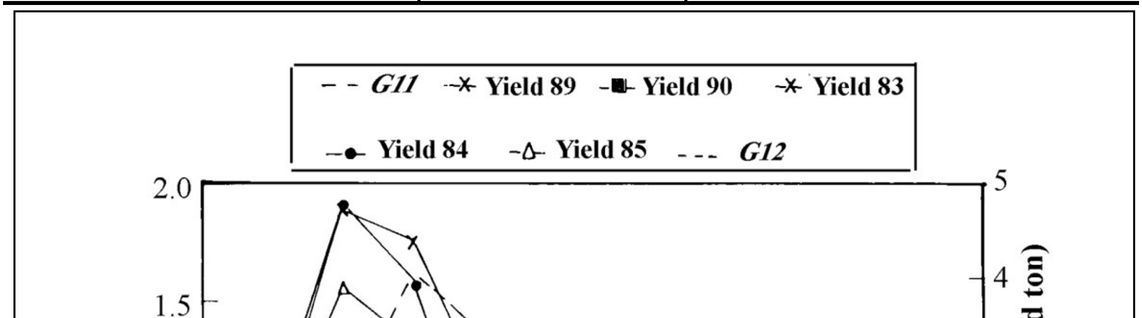


Fig. 172 **The relationship between female gonad index of** ***Oreochromis niloticus*** **and monthly tilapia yield of Lake Nasser in different years (based on data of Latif & Rashid (1972):** ***G1l;*** **Ahmad (1994) and Adam (1994,1995 a and b):** ***G12*****).**

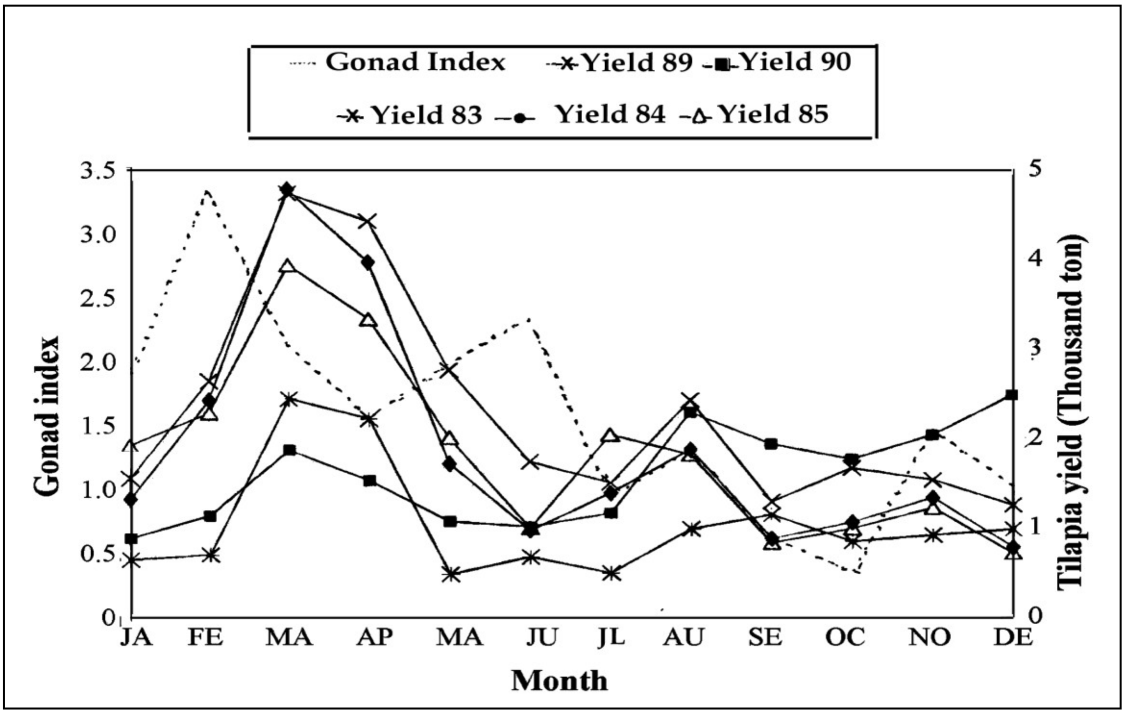


Fig. 173 **The relationship between female gonad index of** ***Sarotherodon galilaeus*** **and monthly tilapia yield of Lake Nasser in different years (based on data of Abdel-Azim (1974) & Ahmad (1994).**

The correlation between the catch of tilapiine species and gonad index (Table, 115) during different years (Mekkawy 1998) showed insignificant correlations in the early years of Lake formation, while those of the latter years exhibited relatively high correlation (except for 1990-catch).

Table 115 **The correlation between the catch of tilapiine fishes and gonad index of *0. niloticus* and *S. galilaeus* of Lake Nasser (Mekkawy 1998) .**

Year	The correlation coefficients with gonad index of:			
	O. niloticus **(Latif & Rashid l972)**	***0. niloticus*** **(Adam 1994)**	***0. niloticus*** **(Adam 1995a & b)**	***S. galilaeus*** **(Abdel-Azim 1974)**
1983	0.63	0.91	0.90	0.40
1984	0.53	0.87	0.85	0.39
1985	0.43	0.85	0.85	0.43
1989	0.58	0.73	0.65	0.00
1990	0.12	-0.27	-0.36	-0.51

RELATIONSHIP BETWEEN PROHIBITING FISHING AND MATURITY

From January to May, *0. niloticus* have maturity stages III-V representing 64.9% of the total mature fishes, while from 15th March to 15th May (prohibiting fishing period) the mature fishes represented 31.65% of the total mature fish examined per year and 48.77% of the total mature fish examined in the first five months (Table 116). Mekkawy (1998) suggested that the production of *0. niloticus is* mainly controlled by mature females during January-May. During the first six months (January-June), the percentage of mature *S. galilaeus* represented 63.6% of the total mature fish examined per year, while it formed only 17.5% during the prohibiting fishing period, and 27.52% of the mature fish during January-June. Considering these results and those of catch gonad-index, Mekkawy (1998) suggested that the prohibiting fishing period should be extended to be six months, from January to June. However, this suggestion is practically inapplicable. Fishing in Lake Nasser cannot be prohibited for more than two months - from March 15th to May 15th . This practice proved to be effective.

FISHING GEARS AND NETS

The fishing gears and nets used for fishing in Lake Nasser are as follows:

1. Floating gill-nets (Sakarota). These nets are designed to fish in surface waters.

The mesh size varies from 3 to 6 cm. The net length varies from 20 to 50 m and depth from 1.5 to 2 m. A number of nets (i.e. from 20 to 40) are stringed together to form a long net. The net is used for fishing raya *(Alestes* spp.) and kalb *(Hydrocynus* spp.). This fishery is operated every night and the catch is gutted and salted.

2. Trammel nets (Duk). The net length ranges from 10 to 20 m and 1.2 to 1.5 m deep. The outside walls have a mesh size of 30 to 40 cm and inside walls of 8 to 10 cm. The trammel net is piled up at the rear of the boat and is easily handled by a fisherman while another man rows the boat. The net is cast and set off against the rocky faces of the shoreline few meters away from the shore. The boat then moves in between shore and the net. A fisherman hits the surface of the water by using a pole. He also drums on the deck with his feet, sending vibrations into the water. Fishes, mainly *Tilapia* spp. (bolti), *Lates niloticus* (samoos), *Bagrus bajad* (bayad) and *Clarias spp.* (hout) drift into nets and get entangled. Fishing starts after darkness and continues till just before dawn. It is confined to shallow water ranging in depth from 1 to 2.5 m. Fishing using trammel nets is the main support for supply of fresh fish.

Table 116 **Frequencies and percentages of *O. niloticus (O.n.)* and S. *galilaeus (S.g.)* at maturity stages III-V in different months (based on studies of Abdel-Azim (1974) and Adam (1994).**

Month	No of fish examined at maturity stages III-V		% relative to total fish examined per month		% relative to total fish examined per year		Cumulative % relative to total fish examined per year	
	O. n.	*S. g.*	*O. n.*	*S. g.*	*O. n.*	*S. g.*	*O. n.*	*S. g.*
Jan.	28	41	51	85	9.1	16.9	9.1	16.9
Feb.	34	20	63	83	11.1	8.3	20.2	25.2
Mar.	45	17	87	94	14.7	7.0	34.9	32.2
Apr.	57	12	89	86	18.6	4.9	53.5	37.1
May	35	22	70	100	11.4	9.1	64.9	46.2
Jun.	14	42	51	100	4.6	17.4	69.5	63.6
Jul.	11	12	33	39	3.6	4.9	73.1	68.4
Aug.	7	19	46	43	5.5	7.9	78.6	76.4
Sept.	29	21	44	39	9.4	8.7	88	85.1
Oct.	16	4	26	11	5.2	1.7	93.2	86.8
Nov.	12	11	19	42	3.9	4.5	97.1	91.3
Dec.	9	21	20	72	2.9	8.7	100	100
Total	**307**	**242**			**100**	**100**		

3- Sunken gill nets (Kobak). The mesh size ranges from 10 to 20 cm. Some of them are as small as 4 m in length. The number of nets joined together is sometimes as many as 20 and the nets may be up to 10 m deep. They are usually set in khors but sometimes in open waters. The fish caught in these nets are *Lates niloticus* (samoos), *Oreochromis niloticus* and *Sarotherodon galilaeus* (bolti), *Labeo* spp. (lebeis), *Bagrus* spp. (bayad), *Barbus bynni* (benny) and *Clarias* spp. (karmout). Most of these fishes are sold as fresh fish. The nets are raised every second night or every night.

4- Beach seines (Gorrafa). The net is used for day-time fishing and catches mainly bolti *(Tilapia* spp.).

5- Long-line. The long-line fishing is operated to a limited extent and is more common in the southern part than in the northern part of the Lake. It is commonly used in deep waters to catch samoos and bayad. The fry and fingerlings of bolti and lebeis are used as bait.

Mesh selectivity curves of trammel net

Adam (1993) carried out experiments on the trammel nets with three mesh sizes, (8, 12 and 18 cm) in stretched measure, over the period of 1983 to 1990 in Lake Nasser. The latter author determined experimentally the mesh selectivities of the trammel net for *Oreochromis niloticus* and *Sarotherodon galilaeus* using Ishida's & McCombie's and Fry's methods. The results of the experiments are shown in Tables 117 & 118 and represented in Figs. 174 -177.

The mesh selectivity curves of the trammel net (Figs. 174-176) were not so clear for *0. niloticus* and *S. galilaeus* (Adam 1993). The figures show that the relative catching efficiency remarkably increased with the length and reached a peak and then gradually decreased as the length increased. Thereby, it was possible to roughly decide the optimum length for a certain mesh size from the curves. Adam (1993) analysed the mesh selectivity for the two fish species using the data obtained through the experiment and summerized his results in the following:

1. The optimum lengths of the fishes show good agreements for each mesh size between the mesh selectivity curves determined by the two methods.

2. The trammel net has a tendency to sharply select small-sized fish, as compared with large-sized ones in both fish species. This tendency is considered to be mainly due to relatively large fishes being entangled both by inside and outside nets.

3. It is likely that the mesh selectivity of the trammel net is weak, at least for the two fish species, compared with that of a gill net.

Table 117 **Number of *0. niloticus* caught by different mesh sizes of inside trammel net and mean of the maximum girth (Adam 1993).**

Fish length (cm)	**Mesh size (cm)**			**Mean of max. girth (cm)**
	8	**12**	**18**	
12.5-14.4 (13.5)	3	0	0	
14.5-16.4 (15.5)	15	1*	0(1)	16.3
16.5-18.4 (17.5)	22	1	0(1)	18.7
18.5-20.4 (19.5)	10	4	1	20.3
20.5-22.4 (21.5)	10	19	3	22.2
22.5 - 24.4 (23.5)	7	30	1	24.3
24.5 - 26.4 (25.5)	3	24	1	26.9
26.5 - 28.4 (27.5)	6	14	1	28.7
28.5 - 30.4 (29.5)	6	8	6	31.0
30.5-32.4 (31.5)	6	8	16	33.3
32.5 - 34.4 (33.5)	8	12	28	34.8
34.5-36.4 (35.5)	9	8	44	37.3
36.5 - 38.4 (37.5)	7	8	23	38.2
38.5 - 40.4 (39.5)	7	7	27	39.7
40.5-42.4(41.5)	2	5	10	42.1
42.5 - 44.4 (43.5)	3	1	10	44.8
44.5 - 46.4 (45.5)	1	1	4	

***(1): Shows one fish caught, for the calculation.**

Table 118 **Number of S. *galilaeus* caught by different mesh sizes of inside trammel net (Adam 1993).**

Fish length (cm)	**Mesh Size**	
	8 cm	**12 cm**
10.5 -12.4(11.5)	6	1
12.5 - 14.4 (13.5)	160	1
14.5 - 16.4(15.5)	303	6
16.5 - 18.4(17.5)	160	22
18.5 - 20.4 (19.5)	89	82
20.5 -22.4(21.5)	54	94
22.5 - 24.4 (23.5)	43	61
24.5 - 26.4 (25.5)	22	50
26.5 - 28.4 (27.5)	8	13

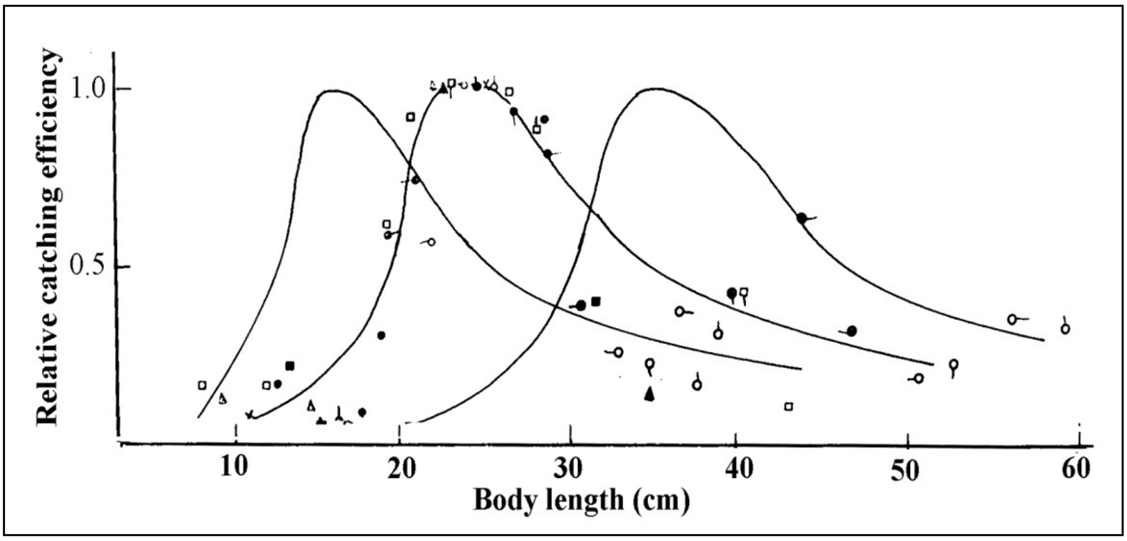


Fig. 174 **Mesh selectivity curve of *O. niloticus* for the trammel net. Plotted points represent the data of 12 cm inside mesh size, Marks show the size classes (Adam 1993). □ 13.5 cm △ 15.5 cm x 17.5 cm ● 19.5 cm ■ 21.5 cm △ 23.5 cm 25.5 cm 27.5 cm 29.5 cm 31.5 cm 33.5 cm 35.5 cm 37.5 cm 39.5 cm 41.5 cm 43.5 cm .**

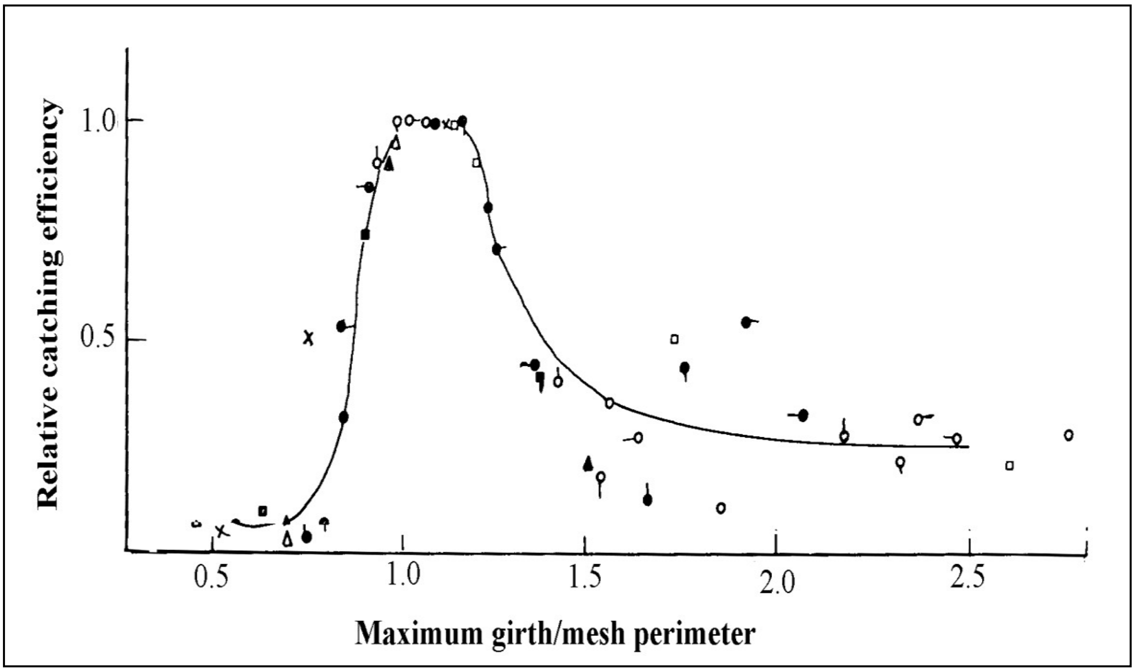


Fig. 175 **Mesh selectivity curve of *O. niloticus* for the trammel net. Plotted points represent the size classes (Adam 1993).**

△ 15.5 cm 17.5 cm ● 19.5 cm ■ 21.5 cm △ 23.5 cm 25.5 cm
27.5 cm 29.5 cm 31.5 cm 33.5 cm 35.5 cm 37.5 cm
39.5 cm □ 41.5 cm ○ 43.5 cm.

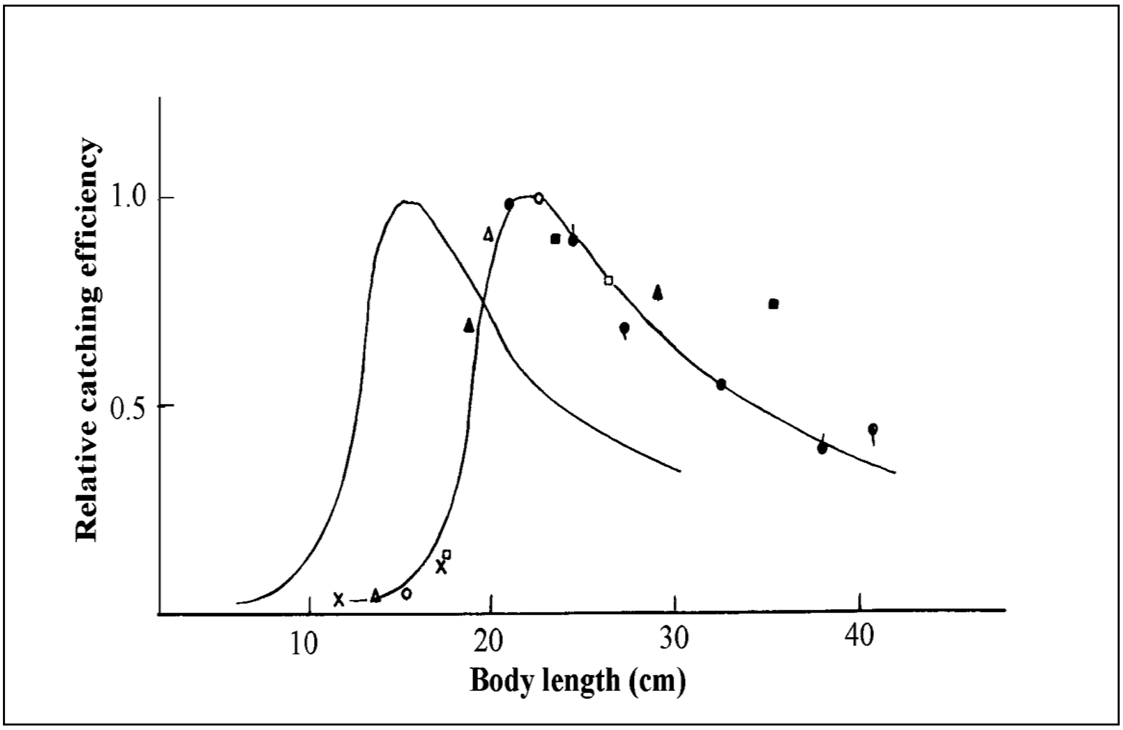


Fig. 176 **Mesh selectivity curve of *S. galilaeus* for the trammel net. Plotted points represent the data of 12 cm inside mesh size. Marks show the size classes (Adam 1993). ✕ 11.5 cm △ 13.5 cm ○ 15.5 cm □ 17.5 cm ▲ 19.5 cm ● 21.5 cm ■ 23.5 cm ⬤ 25.5 cm ⬤ 27.5 cm.**

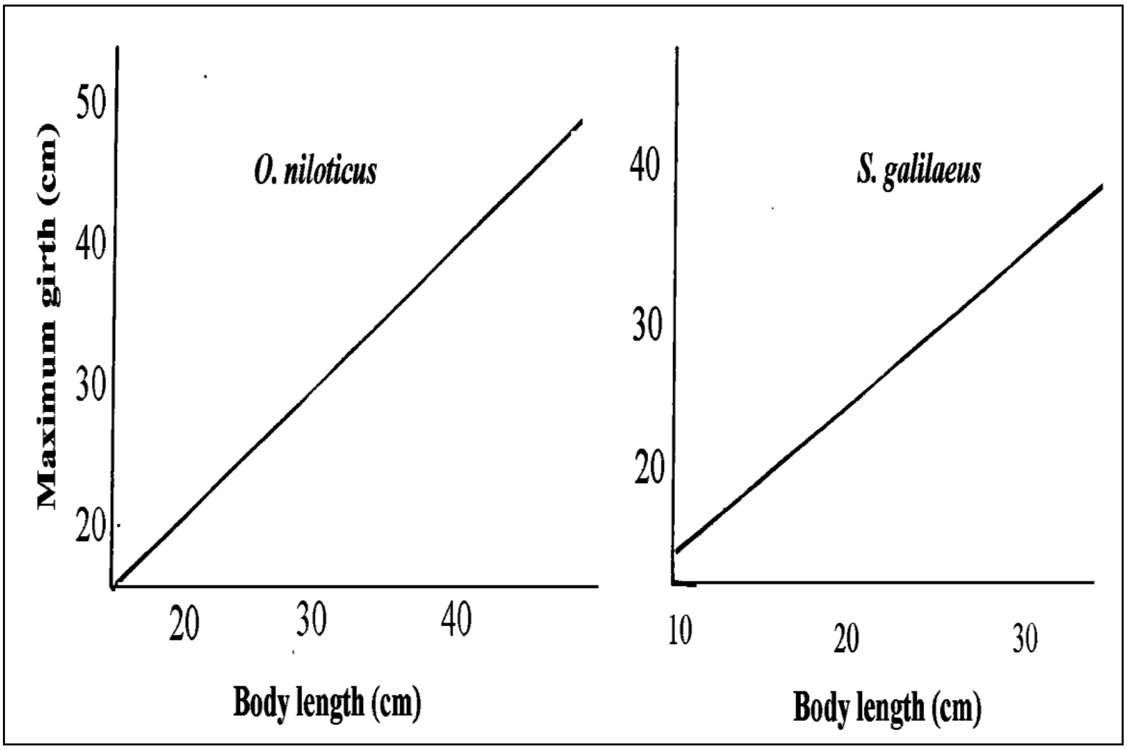


Fig. 177 **Relation between body length of *0. niloticus* and S. *galilaeus* and maximum girth of net (Adam 1993).**

RELATIONSHIP BETWEEN EFFORT AND BIOMASS

Mekkawy (1998) described the effort-biomass relationship for *0. niloticus* and S. *galilaeus* (Fig. 178) by the following equations :

For *0. niloticus*

Biomass (kg) = 4,506,801 + 39,236.75 Effort (boats) where r = 0.577

For *S. galilaeus*

Biomass (kg) = -2,384,143 + 21,503.39 Effort (boats) where r = 0.662

The latter author concluded that fishing can not be considered the only factor or the major one that controls biomass. Furthermore, fishing represents only 33 and 44% of the total effect for *0. niloticus* and *S. galilaeus* respectively.

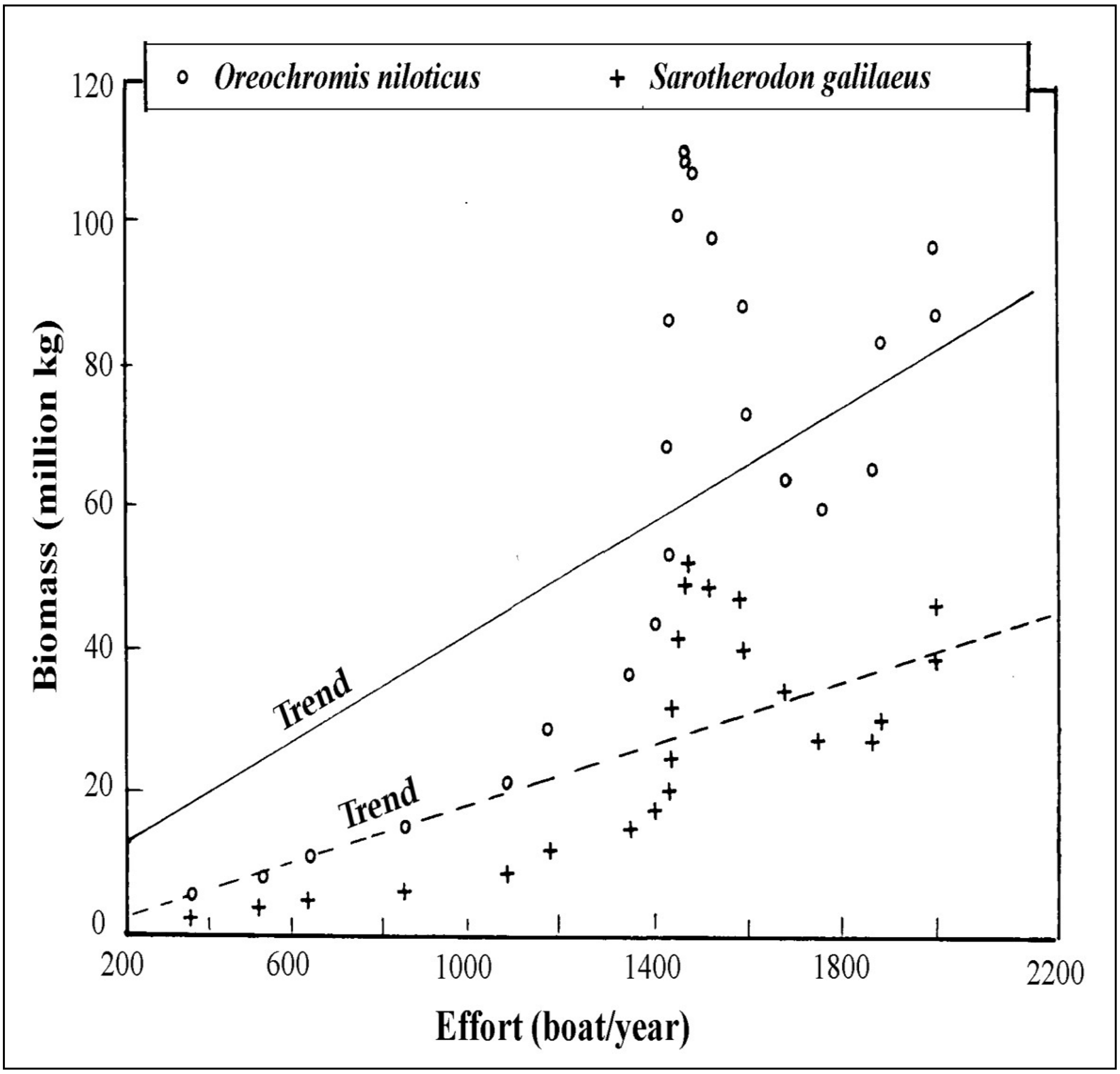


Fig. 178 **The Effort-biomass relationship of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser (Mekkawy 1998).**

VIRTUAL POPULATION ANALYSIS (VPA) AND TURNOVER RATIO

VPA looks at the populations of *0. niloticus* and *S. galilaeus* in a historic perspective. During 1966-1992, the recruits, abundance and biomass of tilapiine species were estimated (Tables 119 and 120 - Mekkawy 1998). The trend of increase in the yield, abundance and biomass per hectare with respect to the corresponding total area of the Lake and 20% of such area (the true exploited spawning -fishing area) are presented in Tables 119 and 120. The Lake yield of the two tilapiine species was relatively high, when considering the true exploited area. The variation in the abundance of the two species may be caused by the variable changes in the rate at which their individuals were added through births or lost through death (Mekkawy 1998).

The latter author determined the fish production of *0. niloticus* and *S. galilaeus* as a function of their mean growth in the cohort, measured by the specific growth rate and the total mortality rate (Tables 119 and 120). The ratio of production to biomass (turnover ratio) was relatively high in the first years of Lake impoundment. However, the turnover ratio of *S. galilaeus* was lower than that of *0. niloticus* through the whole period. The Lake yield of *0. niloticus* and *S. galilaeus,* was smaller than the biomass (Table 119 and 120), which means that their fisheries did not experience difficulties due to the increasing effort during 1966-1991. However, in 1992 the biomass of both species slightly differed from the yield, which means the start of such difficulties. Hence, the fisheries of tilapiine species should be carefully monitored because higher fishing efforts together with a further series of droughts could bring ruin to these fisheries.

GEAR SELECTIVITY

VPA produced an array of estimates of F-values (i.e. fishing pattern). During 1966 -1994, Mekkawy (1998) considered only the fishing pattern of 1979-cohort (since it was with a maximum value of recruitment) for gear selectivity / recruitment curves. F-values of 1979-cohort of *0. niloticus* were 0.005, 0.076, 0.852, 1.124, 2.638 and 1.135 for age groups I, II, III, IV, V and VI respectively. Those of *S. galilaeus* were 0.01,0.312 , 2.864 , 3.403 and 2.579 for age groups I, II, III, IV and V respectively.

Mekkawy (1998) determined the selection curves of *0. niloticus* and *S. galilaeus* (Figs. 179 and 180) and observed that $L_{25\%}$, $L_{50\%}$ and $L_{75\%}$ were 26.25 , 30.42 and 34.58 cm respectively for *0. niloticus* and were 15.26, 16.49 and 17.72 cm respectively for *S. galilaeus,* supposing the trawl fishing was in operation.

According to the length distribution of *0. niloticus* and *S. galilaeus* obtained by Mekkawy *et al.* (1994), Mekkawy & Mohamad (1995) and Shenouda *et al.* (1995) the Lc ($L_{50\%}$) was also estimated by Mekkawy (1998). Such length decreased with time for both species, and these values of Lc refer to the continuous decrease in mesh size used throughout 1970-1994.

Table 119 **The annual yield, biomass, abundance, production and turnover ratio of *0. niloticus* with respect to total area (100%) and the actual exploited area (20%) of Lake Nasser in 1966-1992. (Mekkawy 1998).**

Year	Yield (kg/ha)		Yield (no./ha)		Biomass (kg/ha)		Density (no./ha)		Production (kg/ha)		Turnover ratio (P/B)
	% of Lake Nasser's area										
	100%	20%	100%	20%	100%	20%	100%	20%	100%	20%	
1966	3.6	18.2	1.9	9.5	56.8	283.9	68.2	340.9	35.2	175.9	0.620
1967	2.1	10.6	1.1	5.6	33.2	165.8	39.4	196.8	11.5	57.4	0.346
1968	2.2	11.1	1.2	5.8	34.3	171.4	38.6	192.8	12.7	63.6	0.371
1969	4.8	24.0	2.5	12.5	38.6	193.0	42.2	211.2	14.5	72.3	0.375
1970	5.1	25.5	2.7	13.3	47.1	235.4	52.9	264.3	17.1	85.5	0.363
1971	5.8	29.1	3.0	15.2	59.0	295.2	67.1	335.5	19.0	95.0	0.322
1972	8.3	41.4	4.3	21.6	89.8	448.8	99.8	499.0	28.9	144.7	0.322
1973	14.9	74.3	7.8	38.9	123.4	617.2	132.0	659.9	38.3	191.5	0.310
1974	13.1	65.7	9.5	47.7	132.3	661.6	138.1	690.7	34.2	170.9	0.258
1975	14.0	69.8	10.1	50.6	127.4	636.8	133.9	669.7	31.0	155.2	0.244
1976	14.2	70.9	10.3	51.4	147.6	738.2	160.0	800.0	38.1	190.6	0.258
1977	15.1	75.5	10.9	54.7	186.9	934.4	201.6	1008.0	47.4	237.1	0.254
1978	22.3	111.4	16.2	80.8	223.3	1116.3	231.4	1157.1	60.8	304.1	0.272
1979	30.4	152.1	22.1	110.3	259.3	1296.6	260.4	1302.1	75.7	378.4	0.292
1980	35.3	176.4	25.6	127.9	271.1	1355.5	262.2	1311.1	85.3	426.5	0.315
1981	42.8	214.1	31.0	155.2	271.6	1357.8	260.7	1303.7	75.5	377.3	0.278
1982	34.8	173.9	25.2	126.1	261.0	1305.0	249.1	1245.4	88.0	440.1	0.337
1983	42.7	213.3	30.9	154.7	251.8	1259.0	232.4	1161.8	76.5	382.5	0.304
1984	38.7	193.6	28.1	140.4	237.3	1186.4	215.2	1076.0	87.2	435.8	0.367
1985	45.0	224.8	32.6	163.0	234.6	1173.2	215.0	1075.1	81.5	407.7	0.348
1986	33.4	166.9	24.2	121.0	237.6	1187.8	232.3	1161.6	88.3	441.3	0.372
1987	33.2	166.1	24.1	120.5	255.6	1278.0	260.8	1304.0	78.9	394.4	0.309
1988	35.6	177.9	25.8	129.0	341.1	1705.4	369.8	1848.9	93.0	464.8	0.273
1989	22.1	110.5	16.0	80.1	271.1	1355.4	286.6	1432.8	57.9	289.7	0.214
1990	33.1	165.7	24.0	120.2	280.0	1400.0	257.4	1286.8	69.2	346.2	0.247
1991	50.0	249.8	36.2	181.2	205.9	1029.5	139.0	694.8	77.2	386.0	0.375
1992	45.2	225.8	32.8	163.8	107.1	535.6	55.7	278.3	64.8	323.8	0.605

Table 120 **The annual yield, biomass, abundance, production and turnover ratio of S.** ***galilaeus*** **with respect to total area (100%) and the actual exploited area (20%) of Lake Nasser in 1966-1992. (Mekkawy 1998).**

Year	Yield (kg/ha)		Yield (no./ha)		Biomass (kg/ha)		Density (no./ha)		Production (kg/ha)		Turnover ratio (P/B)
	% of Lake Nasser's area										
	100%	20%	100%	20%	100%	20%	100%	20%	100%	20%	
1966	2.7	13.3	3.8	18.9	13.7	68.7	20.2	101.2	7.1	35.6	0.517
1967	1.6	7.8	2.2	11.0	9.1	45.7	13.9	69.7	2.2	11.0	0.242
1968	1.6	8.1	2.3	11.5	10.8	54.0	16.0	79.8	2.6	13.2	0.245
1969	3.5	17.5	5.0	24.9	13.2	65.8	18.5	92.7	3.3	16.7	0.254
1970	3.7	18.6	5.3	26.4	15.0	74.8	21.3	106.3	4.0	20.0	0.268
1971	4.3	21.3	6.0	30.2	18.4	91.8	26.6	133.1	3.9	19.5	0.212
1972	6.0	30.2	8.6	42.9	27.5	137.4	39.2	196.2	5.7	28.4	0.207
1973	10.8	54.2	15.4	77.1	38.4	192.2	53.8	268.8	6.9	34.5	0.179
1974	9.6	47.9	14.9	74.6	39.7	198.4	55.5	277.3	6.1	30.5	0.154
1975	10.2	50.9	15.8	79.2	37.2	186.1	51.2	256.1	5.1	25.4	0.137
1976	10.3	51.7	16.1	80.5	40.9	204.4	57.7	288.5	6.5	32.3	0.158
1977	11.0	55.1	17.1	85.7	52.2	262.3	75.1	375.6	7.6	38.1	0.145
1978	16.2	81.2	25.3	126.4	67.7	338.6	94.9	474.7	10.2	50.9	0.150
1979	22.2	110.9	34.5	172.6	84.7	423.5	117.6	587.8	13.5	67.5	0.159
1980	25.7	128.7	40.1	200.3	92.5	462.7	125.4	626.8	16.2	81.1	0.175
1981	31.2	156.2	48.6	243.0	95.6	478.2	128.5	642.4	13.5	67.5	0.141
1982	25.4	126.9	39.5	197.4	91.3	456.5	123.8	619.2	17.5	87.6	0.192
1983	31.1	155.6	48.4	242.2	94.1	470.3	125.3	626.4	14.3	71.5	0.152
1984	28.3	141.3	44.0	219.8	89.3	446.4	117.9	589.7	18.4	91.9	0.206
1985	32.8	164.0	51.0	255.2	88.1	440.4	114.8	574.1	17.0	85.1	0.193
1986	24.4	121.8	37.9	189.5	80.7	403.3	108.8	544.0	19.4	96.9	0.240
1987	24.2	121.2	37.7	188.6	79.7	398.6	107.5	537.6	15.7	78.3	0.196
1988	26.0	129.8	40.4	201.9	94.9	474.5	132.6	662.8	16.9	84.6	0.178
1989	16.1	80.6	25.1	125.4	79.2	396.2	114.4	572.2	8.1	40.5	0.102
1990	24.2	120.9	37.6	188.1	101.1	505.6	139.8	698.8	10.2	50.9	0.101
1991	36.4	182.2	56.7	283.6	92.0	460.1	112.7	563.4	14.6	72.9	0.158
1992	32.9	164.7	51.3	256.4	51.9	259.6	56.8	283.9	15.5	77.6	0.299

Mekkawy (1998) estimated the optimum length of *0. niloticus* as 30.1 cm with a selection factor of 2.3684, supposing the trammel-net fishing. Hence, the optimum lengths were 18.94 , 28.42 and 42.63 cm corresponding to 8 - , 12- and 18- mesh size trammel nets respectively in current operations.

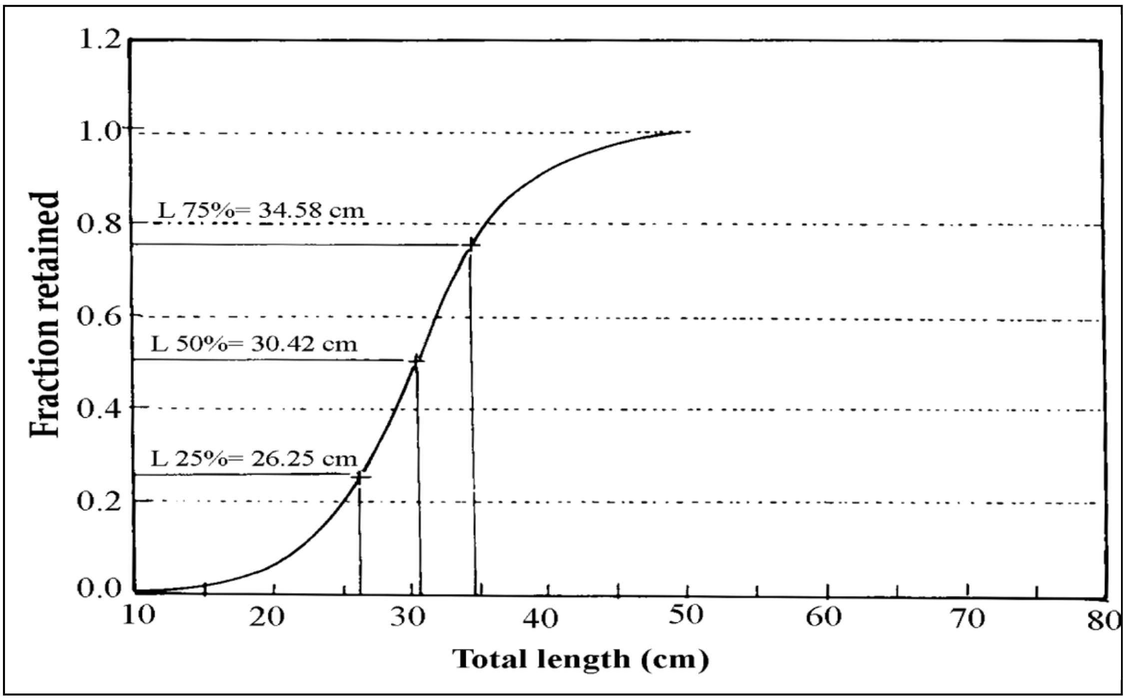


Fig. 179 **Trawl selection curve derived from VPA of *Oreochromis niloticus* as a function of body length (Mekkawy 1998).**

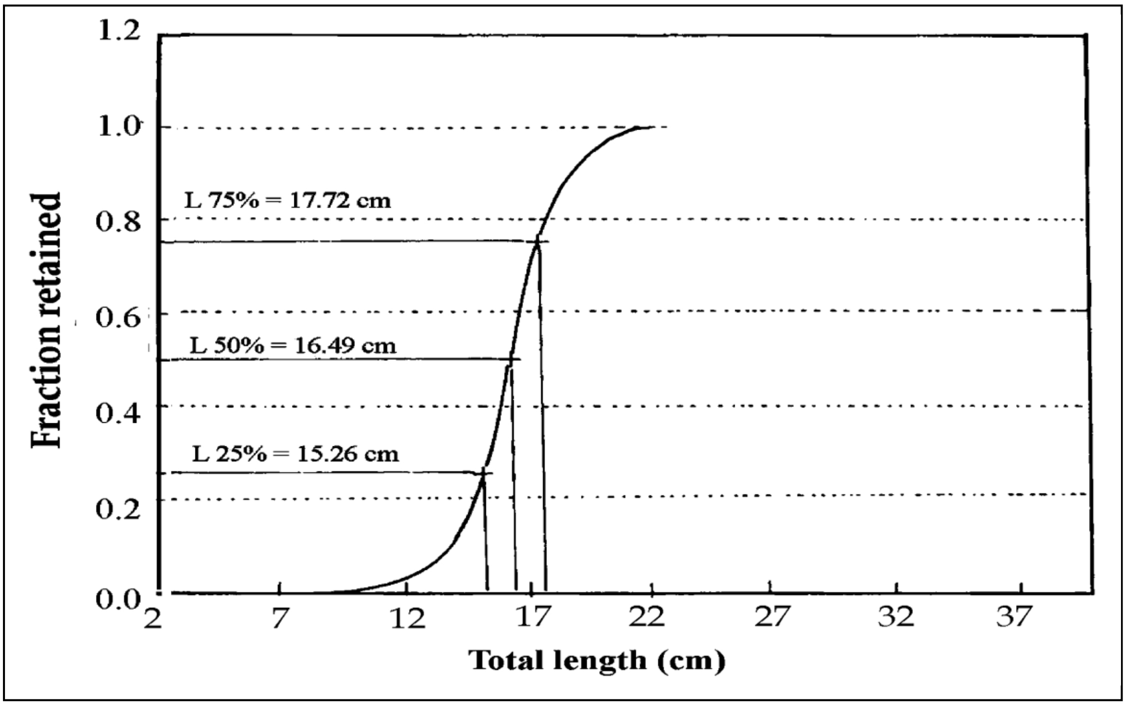


Fig. 180 **Trawl selection curve derived from VPA of *Sarotherodon galilaeus* as a function of body length (Mekkawy 1998).**

These VPA values reflect the long term nature of the data especially those of the first period of Lake formation. The optimum lengths estimated from experimental catch by these trammel nets were 15.45, 23.17 and 34.76 cm for 8 , 12 and 18 mesh size respectively with a selection factor of 1.93116 (Fig. 181). This means that the optimum lengths estimated from experimental catch of the tilapiine species combined were 18.83, 28.24 and 42.36 cm for 8; 12 and 18 mesh sizes respectively. However, Adam (1993) estimated the optimum lengths, according to Ishida (1962), to be 17.0 , 25.5 and 37.0 cm for 8 , 12 and 18 mesh sized trammel nets respectively.

Mekkawy (1998) recorded the VPA-based estimate of the mean optimum length of *S. galilaeus* as 18.45 cm with a selection factor of 1.8448. Hence, the optimum lengths corresponding to 8 and 12 mesh sizes of gill nets in current operation were 14.76 and 22.14 cm respectively and these estimates were lower than those of experimental catch. The latter author showed that the optimum lengths estimated from gill net experimental catch were 16.22 and 24.33 cm for 8 and 12 mesh-sized gill nets respectively with a selection factor of 2.027 (Fig. 182). Such lengths were 15.5 and 23.0 cm for 8 and 12 mesh-sized trammel nets respectively (Adam 1993).

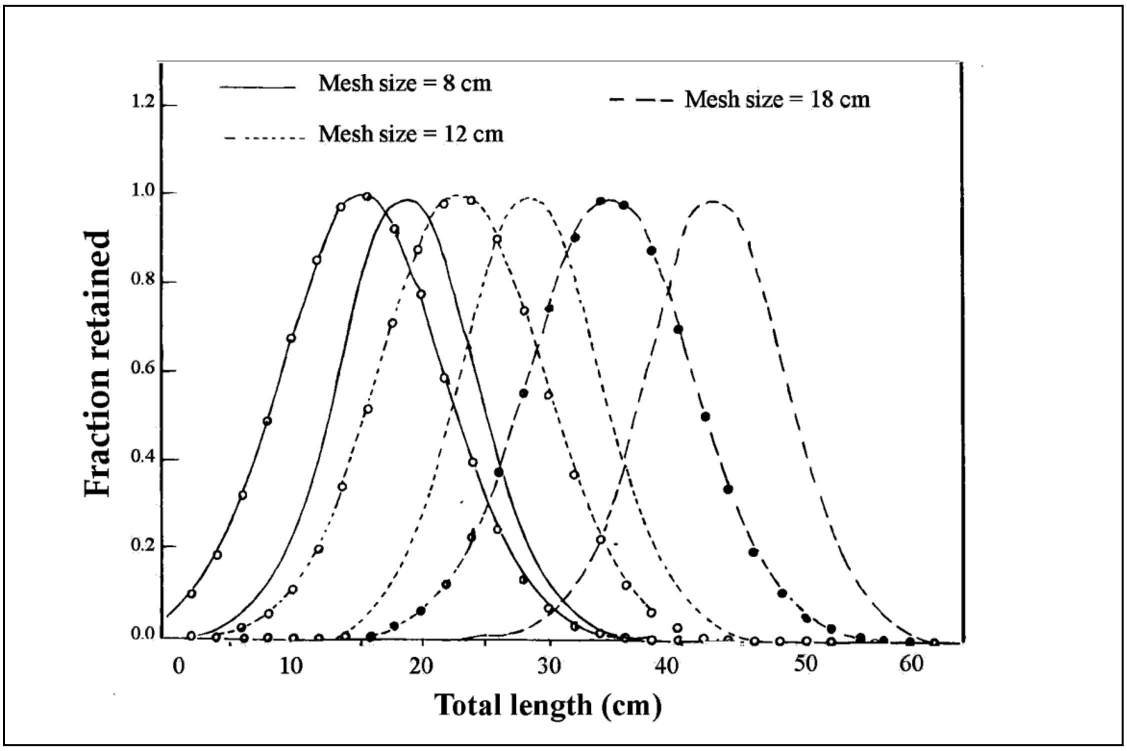


Fig. 181 **Trammel net selection curves for *Oreochromis niloticus* of Lake Nasser (unmarked lines: based on Lm derived from VPA, marked lines: based on Lm derived by analysis of Adam's (1993) raw data according to Sparre *et al.* (1992), (Mekkawy 1998).**

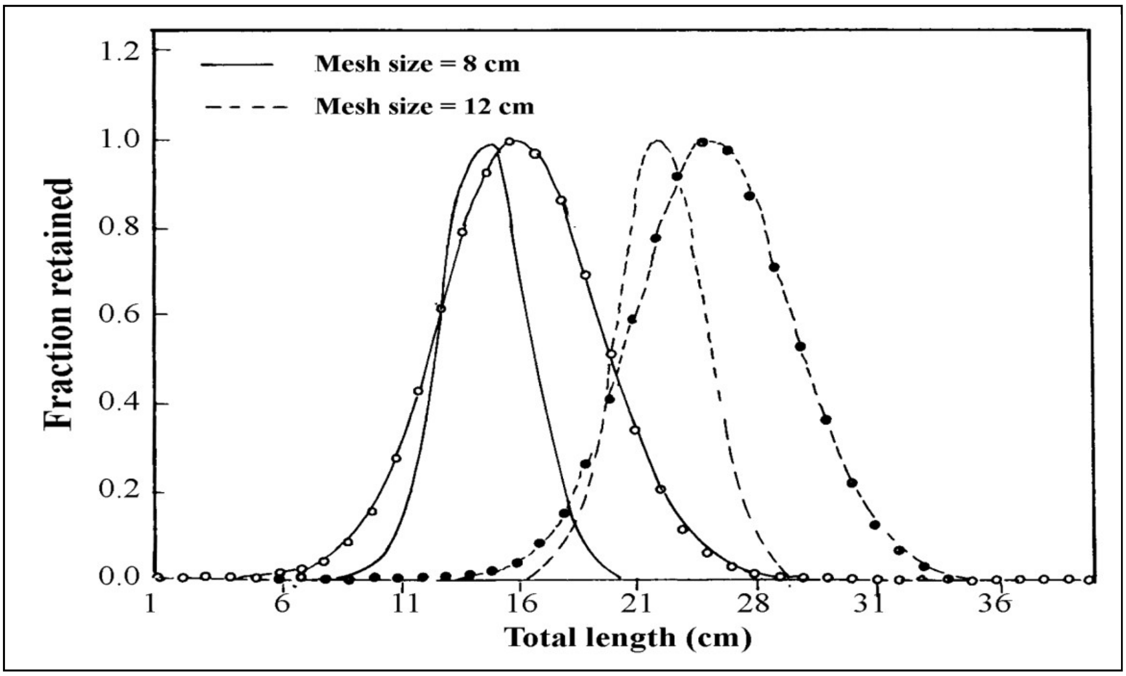


Fig. 182 **Trammel net selection curves for *Sarotherodon galilaeus* of Lake Nasser (unmarked lines: Lm derived from VPA, marked lines: based on Lm derived by analysis of Adam's (1993) raw data according to Sparre *et al.* (1992), (Mekkawy 1998).**

POPULATION CHARACTERISTICS

There were different patterns of growth of *0. niloticus* and *S . galilaeus* during 1970-1990 (Tables 121 and 122). These growth patterns reflect different growth performance indices (ϕl). Thus, during the first period of Lake formation, isometric and positive allometric growth were recorded for the two fish species, whereas negative allometry was observed during the latter years (Tables 121 and 122 - Mekkawy, 1998). In general, the maximum length estimated for the two tilapiine species exhibited a decrease trend with the progression of years. The latter author attributed the reduction in the average size of tilapiine species to two reasons. The first one is the high exploitation rate, while the second possible reason is that large fish migrate from shallow to deep waters during the fishing process. It is suggested to carry further detailed studies on these species to give a satisfactory explanation for the gap between observed maximum length and Lα . The variation in the aforementioned growth parameters reflects the variation in age composition (Table 123).

Other population characteristics of *0 . niloticus, S . galilaeus* and *Lates niloticus* from Lake Nasser, are calculated by Mekkawy (1998) and are presented later in the estimation of the maximum sustainable yield (MSY), using some population characteristics. The actual total mortality rate (A) of both *Tilapia* spp. in Lake Nasser during different years, derived from or based on data of Mekkawy (1998), are presented in Table 124 and Fig. 183.

Table 121 **Estimates of growth parameters and the index of growth performance of *O. niloticus* of Lake Nasser, derived from or based on data of different authors (Mekkawy 1998) .**

Author	**Growth parameters**						
	von Bertalanffy equation ** L(t)=Lα[l-exp(-k(t-to))]				**Growth perfor-mance***	**Power function equation ** W=aL"**	
	k(per year)	**to (years)**	**Lα (cm)**	**Wα (g)**	**ϕ^1**	**n**	**a**
Abdel-Azim (1974)	0.1925	-0.9746	81.57	12289	7.16	3.023++	0.0205
Latif & Khallaf (1987)[a]	0.340	0.59	53.2 (TLα =66.73)	5312.8	6.87	2.8789+	0.0571
Mekkawy *et al.* (1994)	0.0875	-0.9315	76.38	8147	6.24	2.9310+	0.02466
Yamaguchi *et al.* (1990) (Khor Gazal)[a]							
Males	0.384	-0.359	42.77 (TLα =53.94)		6.55		
Females	0.545	-0.117	36.90 (TLα =46.75)		6.61		
Agaypi (1992a) Khors:							
El-Ramla	0.166	-0.94	68.7		6.66		
Gazal	0.472	0.09	47.0		6.95		
El-Allaqi	0.482	0.11	45.2		6.89		
Korosko	0.263	0.44	45.0		6.64		
All khors	**0.275**	**0.75**	**52.0**	**4697.3**	**6.61**	**2.72+**	**0.101**

****: length used in all cases is total length with the exception that "a" length used is standard length.**

***φ=In k+2 In Lα (Pauly & Munro 1984); + and ++ = negative allometric and isometric growth respectively.**

Table 122 **Estimates of growth parameters and the index of growth performance of *S. galilaeus* of Lake Nasser, derived from or based on data of different authors (Mekkawy, 1998).**

Author	Growth parameters						
	von Bertalanffy equation ** L(t)= Lα [1-exp(-k(t-to))]				Growth perfor-mance*	Power function equation ** $W=aL^n$	
	k (per year)	to (years)	Lα (cm)	Wα (g)	ϕ^1	n	a
Abdel-Azim (1974)	0.0365	-6.910	56.89	3047	4.77	3.124+++	0.0162
Latif & Khallaf (1987)[a]	0.27	-1.74	37.6 (TLα =48.75)	1946	5.94	2.2503+	0.5553
Mekkawy & Mohamad (1995)	0.0908	-3.2444	38.33	1097	4.89	2.8687+	0.0315
Yamaguchi *et al.* (1990) (Khor Gazal)[a]							
Males	0.681	-0.052	27.29 (TLα =35.6)		6.23		
Females	0.525	--0.195	28.82 (TLα =37.58)		6.08		
Agaypi (1992a)							
Khors:							
Gazal	0.216	-0.93	36.0		6.63		
El-Allaqi	0.631	0.04	31.0		6.41		
Korosko	0.333	-0.46	33.5		5.92		
All khors	**0.194**	**-0.64**	**42.0**	**2741**	**5.84**	**2.60+**	**0.125**

****: length used in all cases is total length with the exception that "a" length used is standard length.**

***ϕ=In k+2 In Lα (Pauly & Munro 1984); + and ++ = negative allometric and isometric growth respectively.**

Table l23 **Percentages of occurrence of different age groups of** ***O . niloticus*** **and** ***S galilaeus*** **of Lake Nasser in 1965-1990 (Mekkawy, 1998).**

Author	**Age groups**									
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**Mean**
					O . niloticus					
Abdel-Azim (1974) in 1965-1970	30.02	51.76	13.32	4.90						1.83
Latif & Khallaf (1987)in:										
1984	3.20	29.20	30.40	13.10	12.20	7.70	2.90	0.90	0.40	3.44
1985	18.30	41.00	26.60	11.50	2.60					2.39
Mekkawy ***et al.*** **(1994) in 1989-1990**	2.22	16.76	56.65	19.94	4.29	0.14				3.08
Adam (1994) in 1989-1990	21.66	40.82	31.79	5.73						2.22
					S. galilaeus					
Abdel-Azim (1974) in 1972-1973	56.58	31.39	11.29	0.74						1.56
Latif & Khallaf (1987) in:										
1984	14.20	65.40	15.40	3.50	1.40	0.10				2.13
1985	30.10	37.70	30.00	2.30						2.03
Mekkawy & Mohamed (1995) in 1989-1990	1.40	31.10	62.96	4.43	0.11					2.71
Adam (1994) in 1989-1990	57.10	39.16	3.74							1.47

Table 124 **Actual total mortality rate (A) of** ***Oreochromis niloticus*** **and** ***Sarotherodon galilaeus*** **in Lake Nasser during different years (1966-1992). Derived from or based on data of Mekkawy (1998).**

Year	Actual total mortality rate (A)	
	0. niloticus	*S. galilaeus*
1966	0.535	0.291
7	0.583	0.424
8	0.625	0.533
9	0.651	0.592
1970	0.702	0.698
1	0.746	0.778
2	0.763	0.805
3	0.811	0.875
4	0.817	0.882
5	0.846	0.916
6	0.810	0.873
7	0.810	0.873
8	0.791	0.849
9	0.800	0.860
1980	0.807	0.869
1	0.872	0.940
2	0.826	0.892
3	0.860	0.929
4	0.827	0.894
5	0.838	0.906
6	0.804	0.865
7	0.804	0.865
8	0.805	0.866
9	0.894	0.958
1990	0.894	0.958
1	0.872	0.941
1992	0.859	0.927

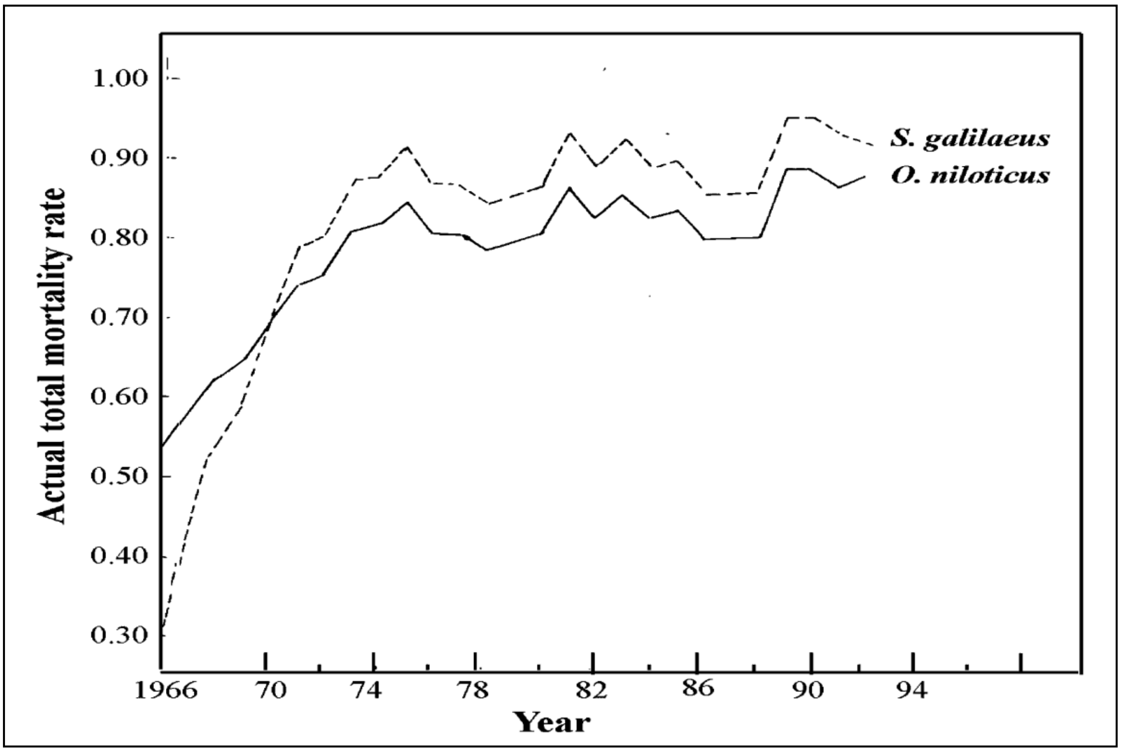


Fig. 183 **Actual total mortality rate of *O. niloticus* and *S. galilaeus* during 1966 -1992 in Lake Nasser.**

DEMOGRAPHIC CHARACTERISTICS

Mekkawy (1998) built up the life tables of 1979 and 1985-cohorts of *O. niloticus* and *S . galilaeas* (Table 125) according to Murray (1979), Krebs (1985) and Wootton (1991). The related parameters are given in Table 125. The survivorship curves of 1979-cohorts of the two tilapiine species exhibited two different curves (Mekkawy 1998-Figs. 184 and 185). That of *0 . niloticus* occupies an intermediate position between type I and type II curves of Krebs (1985). According to the latter author, type I curve represents populations with very little loss for most of the life span and then high losses of older organisms, whereas type II curve, the diagonal survivorship curve, implies a constant rate of mortality independent of age. The survivorship curve of *S. galilaeus* was close to type I.

Table 125 shows the growing nature in the abundance of *0 . niloticus* and *S. galilaeus* . Slight differences in the population characteristics were observed. Figs. 186 and 187 show the relationships between the abundance of adult stock of both tilapiine species in year Y and its abundance in year Y+1 during 1966-1992 (Mekkawy 1998). The relationship was evaluated according to the equation:

$$N_y + 1 = \lambda N_y \text{ (Wootton 1991).}$$

Table 125 **Population parameters of *0. niloticus* and S. *galilaeus* of Lake Nasser based on life tables of their 1979 - and 1985 - cohorts (Mekkawy 1998).**

Parameter	*O. niloticus*		*S. galilaeus*	
	1979-cohort	**1985-cohort**	**1979-cohort**	**1985-cohort**
Ro	1746	2079	2978	4766
rm	4.57	4.57	4.90	4.89
b	9.76	9.75	11.48	11.45
d	5.19	5.18	6.58	6.56
λ	96.37	96.13	133.60	132.93
T	2.09	2.36	2.02	2.51

Ro = net reproductive rate , rm = intrinsic or maximum rate of increase, b = instantaneous birth rate, d = instantaneous death rate; λ = finite rate of increase; T = generation length of population .

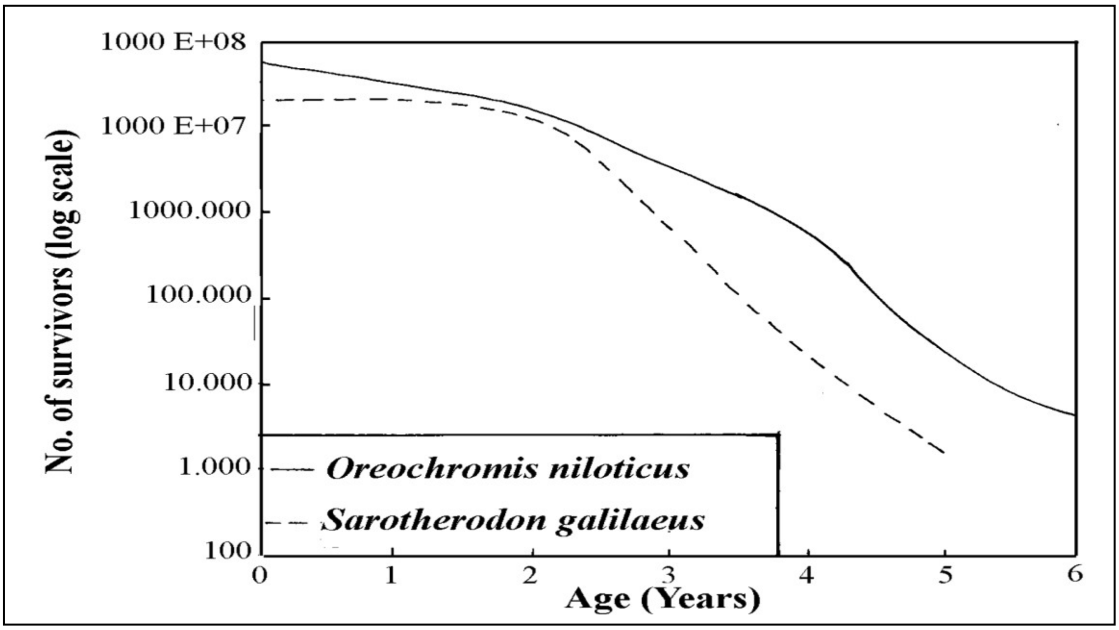


Fig. 184 **Survivorship curves (log scale) of 1979-cohorts of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser (Mekkawy 1998).**

Comparing λ values of Table 125 with those derived from the relationships between the abundance of year Y (Ny) and abundance of year Y + 1 (Ny +1), Mekkawy (1998) concluded that there was a great loss in the pre-recruit stages of both tilapiine species, which was emphasized by the S / R - relationships. Figs. 186 and 187 show general trends towards increase in the abundance relationships in 1966-1992. The latter author concluded that high fecundity, reflected by the aforementioned parameters and long breeding season (Table 114) of these tilapiine species can be considered an adaptation to a short life and to colonize and exploit the fluctuating and unpredictable environment of Lake Nasser.

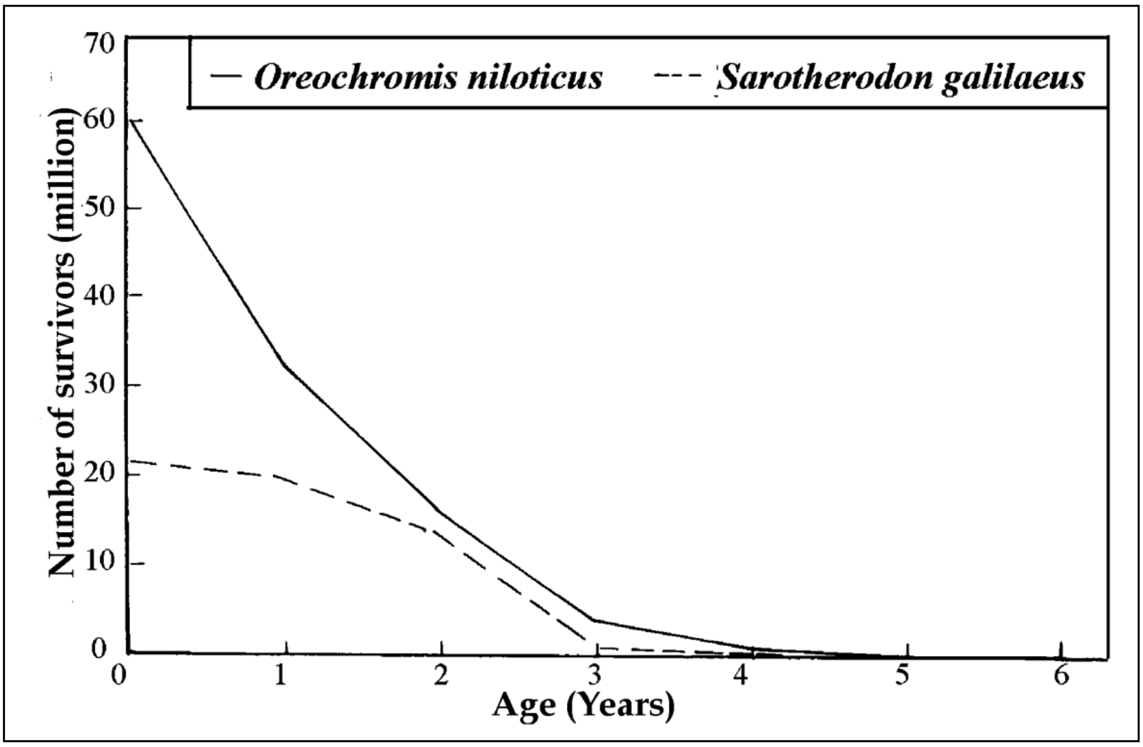


Fig. 185 **Survivorship curves of 1979-cohorts of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser (Mekkawy 1998).**

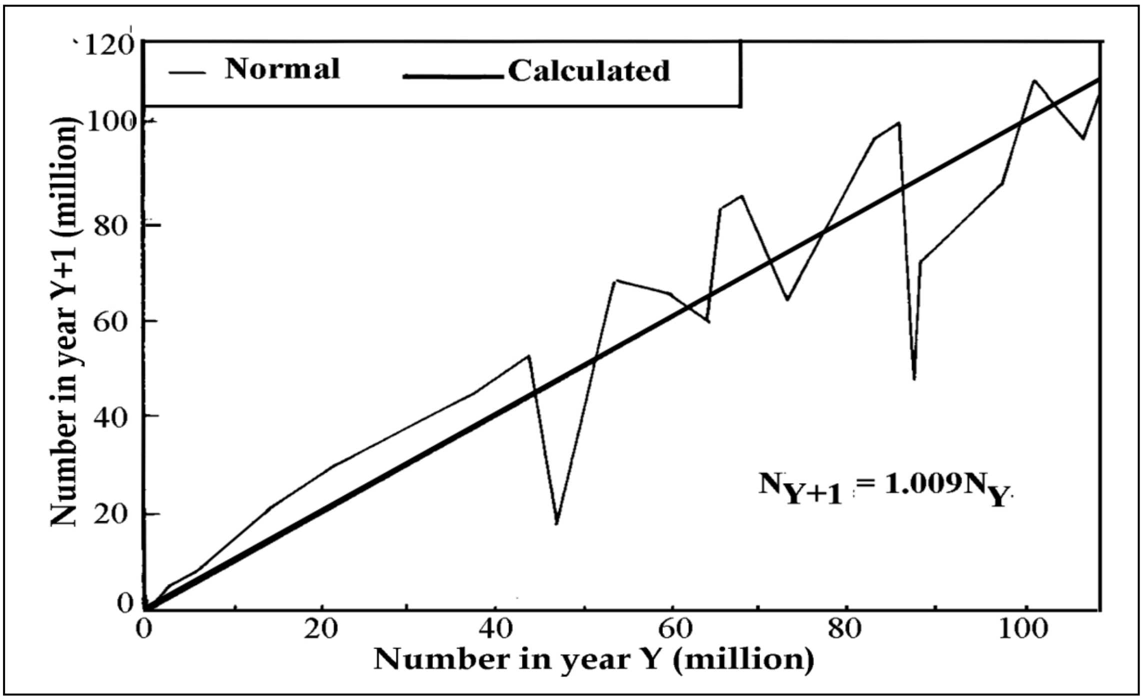


Fig. 186 **The relationship between the abundance of adult stock of *Oreochromis niloticus* in year Y and its abundance in year Y + 1 in 1966-1992 period (Mekkawy 1998).**

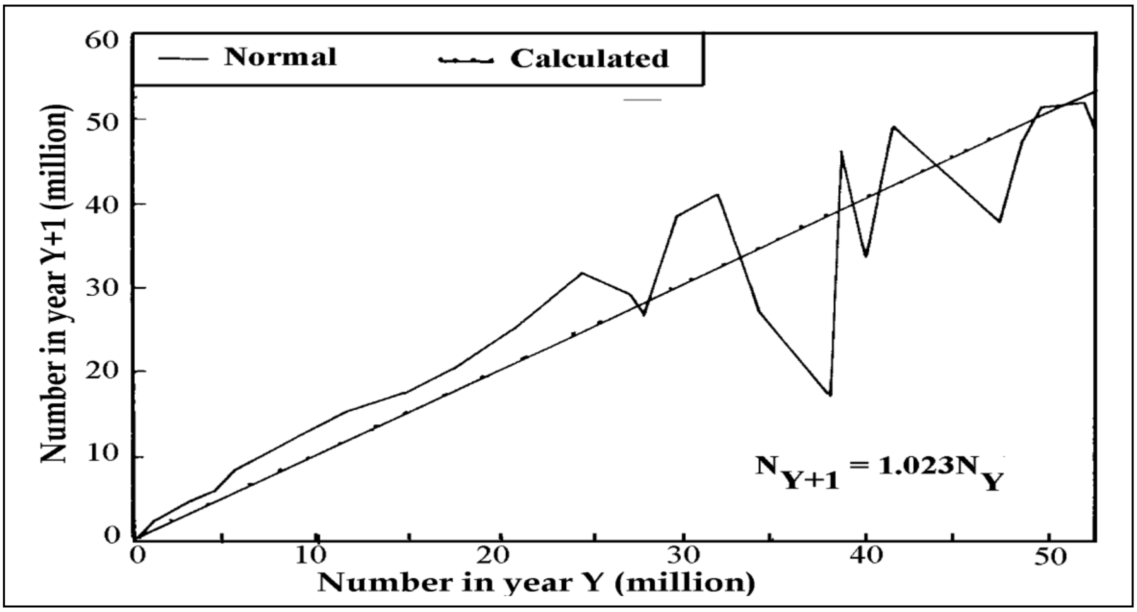


Fig. 187 **The relationship between the abundance of adult stock of *Sarotherodon galilaeus* in year Y and its abundance in year Y + 1 in 1966-1992 (Mekkawy 1998).**

CATCH PER UNIT EFFORT (CPUE)

In Lake Nasser, there are 91 carrier boats, which collect fishes caught by fishermen from the fishing grounds, and transport the catch to Aswan Harbour. The total catch from any fishing ground during one month may be divided by the number of fishing boats working in it, to get the value of CPUE (ton/boat/month). It is important to know the distribution of CPUE in order to exploit rationally fish resources in Lake Nasser. In addition, if one analyses the fluctuations of CPUE throughout the year, it may be possible to estimate the distribution of fish density and spawning grounds, and the relationship between fish distribution and environmental conditions. Accordingly, one can assign the number of fishing boats to each fishing ground.

The average CPUE in Lake Nasser during 1966-1999 was calculated and presented in Table 126. It is clear that the CPUE was less than one ton/boat/month during 1966-1977. Thus, it started at 0.31 ton/boat/month in 1966, and then gradually increased and reached 0.91 ton/boat/month in 1977 (Table 126). The CPUE fluctuated between about one and two ton/boat/month during 1978-1992. The maximum CPUE was 1.90 ton/boat/month and occurred in 1981 (Table 126). Then, the CPUE sharply decreased and was around 0.80 ton/boat/month during 1993-1996, and reached 0.64 ton/boat/month in 1999. It is worth mentioning that during the last 10 years, a part of the commercial catch is sold in the black market illegally at high prices. This leads to a drop in the calculated figures of the CPUE, during recent years.

Table 126 **Catch per unit effort (CPUE) (1966-1999).**

Year	Total fish catch (ton)	Number of fishing boats	Average CPUE (ton/boat/month)
1966	751	200	0.31
67	1415	350	0.34
68	2662	500	0.44
69	4670	599	0.65
1970	5676	816	0.58
71	6819	1039	0.55
72	8343	1135	0.61
73	10587	1440	0.61
74	12255	1540	0.66
75	14635	1630	0.75
76	15791	1680	0.78
77	18471	1690	0.91
78	22725	1700	1.11
79	27021	1613	1.40
1980	30216	1570	1.60
81	34206	1500	1.90
82	28667	1450	1.65
83	31282	1388	1.88
84	24534	1385	1.48
85	26450	1382	1.59
86	16315	1379	0.99
87	16815	1379	1.02
88	15888	1244	1.06
89	15650	1175	1.11
1990	21882	1915	0.95
91	30838	1927	1.33
92	26219	1961	1.11
93	17931	1900	0.79
94	22074	2200	0.80
95	22058	2200	0.84
96	20541	2200	0.78
97	20601	2200	0.78
98	19203	2200	0.73
1999	13983	2200	0.64

Regional and seasonal fluctuations of total catch and CPUE

For analysis of fish catch from the different areas, the northern and southern regions of the Lake are divided into fishing zones. Ecologically, these two regions of the Lake are considerably different from each other especially during the annual flood and or shortly afterwards. Only the southern part of the lake shows turbidity signs of flood.

As previously mentioned, the southern region of Lake Nasser showed higher mean annual values of chlorophyll "*a*" (about 12 mg/m^3) than the northern part (about 8-11 mg/m^3), and this may be due to the supply of sufficient nutrient salts from upper stream of the Nile to the southern part of the Lake (Mohamed, I. 1993a). Furthermore, Mohamed, I. (1993a) pointed out that the southern region of Lake Nasser is richer in zooplankton than the northern part.

Mohamed, M. (1993f) recorded the annual and monthly distribution of fish catch in each fishing ground from each region. The northern region was divided into 40 sectors (no. 1-40), while the southern region included 39 sectors (no. 41-79, Table 127, Figs, 188 a,b,c and d; 189 and 190).

Table 127 **Total monthly catch and CPUE (catch / boat / month) of the northern and southern regions of Lake Nasser (Mohamed, M. 1993f).**

Year	Fishing* ground (No.)	Total catch(kg)		CPUE (ton / boat / month)		No. of fishing boats	
		Aug.	Dec.	Aug.	Dec.	Aug.	Dec.
1988	1) 1-40	677767	587289	1.10	0.95	616	616
	2) 41-79	1031416	442279	1.64	0.70	+628	+628
	(2) / (1)	1.52	0.75	1.49	0.74	1244	1244
1989	1) 1 - 40	675892	610929	1.09	0.98	621	621
	2) 41 - 79	378288	526401	0.80	0.95	+473	+553
	(2)/(1)	0.56	0.86	0.73	0.97	1094	1174
1990	1) 1 - 40	1221319	1104181	1.13	1.03	1,070	1,070
	2) 41 - 79	1106638	1254249	1.31	1.48	+845	+845
	(2)/(1)	0.91	1.14	1.16	1.44	1915	1915
1991	1) 1 - 40	1480850	1346548	1.38	1.26	1,070	1,070
	2) 41 - 79	1963176	1813525	2.29	2.12	+857	+857
	(2)/(1)	1.33	1.35	1.66	1.68	1927	1927
1992	1) 1 - 40	847674	907116	0.79	0.85	1,070	1,070
	2) 41 - 79	1497936	1242001	1.68	1.41	+891	+880
	(2)/(1)	1.77	1.37	2.13	1.66	1961	1950

*** For fishing grounds refer to Fig. 188 a - d.**

The total fish catches of the northern and southern regions were compared during August and December 1988-1992, and the results (Table 127 - Mohamed, M. 1993f) indicate that there were no remarkable differences between the total catches during August and December in the same region. However, appreciable differences were recorded between the two regions, the highest fish yield was recorded in the southern region, compared to that from the northern region during the same period, except in 1989, when the reverse was true, and this may be attributed to the low number of fishing boats operating in the southern region.

The results show that the highest catches during five years (1988/92), were recorded in 15 fishing grounds in the Lake i.e. no. 4,11, 30, 31, 36, 38,42, 44, 50, 62, 67, 69, 70, 71 and 75 (Fig. 189). Most of the locations of fishing grounds with high catch were found in the southern region. While the

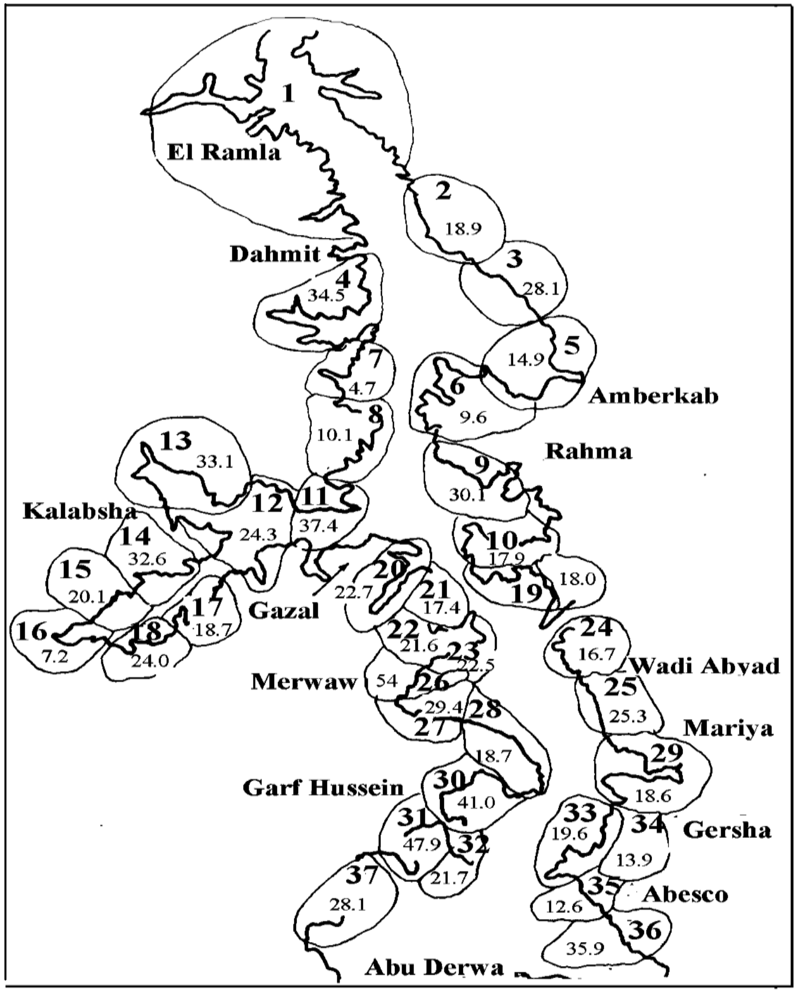


Fig. 188 a. **Mean value of total monthly catch (ton) from 1988 to 1992, fishing grounds no. 2-37 located in the northern region of Lake Nasser (Mohamed, M. 1993f).**

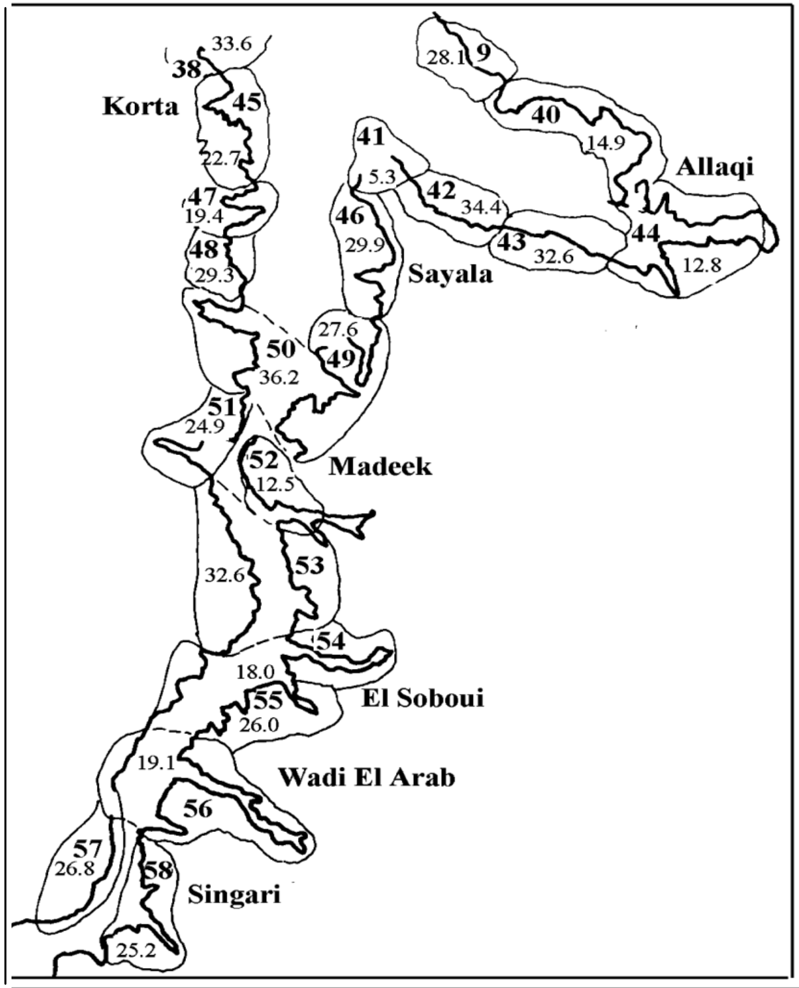


Fig. 188 b. **Mean value of total monthly catch (ton) from 1988 to 1992, fishing ground no. 38-58 located in the southern region of Lake Nasser (Mohamed, M. 1993f).**

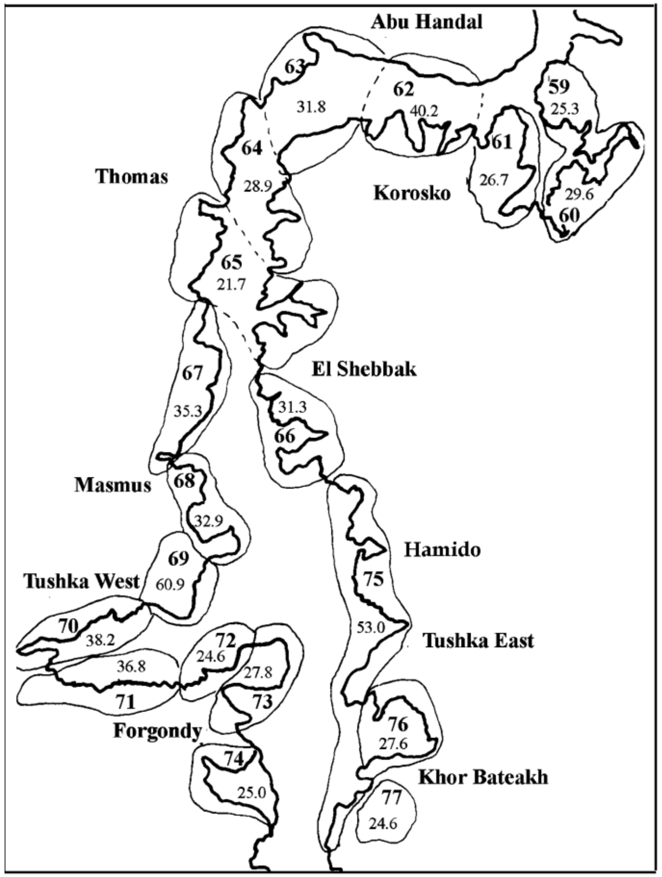


Fig. 188 c. **Mean value of total monthly catch (ton) from 1988 to 1992, for fishing grounds no. 59-77 located in the southern region of Lake Nasser (Mohamed, M. 1993f).**

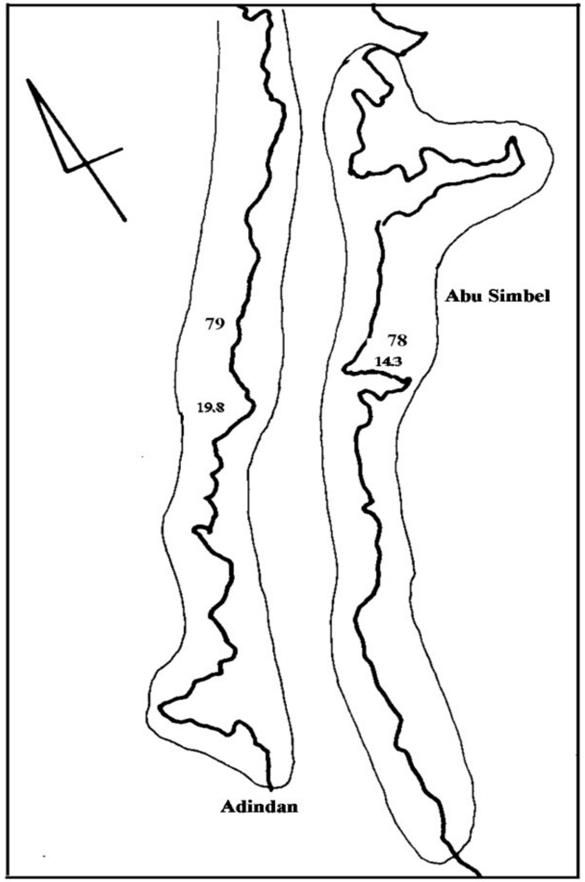


Fig. 188 d. **Mean value of total monthly catch (ton) from 1988 to 1992, for fishing grounds no. 78-79 located in the southern region of Lake Nasser (Mohamed, M. 1993f).**

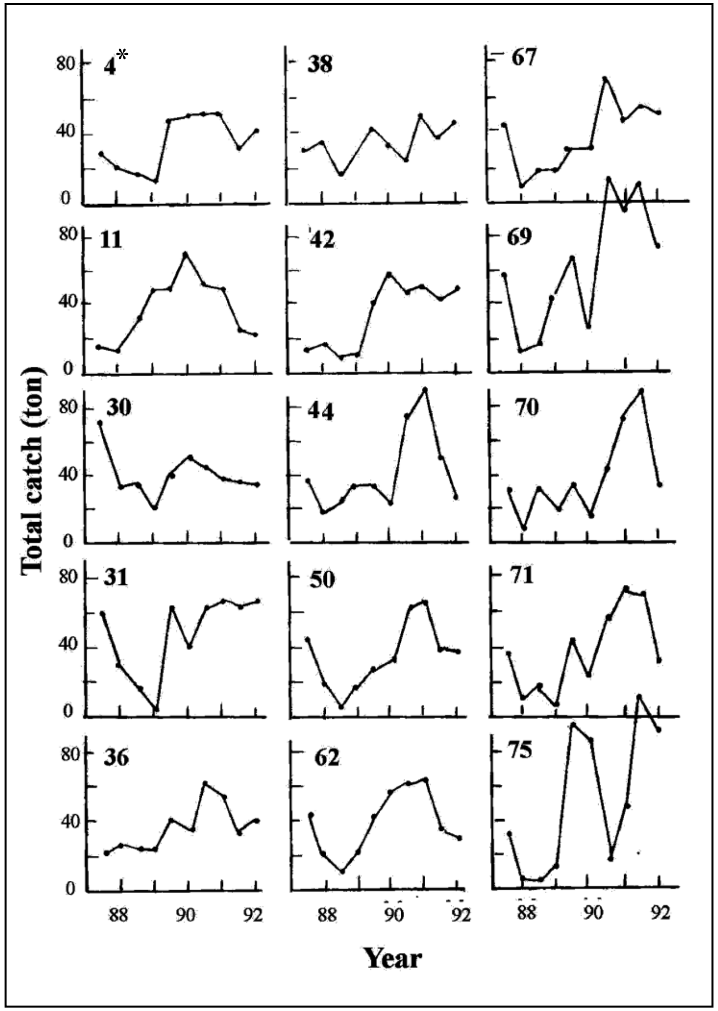


Fig. 189. **Variation of total monthly catch in the 15 fishing grounds with high catch amounting more than 335 and 833 kg from 1988 to 1992 (Mohamed, M. 1993f).** (*For fishing grounds refer to Fig. 188a-c).

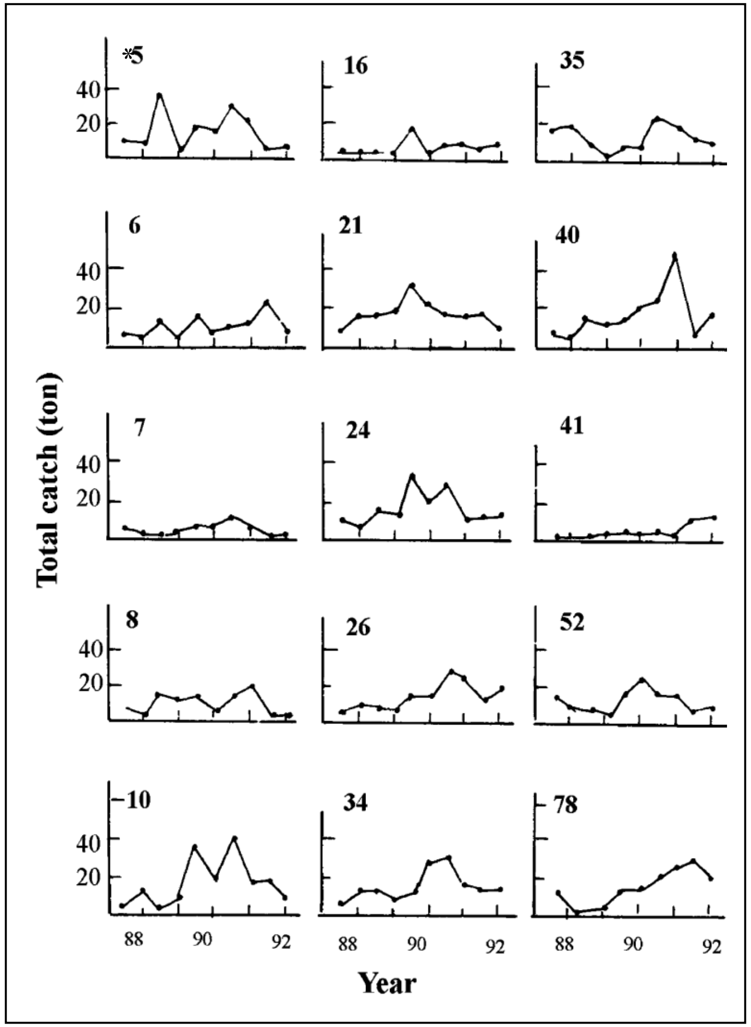


Fig. 190. **Variation of total monthly catch in the 15 fishing grounds with low catch amounting more than 179 and 225 kg from 1988 to 1992 (Mohamed, M. 1993f). (* For** fishing grounds refer to Fig. 188a-d).

lowest catches were collected from 15 fishing grounds, most of them are located in the northern region: no. 5, 6, 7, 8, 10, 16, 21, 24, 26, 34, 35, 40, 41, 52 and 78 (Fig. 190). This phenomenon suggests the possibility of developing active fisheries in the southern region of the Lake. High fish yields were collected from regions close to Allaqi, Korosko and Tushka (Mohamed, M. 1993e).

Adam (1992b) estimated CPUE in five widely separated areas of Lake Nasser, and therefore, it was difficult to get detailed information concerning the fishing grounds. Mohamed, M. (1993a) analysed CPUE of 79 fishing grounds during December, 1991. The location of each fishing ground is assigned a number starting from north to south. The latter author compared CPUE of the northern and southern fishing grounds, and obtained useful information on the exploitation of fishing resources, but the period was restricted only to one month (i.e. December, 1991). The results may be summerized as follows:

1. Total fish yield increases with increase of number of fishing boats.

2. CPUE decreases with the increase of the number of fishing boats, but the frequency distribution of CPUE was different between the northern and southern fishing grounds in the Lake.

3. The values of CPUE are higher in the southern fishing grounds than those in the northern grounds. This phenomenon shows high density of fishes in the southern fishing grounds.

In another investigation, Mohamed, M. (1993d) analysed CPUE and total catch of 79 fishing grounds during two months (August and December, 1991) in order to obtain information on the abundance of fish, actual condition of fishing and density of fishing boats. The results obtained by the latter author may be summerized as follows:

1. The mean value of total catch by fishing grounds of the southern region (i.e. 50.34 and 46.5 kg in August and December respectively) was 1.4 times that of the northern region (i.e. 37.02 and 33.66 kg) during the same month.

2. The mean value of CPUE in the southern region (i.e. 2.6 ton/boat/month) was 1.8 times higher than that of northern region (1.4 ton/boat/month). The density of fish mainly *Tilapia* species was high in the southern region of Lake Nasser.

In order to examine the value and distribution of CPUE (ton/boat/month) in each fishing ground of Lake Nasser Mohamed, M. (1993f) analysed the monthly catch of August and December from 1988 to 1992. The results indicate that the fishing grounds having high CPUE were found in the southern region of the Lake and were concentrated close to Allaqi, Korosko and Tushka (Tables 128 and 129). It is worth mentioning that the average value of

Table 128 **Mean value of CPUE (ton / boat / month) of the northern fishing grounds (No. 1-40).**

Fishing ground		**Mean value of CPUE (ton / boat / month)**			
No.	**(Name)**	**(1988-1992) ***	**(1993)****	**(1994)*****	
				Spring	**Summer**
1	**EI Ramla**	-	0.45	1.39	0.97
2	**Dihmit (East)**	1..24	1.44	1.46	0.64
3	**Dihmit (East)**	1.07	1.42	1.18	0.59
4	**Dihmit (West)**	1.15	0.75	1.30	0.40
5	**Amberkab (East)**	1.02	0.64	0.90	0.43
6	**Amberkab (East)**	0.92	0.56	1.00	0.46
7	**Amberkab (West)**	0.58	0.43	0.99	0.99
8	**Amberkab (West)**	0.95	0.53	1.00	0.47
9	**Rahma (East)**	1.34	0.78	0.96	0.43
10	**Rahma (East)**	1.34	0.77	0.69	0.68
11	**Kalabsha**	1.17	0.41	0.80	0.38
12	**Gazal (North)**	0.96	0.23	0.93	0.41
13	**Gazal (North)**	1.07	0.36	1.26	0.43
14	**Gazal (North) inter**	1.29	0.40	1.04	0.16
15	**Gazal (North)**	0.77	0.22	1.06	0.51
16	**Gazal (Inter)**	0.57	0.15	0.46	0.49
17	**Kalabsha (South)**	0.82	0.23	0.86	0.45
18	**Gazal (South)**	0.85	0.21	0.92	0.28
19	**Merwaw (East)**	1.46	0.57	1.05	0.66
20	**Fallahin (West)**	0.82	0.59	0.99	0.25
21	**Merwaw (West)**	1.16	0.44	1.02	0.62
22	**Merwaw (West)**	0.85	0.33	0.96	0.35
23	**Merwaw (East)**	0.91	0.56	1.00	0.32
24	**Wadi Abyad (East)**	0.71	0.40	0.81	0.26
25	**Wadi Abyad (East)**	1.11	0.75	0.71	0.15
26	**Wadi Abyad**	1.28	0.71	0.71	0.35
27	**Wadi Abyad**	1.25	0.78	0.66	0.43
28	**Galal**	1.17	0.36	1.31	0.44
29	**Mariya**	1.35	0.52	0.97	0.35
30	**Garf Hussein (West)**	1.20	0.54	0.86	0.51
31	**Garf Hussein**	0.91	0.47	0.62	0.17
32	**Garf Hussein (West)**	1.22	0.71	0.68	0.19
33	**Gersha**	1.93	1.28	0.73	0.58
34	**Gersha (East)**	1.46	0.58	0.63	0.09
35	**Abesco (East)**	1.15	0.74	1.43	0.22
36	**Abesco (East)**	1.65	0.76	1.13	0.18
37	**Abu-Derwa (West)**	1.31	0.59	0.77	0.45
38	**Abu-Derwa (West)**	1.01	0.55	0.68	0.12
39	**Allaqi (North)**	1.45	0.65	0.67	0.16
40	**Allaqi (South)**	0.99	0.53	1.05	0.12
Average		**1.11**	**0.59**	**0.94**	**0.48**

*** Mohamed, M. (1993 f).** **** Mohamed, M. (1995 a).** ***** Mohamed, M. (1995 b).**

(For stations refer to Figs. 188 a and b).

Table 129 **Mean value of CPUE (ton / boat / month) of the southern fishing grounds (No. 41-79).**

Fishing ground		Mean value of CPUE (ton / boat / month)			
No.	(Name)	(1988 - 1992)*	(1993)**	(1994)*** Spring	(1994)*** Summer
41	**Allaqi**	1.24	0.98	0.57	0.37
42	**Allaqi**	2.77	1.61	1.20	0.46
43	**Allaqi**	1.77	1.05	0.77	0.36
44	**Allaqi (East)**	1.08	0.71	0.68	0.65
45	**Korta (West)**	1.06	0.67	1.07	0.30
46	**Moharaka**	1.04	0.89	1.93	0.71
47	**Sayala (West)**	1.97	0.79	1.07	0.36
48	**Sayala (West)**	1.00	0.61	0.37	0.31
49	**Sayala (East)**	1.24	0.81	0.53	0.41
50	**Sayala (West)**	1.55	0.72	0.44	0.30
51	**Sayala (East - West)**	2.16	1.24	0.86	0.27
52	**Madiq (East)**	1.07	0.93	0.83	0.46
53	**Madiq (East - West)**	1.05	0.95	1.35	0.49
54	**El Soboui (East)**	2.26	1.36	1.03	0.86
55	**El Soboui (West - East)**	1.26	1.04	1.34	0.86
56	**Wadi El-Arab**	1.02	0.58	1.39	0.70
57	**Malki - Singary**	1.36	0.67	0.53	0.30
58	**Malki (East)**	2.81	1.05	0.71	0.86
59	**Korosko (East)**	1.64	0.77	1.02	0.43
60	**Korosko (Inter)**	2.51	0.97	0.63	0.23
61	**Korosko**	3.25	1.73	0.87	0.35
62	**Abu - Handal (East - West)**	1.64	1.00	0.88	0.45
63	**Abu - Handal (East - West)**	1.27	0.59	0.88	0.40
64	**Thomas - Afia**	1.44	0.99	1.60	0.75
65	**Ibrim - Afia**	1.78	0.56	1.09	0.76
66	**El Shebbak**	1.81	0.97	0.90	0.49
67	**Masmas (Inter)**	1.69	1.22	0.72	0.40
68	**Masmas (West)**	1.34	0.85	1.29	0.78
69	**Tushka (West)**	1.78	1.03	1.44	1.44
70	**Tushka (West)**	1.81	1.75	2.08	0.98
71	**Tushka (West)**	1.91	1.80	1.62	1.28
72	**Tushka (West)**	1.48	0.86	2.24	1.13
73	**Forgondy (West)**	1.59	0.92	2.54	1.74
74	**Forgondy (West)**	1.10	0.72	1.56	1.11
75	**Tushka (East)**	1.18	1.04	1.90	1.21
76	**Hamido (East)**	1.50	1.36	1.91	1.15
77	**Khor Bateakh**	2.59	1.36	1.66	1.31
78	**Abu Simbel (East)**	0.74	0.33	0.86	0.47
79	**Abu Simbel (West)**	0.96	0.41	1.22	0.54
	Average	**1.61**	**0.97**	**1.17**	**0.69**

*** Mohamed, M. (1993f) ** Mohamed, M. (1995 a) *** Mohamed, M . (1995 b). (For stations refer to Figs. 188 b and c).**

CPUE in the southern region (i.e. 1.61 ton/boat/month) was about 1.45 times that of the northern region of the Lake (1.11 ton/boat/month) (Tables, 128 & 129). Mohamed, M. (1993f) selected 15 fishing grounds showing high values of CPUE and other 15 fishing grounds showing low values of CPUE and compared them in order to examine the variation of CPUE for five successive years (1988-1992). The results show that there are remarkable annual and monthly changes in the CPUE for fishing grounds where high catches were recorded especially during 1990 and 1991 (Figs. 191 & 192). On the other hand, the CPUE values did not change so much for the fishing grounds of low CPUE in 1990 and 1991. This may be attributed to location such as: close to khor inlet or on flat shoreline, or to bottom characters (sandy or rocky) and to other reasons.

When considering the relation between the mean value of CPUE and number of fishing grounds in the northern and southern regions of Lake Nasser, it seems that higher values of CPUE (more than 2 ton/boat/month) were recorded from the fishing grounds, located in the southern region of the Lake (Table 130). Thus, six fishing grounds having mean values of CPUE ranging from 2 to 3 ton/boat/month, and one fishing ground, having a mean value of CPUE more than 3 ton/boat/month were recorded in the southern region of the Lake (Table 130).

The fishing grounds no. 42, 58 and 61 have the highest CPUE (over 2.7 ton/boat/month) (Table 131). Nevertheless, their total yields (1988-1992) were 344, 252 and 267 ton respectively (Table 131). Therefore, it is difficult to evaluate the potential productivity of each fishing ground by the value of CPUE (Mohamed, M. 1993f). In order to compare the environmental conditions of the high and low CPUE fishing grounds, more elaborate studies should be carried out in future.

Mohamed, M. (1995 a) studied the distribution of CPUE in Lake Nasser in 1993 (Tables, 132 & 133, and Fig. 193 a - d) and found high values of CPUE in the southern areas of the Lake (Fig. 193 b-d). The mean value of CPUE in the fishing grounds from no. 1 to 40 (northern region of the Lake) was 0.59 ton / boat / month, while the mean value of CPUE from no. 41 to 79 (the southern region of the lake) was 0.97 ton / boat / month. The value of CPUE in the southern region reached 1.6 times that in the northern region of the Lake (Mohamed, M. 1995 a), thus confirming the previous findings (Mohamed, M. 1993d).

The monthly mean catch in 1993 was 526.8 ton in fishing grounds from no. 1 to 40, and the mean value per fishing ground was 13.2 ton. However, the monthly mean catch in 1993 from fishing grounds no. 41 to 79 in the southern region was 810.5 ton and the mean value per fishing ground was 20.8 ton. Thus, the total catch of the southern region reached 1.5 times that of the northern region of the Lake (Mohamed, M. 1995 a).

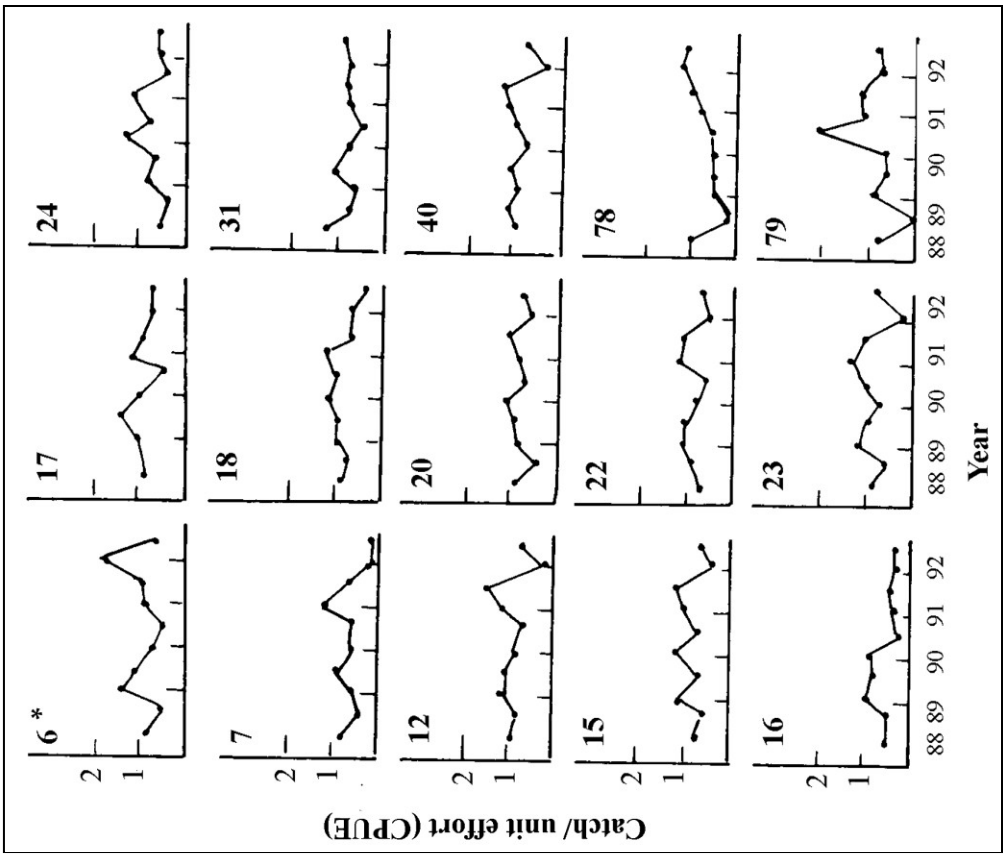


Fig. 192. Variation of CPUE by month in 15 fishing grounds with low CPUE (Mohamed, M. 1993f) (*For fishing grounds refer to Fig. 188 a-d).

Table 130 **Relation between mean value of CPUE and number of fishing**

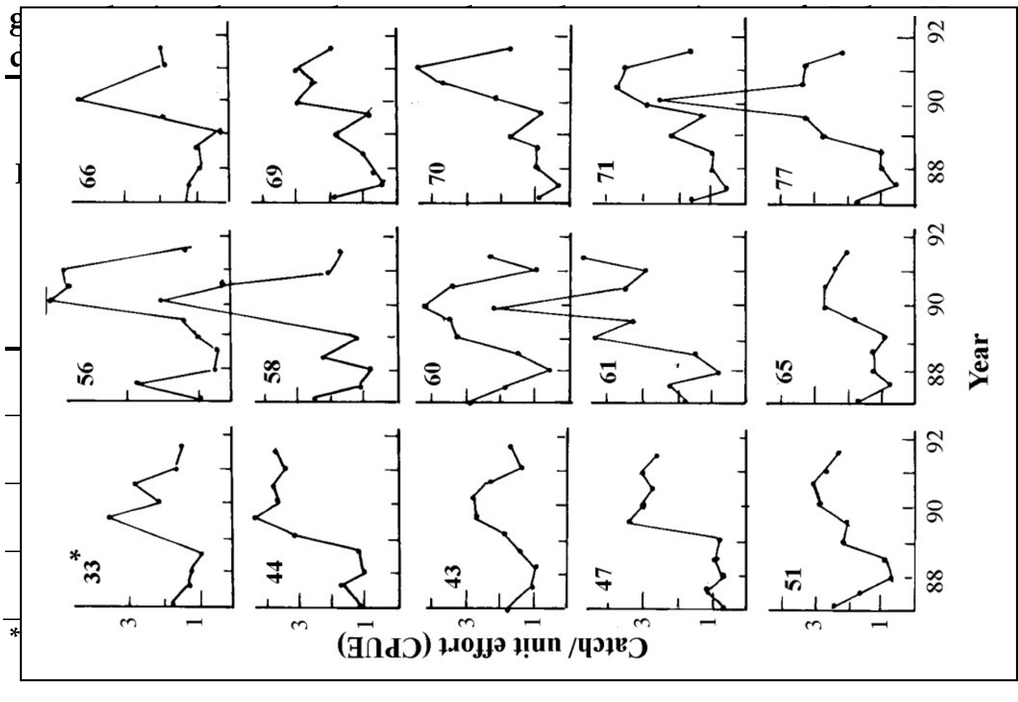


Fig. 191 Variation of CPUE by month in 15 fishing grounds with high CPUE (Mohamed, M. 1993f) (*For fishing grounds refer to Fig. 188a-c).

Table 131 **Mean value of CPUE, total catch from 1988 to 1992 and number of**

fishing boats in 15 fishing grounds with high CPUE (Mohamed, M. 1993f) (For fishing grounds refer to Fig. 188 a-c).

Fishing ground No.	Mean value of CPUE (ton / boat / month)	Total catch-Aug. Dec. (1988 - 1992) (ton)	Number of fishing boats (Dec. 1992)
33	1.93	194.54	9
42	2.77	344.45	13
43	1.77	325.90	17
47	1.97	194.09	10
51	2.16	249.21	11
54	2.26	179.58	27
58	2.81	251.75	12
60	2.51	296.14	12
61	3.25	266.89	8
65	1.78	217.21	14
66	1.81	312.88	19
69	1.78	609.00	36
70	1.81	381.52	20
71	1.91	368.42	20
77	2.59	246.31	13

Table 132 **CPUE, total catch, number of fishing boats and fishermen in the northern region of Lake Nasser in 1993 (monthly average). (Mohamed, M.1995a).**

Fishing ground		Capacity (ton)	No. of cruises	Total catch (kg)	No. of fishing boats	No. of fisher-men	No. of fishing camps	CPUE
No.	Name							
1	**EI Ramla**		39	38.961	86	162	18	0.45
2	**Dihmit (East)**	77	3	14.608	10	21	5	1.44
3	**Dihmit (East)**	10	3	18.771	13	23	7	1.42
4	**Dihmit (West)**	10	4	23.853	31	62	10	0.75
5	**Amberkab (East)**	7	3	8.920	14	29	5	0.64
6	**Amberkab (East)**	7	3	8.912	16	32	5	0.56
7	**Amberkab (West)**	7	2	3.873	9	20	3	0.43
8	**Amberkab (West)**	7	3	7.449	14	27	4	0.53
9	**Rahma (East)**	20	5	26.460	34	65	9	0.78
10	**Rahma (East)**	10	6	13.922	18	45	3	0.77
11	**Kalabsha**	10	3	10.972	27	58	4	0.41
12	**Gazal (North)**	10	3	7.840	34	70	7	0.23
13	**Gazal (North)**	20	3	14.590	40	7	6	0.36
14	**Gazal (North) Inter**	20	3	12.124	30	61	8	0.40
15	**Gazal (North)**	20	4	8.248	37	75	9	0.22
16	**Gazal (Inter)**	7	2	3.492	20	38	5	0.15
17	**Kalabsha (south)**	20	3	9.211	39	79	7	0.23
18	**Gazal (South)**	20	4	7.993	38	72	10	0.21
19	**Merwaw (East)**	10	5	10.896	19	33	4	0.57
20	**Fallahin (West)**	10	2	14.278	24	52	7	0.59
21	**Merwaw (West)**	10	3	6.614	15	29	3	0.44
22	**Merwaw (West)**	10	41	9.433	26	50	6	0.33
23	**Merwaw (East)**	10	3	15.072	27	56	7	0.56
24	**Wadi Abyad (East)**	20	2	9.988	25	52	4	0.40
25	**Wadi Abyad (East)**	20	3	23.147	31	55	5	0.75
26	**Wadi Abyad**	20	3	9.868	14	27	3	0.71
27	**Wadi Abyad**	20	3	20.245	26	48	5	0.78

Table 132 **Cont.**

Fishing ground		Capacity (ton)	No. of cruises	Total catch (kg)	No. of fishing boats	No. of fisher-men	No. of fishing camps	CPUE
No.	**Name**							
28	**Galal**	20	1	6.495	18	35	4	0.36
29	**Mariya**	20	1	7.809	15	42	3	0.52
30	**Garf Hussein (West)**	20	1	6.536	12	26	4	0.54
31	**Garf Hussein**	30	1	19.670	39	89	8	0.47
32	**Garf Hussein (West)**	20	1	12.477	12	27	3	0.71
33	**Gersha**	20	2	11.504	9	18	1	1.28
34	**Gersha (East)**	20	2	8.751	15	45	4	0.58
35	**Abesco (East)**	10	2	9.591	13	40	6	0.74
36	**Abesco (East)**	20	2	19.072	23	47	8	0.76
37	**Abu-Derwa (West)**	20	1	4.109	24	48	8	0.59
38	**Abu-Derwa (West)**	20	1	13.585	25	53	7	0.55
39	**Allaqi (North)**	20	2	29.607	41	67	14	0.65
40	**Allaqi (South)**	20	2	10.807	20	61	7	0.53
	Total			**526.753**				**23.39**
	Mean			**13.169**				**0.59**

(For fishing grounds refer to Fig. 188 a and b).

Mohamed, M. (1995 b) compared the catch per unit effort and the total catch per month from Lake Nasser between spring and summer of 1994 (Tables, 134 and 135, and Figs. 194 and 195). The results may be summerized as follows:

1. During spring, there was no fishing ground having CPUE more than 2.0 ton/boat/month in the northern region of Lake Nasser; while in the southern region of the Lake three fishing grounds (no. 70, 72 and 73) had CPUE more than 2.0 ton / boat / month. Twenty four fishing grounds had CPUE less than 1.0 ton / boat / month in the northern region of the Lake, compared with only seventeen fishing grounds in the southern region. The mean value of CPUE by fishing grounds was 0.94 ton / boat / month in the northern region of the Lake, and 1.17 ton / boat / month in the southern region. Thus the mean value of CPUE in the southern region reached 1.3 times as much as that of the northern region (Tables 134 and 135).

Table 133 **CPUE (ton/boat/month), total catch, number of fishing boats and fishermen in the southern region of Lake Nasser in 1993 (monthly average) (Mohamed, M. 1995a).**

Fishing ground No.	Fishing ground Name	Capacity (ton)	No. of cruises	Total catch (kg)	No. of fishing boats	No. of fisher-men	No. of fishing camps	CPUE
41	**Allaqi**	10	2	6.668	7	22	2	0.98
42	**Allaqi**	20	3	30.547	19	57	2	1.61
43	**Allaqi**	20	1	18.160	13	43	5	1.05
44	**Allaqi (East)**	30	2	31.990	45	123	18	0.71
45	**Korta (West)**	20	2	16.099	24	70	7	0.67
46	**Moharrka**	30	3	27.541	31	90	15	0.89
47	**Sayala (West)**	20	1	7.910	10	22	2	0.79
48	**Sayala (West)**	20	3	23.889	39	78	7	0.61
49	**Sayala (West)**	20	1	16.825	21	57	11	0.81
50	**Sayala (West)**	20	2	20.209	27	72	10	0.72
51	**Sayala (East-West)**	20	3	13.656	11	30	4	1.24
52	**Madiq (East)**	20	1	13.929	15	48	3	0.93
53	**Madiq (East-West)**	30	2	26.575	28	84	9	0.95
54	**El Soboui (East)**	20	2	12.476	9	29	2	1.36
55	**El Soboui (East-West)**	30	3	22.757	22	91	12	1.04
56	**Wadi El Arab**	20	1	11.077	19	78	7	0.58
57	**Malki- Singary**	30	2	18.030	27	82	8	0.67
58	**Malki**	20	2	8.422	8	30	2	1.05
59	**Korosko (East)**	20	2	11.566	15	72	7	0.77

(For fishing grounds refer to Fig. 188 b and c).

Table 133 **Cont.**

Fishing ground		Capacity (ton)	No. of cruises	Total catch (kg)	No. of fishing boats	No. of fisher-men	No. of fishing camps	CPUE
No.	**Name**							
60	**Korosko (Inter)**	20	3	13.572	14	48	73	0.97
61	**Korosko**	20	2	20.785	12	30	3	1.73
62	**Abu Handal (East - West)**	30	3	36.905	37	98	18	1.00
63	**Abu Handal (East - West)**	20	2	18.702	26	86	14	0.59
64	**Thomas, Afia (East - West)**	20	2	23.890	24	85	77	0.99
65	**Ebrim, Afia**	20	1	10.578	14	44	4	0.56
66	**El-Shebbak**	30	1	20.461	19	66	11	0.97
67	**Masmas (West)**	30	2	27.985	23	92	2	1.22
68	**Masmas (inter)**	30	2	24.527	29	82	5	0.85
69	**Tushka (West)**	60	3	30.369	36	146	5	1.03
70	**Tushka (West)**	30	2	36.745	21	78	6	1.75
71	**Tushka (West)**	30	2	36.059	20	69	4	1.80
72	**Tushka (West)**	20	2	16.341	19	54	6	0.86
73	**Forgondy (West)**	20	2	18.450	20	68	8	0.92
74	**Forgondy (West)**	20	2	20.000	28	97	5	0.72
75	**Hamido (East)**	30	3	46.059	42	141	22	1.04
76	**Hamido (East)**	20	3	28.564	21	84	15	1.36
77	**Khor Bateakh**	20	3	19.202	14	34	3	1.36
78	**Abu Simbel (East)**	20	2	10.184	25	57	10	0.33
79	**Abu Simbel (West)**	20	2	13.004	39	112	13	0.41
Total				**810.489**				**37.89**
Mean				**20.782**				**0.97**

(For fishing grounds refer to Fig. 188 c and d).

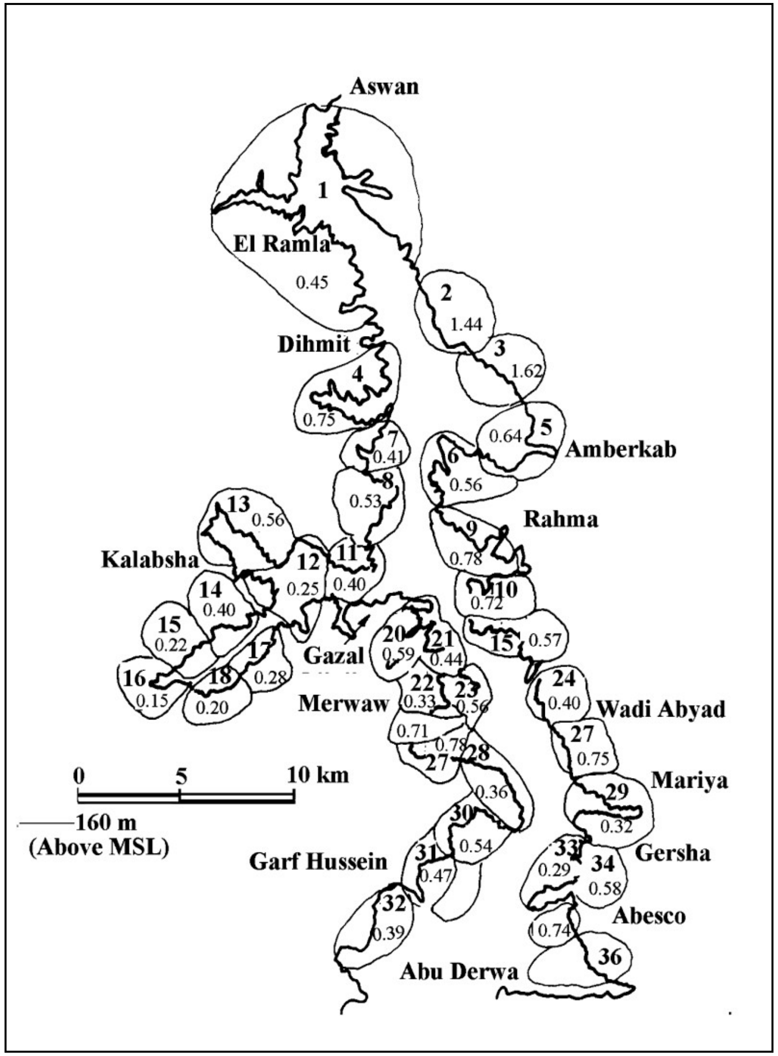


Fig. 193 a. **Distribution of CPUE (ton/boat/month) in Lake Nasser, fishing grounds no. 1-37 (Mohamed, M. 1995a).**

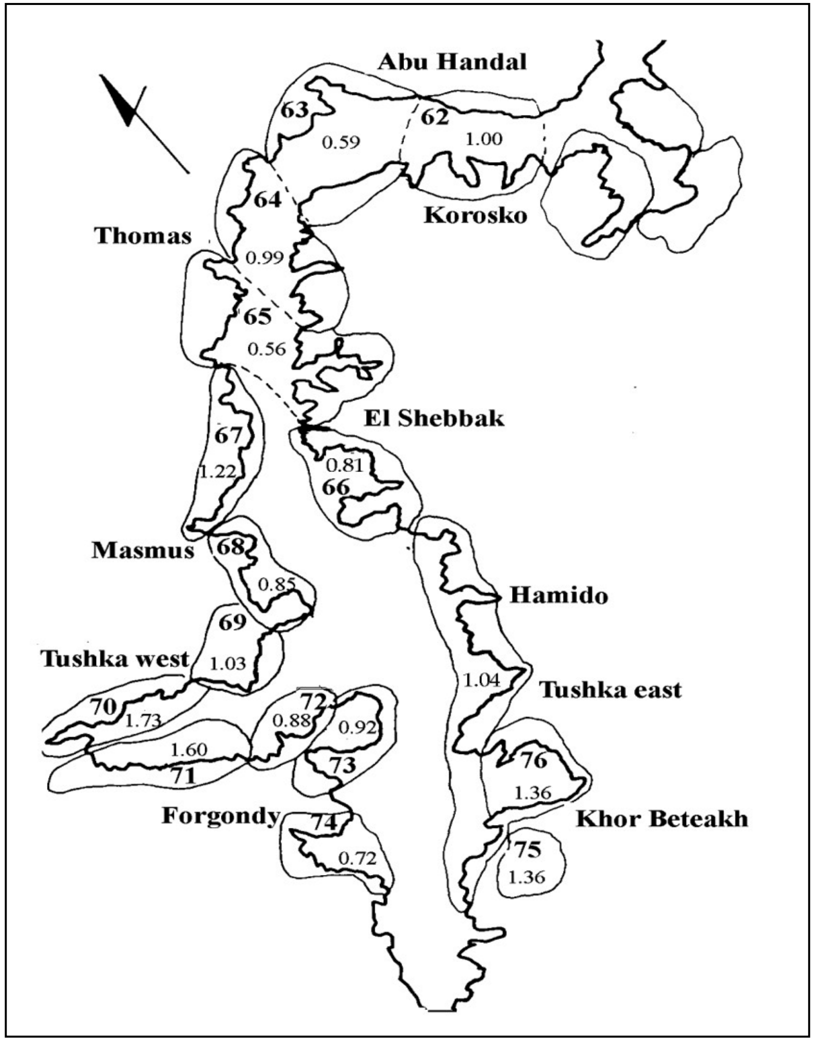


Fig. 193 b. **Distribution of CPUE (ton/boat/month) in Lake Nasser, fishing grounds no. 38-58 (Mohamed, M. 1995a).**

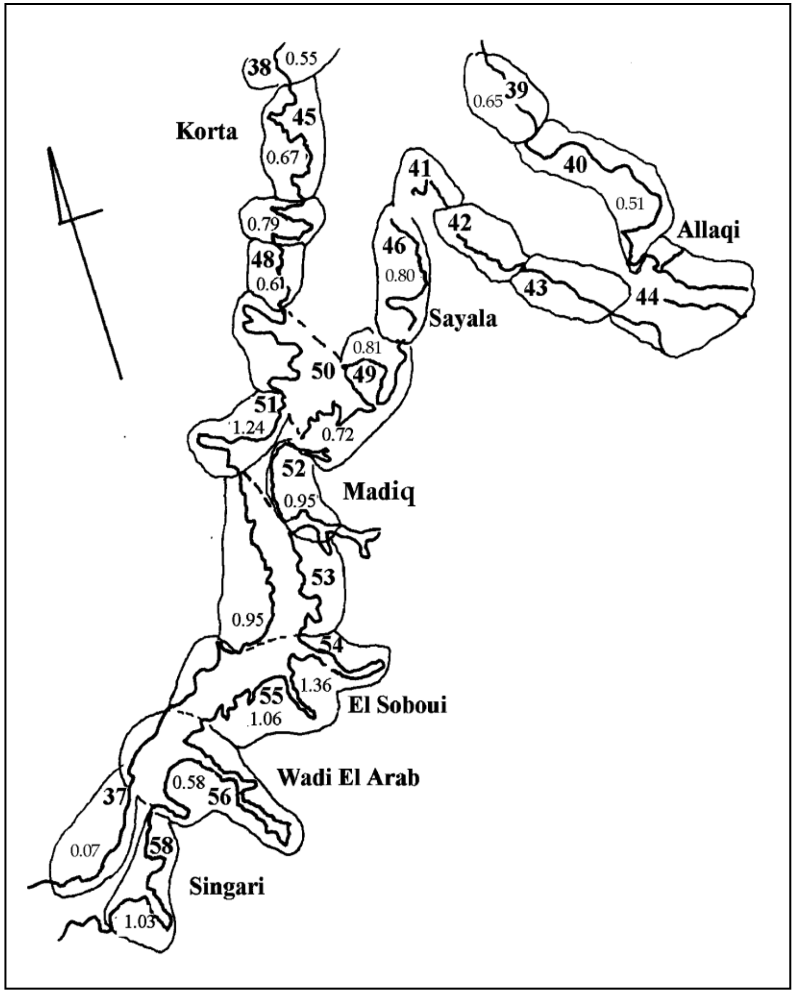


Fig. 193 c. Distribution of CPUE (ton/boat/month) in Lake Nasser, fishing grounds no. 59-77 (Mohamed, M. 1995a).

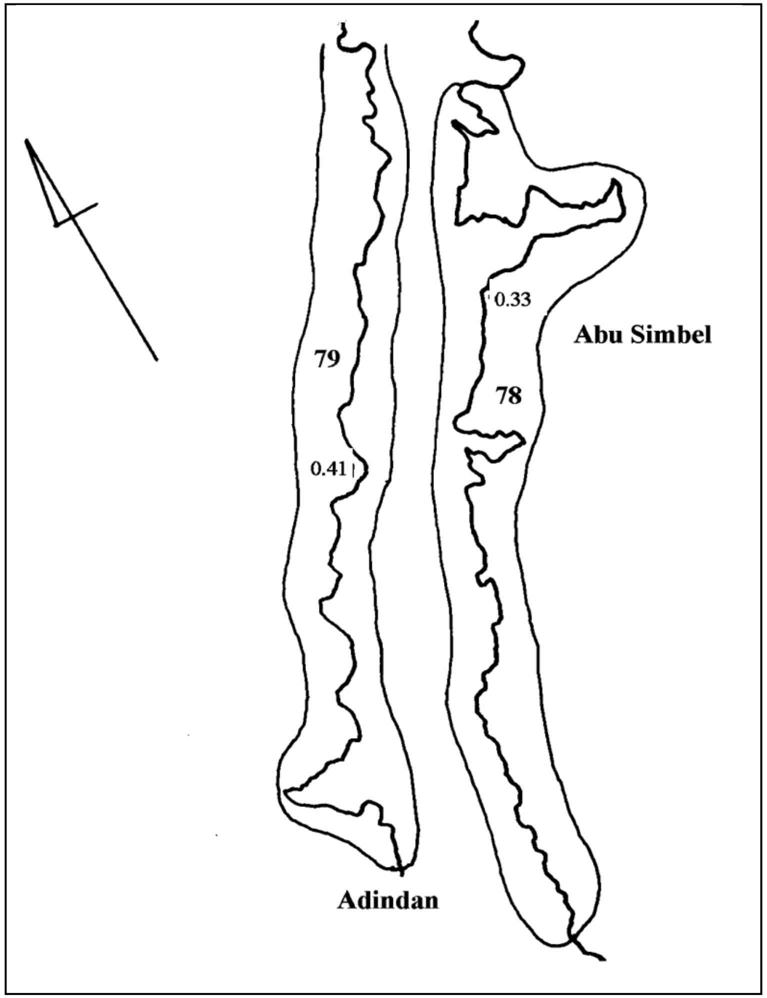


Fig. 193 d. Distribution of CPUE (ton/boat/month) in Lake Nasser, fishing grounds no. 78 and 79 (Mohamed, M. 1995a).

2. During summer, there was only one fishing ground having CPUE more than 1.0 ton / boat / month in the northern region of the lake, but in the southern region eight fishing grounds (no. 69, 71, 72, 73, 74, 75, 76 and 77) had CPUE more than 1.0 ton / boat/ month. The mean value of CPUE by fishing ground was 0.48 ton / boat / month in the northern region and 0.69 ton / boat / month in the southern region of the Lake. The mean value of CPUE in the southern region reached 1.4 times as much as that in the northern part of the Lake (Tables. 134 and 135).

Generally in 1994, the mean value of CPUE in spring was 1.05 ton / boat / month, but in summer it was 0.59 ton / boat / month. The mean value of CPUE in spring reached 1.8 times as high as that in summer . This phenomenon suggests that the density of fish, mainly *Tilapia* spp. was higher in spring than in summer. The frequency distribution of CPUE of 0.6 - 1.0 ton / boat / month was dominant in spring, but it was less than 0.5 ton / boat / month in summer.

The total catch per month by each fishing ground is represented in Tables 134 and 135 . In spring, fishing grounds having total catch per month more than 50 ton were no. 1 and 3 (in the northern region) and no. 62, 64, 69, 70, 71, 72, 73, 75, 76, and 77 (in the southern region). In summer, those having total catch per month more than 50 ton were no. 1 (in the northern region) and no. 69, 70, 71, 75 and 77 in the southern region. Only five fishing grounds had a total catch per month less than 10 ton in spring, but in summer there were 35 fishing grounds. The mean value of total catch per month by fishing ground in spring was 26.64 ton in the northern region and 40.96 ton in the southern region. Hence, the mean value in the southern region reached 1.5 times higher than that in the northern region of the Lake.

The mean value of total catch per month by fishing ground in summer was 10.36 ton in the northern region and 24.25 ton in the southern region. Hence, the mean value of the southern region reached 2.4 times that in the northern region. The total catch per month in spring was nearly twice that in summer in both northern and southern regions. The frequency of total catch per month of value 10.1 to 20 ton was dominant in spring but in summer it was less than 10 ton (Fig. 194).

When comparing the mean values of CPUE of the northern fishing grounds (no. 1-40) in two different periods (Table 128), we find that it was 1.11 ton / boat / month during 1988 - 1992 and 0.59 ton / boat / month during 1993. The same trend is observed in case of the southern fishing grounds (no. 41 - 79), as the average CPUE was 1.61 ton / boat / month during 1988 - 1992 and 0.97 ton/ boat / month in 1993 (Table 129). This means that there is a decrease in the average CPUE in the northern as well as the southern fishing grounds. However, it is obvious that, the southern fishing grounds are still higher in the density of fish than those of the northern fishing grounds (Tables 128 and 129).

Table 134 **Total catch per month and CPUE of the different fishing grounds in the northern region of Lake Nasser (spring and summer, 1994) (Mohamed, M. 1995 b).**

Fishing ground		Total catch (ton) per month		Number of fishing boats	CPUE (ton / boat / month)	
No	Name	Spring	Summer		Spring	Summer
1	**El-Ramla**	169.261	116.035	120	1.39	0.97
2	**Dihmit (East)**	27.801	12.116	19	1.46	0.64
3	**Dihmit (East)**	57.812	29.111	49	1.18	0.59
4	**Dihmit (West)**	23.308	7.230	18	1.30	0.40
5	**Dihmit (East)**	12.584	6.075	14	0.90	0.43
6	**Amberkab (East)**	13.030	6.002	13	1.00	0.46
7	**Amberkab (West)**	1.970	1.988	2	0.99	0.99
8	**Amberkab (West)**	9.991	4.717	10	1.00	0.47
9	**Rahma (East)**	30.610	13.661	32	0.96	0.43
10	**Rahma (South)**	2.059	2.050	3	0.69	0.68
11	**Kalabsha**	18.381	8.688	23	0.80	0.38
12	**Gazal (North)**	13.992	6.102	15	0.93	0.41
13	**Gazal (West)**	16.323	5.565	13	1.26	0.43
14	**Gazal (North)**	29.052	4.380	28	1.04	0.16
15	**Gazal (North)**	11.659	5.573	11	1.06	0.51
16	**Gazal (Inter)**	4.171	4.380	9	0.46	0.49
17	**Kalabsha (South)**	14.648	7.685	17	0.86	0.45
18	**Gazal (South)**	17.499	5.400	19	0.92	0.28
19	**Merwaw (East)**	25.227	15.815	24	1.05	0.66
20	**Fallahin (West)**	17.865	4.408	18	0.99	0.25
21	**Merwaw (West)**	7.150	4.350	7	1.02	0.62
22	**Merwaw (South)**	14.405	5.255	15	0.96	0.35
23	**Merwaw (West)**	20.077	6.321	20	1.00	0.32
24	**Wadi Abyad (East)**	23.467	7.590	29	0.81	0.26
25	**Wadi Abyad (East)**	18.378	4.011	26	0.71	0.15
26	**Wadi Abyad**	19.855	9.820	28	0.71	0.35
27	**Wadi Abyad**	19.150	12.473	29	0.66	0.43
28	**Galal**	32.828	11.028	25	1.31	0.44
29	**Mariya**	23.272	8.973	24	0.97	0.35
30	**Garf Hussein (East)**	24.799	14.731	29	0.86	0.51
31	**Garf Hussein**	18.045	4.930	29	0.62	0.17
32	**Gersha**	19.789	5.400	29	0.68	0.19
33	**Gersha (East)**	20.403	16.138	28	0.73	0.58
34	**Abesco (East)**	18.850	2.765	30	0.63	0.09
35	**Abesco**	41.588	6.250	29	1.43	0.22
36	**Abu-Derwa (West)**	36.080	5.680	32	1.13	0.18
37	**Allaqi (North)**	23.075	13.575	30	0.77	0.45
38	**Allaqi (South)**	19.080	3.335	28	0.68	0.12
39	**Allaqi**	20.907	4.935	31	0.67	0.16
40	**Allaqi**	27.280	5.540	26	1.05	1.12
Total		**1065.675**	**414.564**	**981**	**37.64**	**19.90**
Mean		**26.642**	**10.364**		**0.94**	**0.48**

(For fishing grounds refer to Fig. 188 a and b).

Table 135 **Total catch per month and CPUE of the different fishing grounds in the southern region of Lake Nasser (spring and summer, 1994) (Mohamed, M. 1995 b).**

Fishing ground		Total catch (ton) per month		Number of fishing boats	CPUE (ton / boat / month)	
No	**Name**	**Spring**	**Summer**		**Spring**	**Summer**
41	**Allaqi**	17.148	11.180	30	0.57	0.37
42	**Allaqi**	28.712	15.237	24	1.20	0.46
43	**Allaqi**	18.830	15.207	24	0.77	0.36
44	**Allaqi (East)**	19.058	18.315	28	0.68	0.65
45	**Korta (West)**	30.002	8.390	28	1.07	0.30
46	**Moharaka**	17.337	6.390	9	1.93	0.71
47	**Sayala (West)**	33.049	11.112	31	1.07	0.36
48	**Sayala (West)**	13.433	11.257	26	0.37	0.31
49	**Sayala (East)**	18.941	14.660	26	0.53	0.41
50	**Sayala (West)**	15.980	10.702	26	0.44	0.30
51	**Sayala (East - West)**	21.410	6.745	25	0.86	0.27
52	**Madiq (East)**	20.710	11.418	25	0.83	0.46
53	**Madiq (East - West)**	49.880	18.085	37	1.35	0.49
54	**El Soboui (East)**	23.60	19.768	23	1.03	0.86
55	**El Soboui (West - East)**	20.031	12.823	15	1.34	0.86
56	**Wadi El-Arab**	44.383	22.430	32	1.39	0.70
57	**Malki - Singary**	15.942	8.880	30	0.53	0.30
58	**Malki (East)**	19.880	24.255	28	0.71	0.86
59	**Korosko (East)**	48.759	20.620	48	1.02	0.43
60	**Korosko (Inter)**	13.754	5.050	22	0.63	0.23
61	**Korosko**	48.807	19.800	56	0.87	0.35
62	**Abu - Handal (East - West)**	57.150	29.295	65	0.88	0.45
63	**Abu - Handal (East - West)**	31.660	14.502	36	0.88	0.40
64	**Thomas - Afia**	86.620	40.378	54	1.60	0.75
65	**Ibrim - Afia**	38.165	26.707	35	1.09	0.76
66	**Shebbak**	45.895	25.010	51	0.90	0.49
67	**Masmas (Inter)**	25.847	14.555	36	0.72	0.40
68	**Masmas (West)**	37.353	22.525	29	1.29	0.78
69	**Tushka (West)**	51.671	51.760	36	1.44	1.44
70	**Tushka (West)**	116.397	54.734	56	2.08	0.98
71	**Tushka (West)**	84.179	66.749	52	1.62	1.28
72	**Tushka (West)**	62.638	31.665	28	2.24	1.13
73	**Forgondy (West)**	50.834	34.820	20	2.54	1.74
74	**Forgondy (West)**	29.724	21.068	19	1.56	1.11
75	**Tushka (East)**	104.256	66.728	55	1.90	1.21
76	**Hamido (East)**	70.563	42.692	37	1.91	1.15
77	**Khor Bateakh**	101.140	79.637	61	1.66	1.31
78	**Abu Simbel (East)**	21.545	11.706	25	0.86	0.47
79	**Abu Simbel (West)**	42.615	18.925	35	1.22	0.54
Total		**1597.239**	**945.774**	**1323**	**45.59**	**26.89**
Mean		**40.955**	**24.251**		**1.17**	**0.69**

(For fishing grounds refer to Fig. 188 b - d).

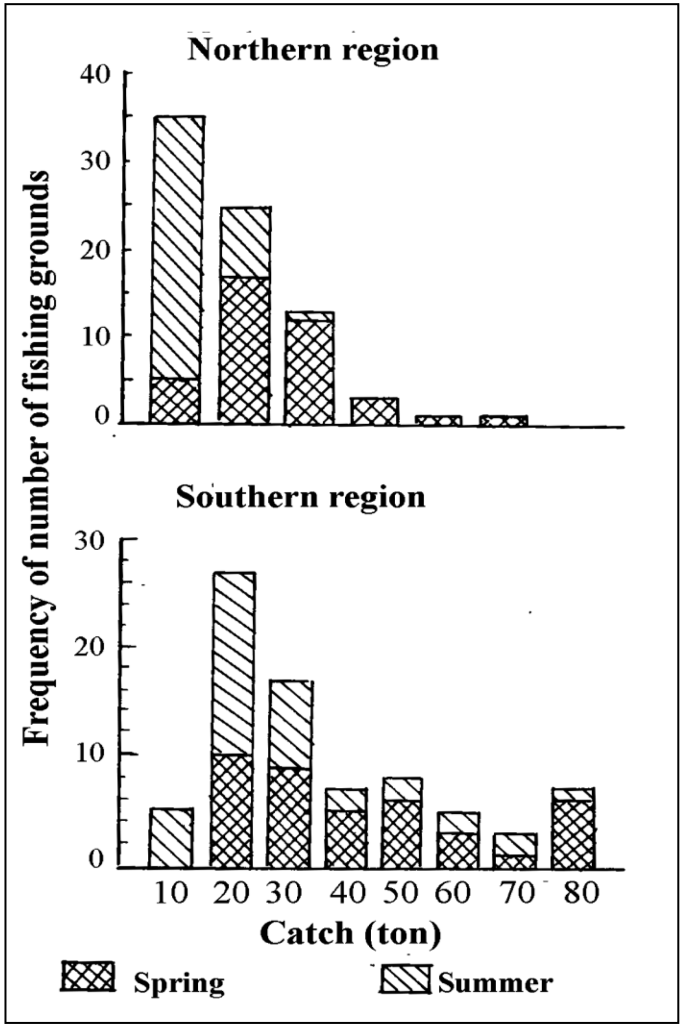


Fig. 194 **Frequency distribution of catch/month during spring and summer in Lake Nasser, 1994 (Mohamed, M. 1995b)**

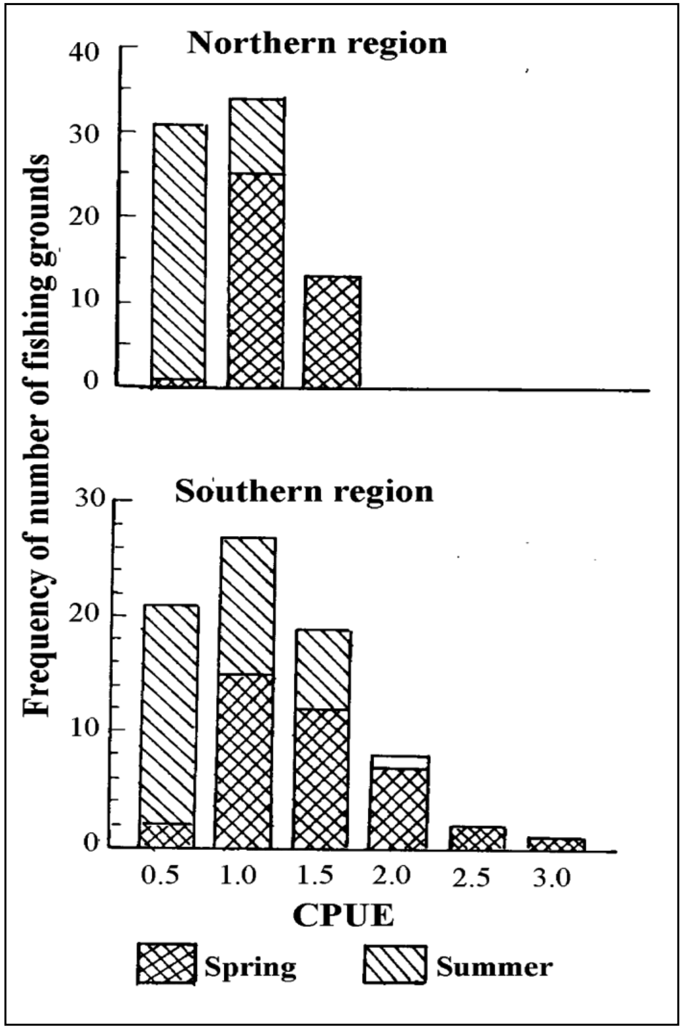


Fig. 195 **Frequency distribution of CPUE during spring and summer in Lake Nasser, 1994 (Mohamed, M. 1995b)**

Comparing the mean values of CPUE during 1994 in spring with those in summer in the northern fishing grounds, we find that the mean CPUE in spring was 0.94 ton / boat / month, and 0.48 ton / boat / month in summer (Table 136). The same trend was observed in the southern fishing grounds, as it was 1.17 in spring and 0.69 ton / boat / month in summer (Table 136). This means that the mean CPUE was higher in spring than that in summer in Lake Nasser. But, the mean CPUE is still higher in the southern fishing grounds during 1994.

***Table 136.* A comparison between the total catch/month (ton) and CPUE (ton/boat/month) of the northern and southern regions of Lake Nasser during spring and summer 1994.**

	1994	
	Spring	**Summer**
Northern region		
Total catch/month (ton)	1065.68	414.56
Mean (ton)	26.64	10.36
CPUE (ton/boat/month)	0.94	0.48
Southern region		
Total catch/month (ton)	1597.24	945.77
Mean (ton)	40.96	24.25
CPUE (ton/boat/month)	1.17	0.69

Relationship between CPUE of the total catch and of fish species catch of Lake Nasser and water level

Fig. 196 shows the relationships between catch per unit effort of the total catch and that of *Tilapia* spp. catch and water level (WLl - WL6 : one to six years previous to the catch) of Lake Nasser during 1972 - 1992 (Mekkawy 1996). The latter author recorded the relationships between the catch per unit effort of *Lates niloticus, Hydrocynus, Labeo, Bagrus* and *Clarias* spp. and water levels (WL1 to WL6) of Lake Nasser during the same period 1972 - 1992 (Figs. 197 and 198). The simple correlation coefficients between fish species catch of Lake Nasser and water levels of the six preceding years and number of boats and that of fishermen is previously mentioned (page 314 - Table 112).

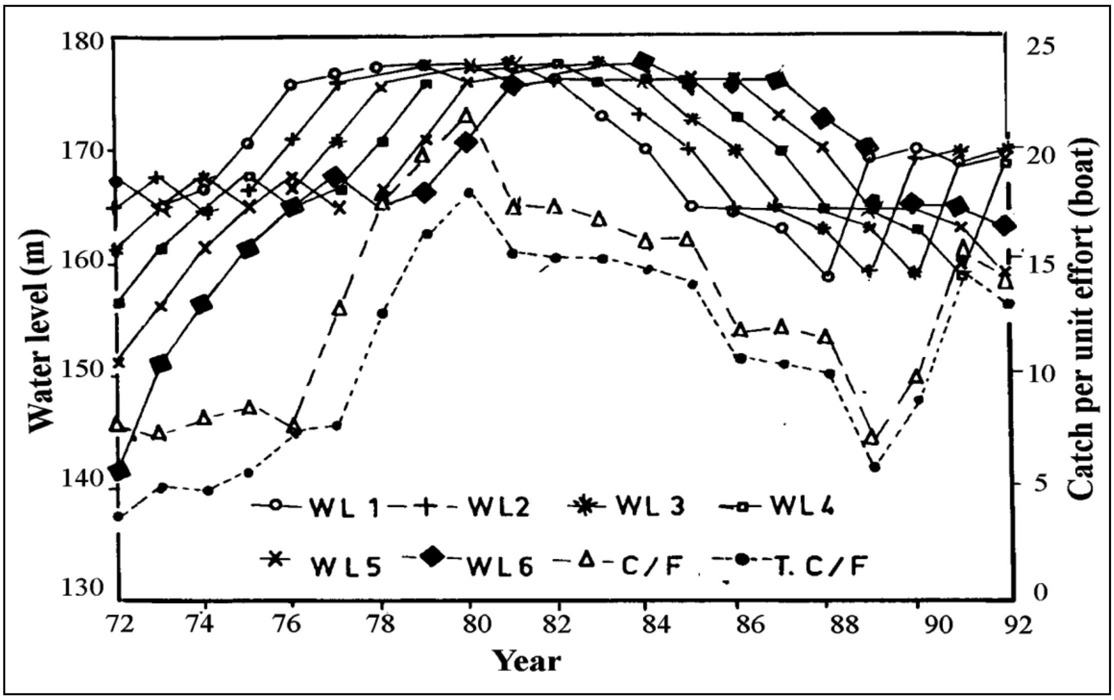


Fig. 196 **The relationship between catch per unit effort of the total catch (C/F) and of *Tilapia* spp. catch (T.C/F) and water levels (WL1 - WL6) of Lake Nasser during 1972 - 1992 (Mekkawy 1996).**

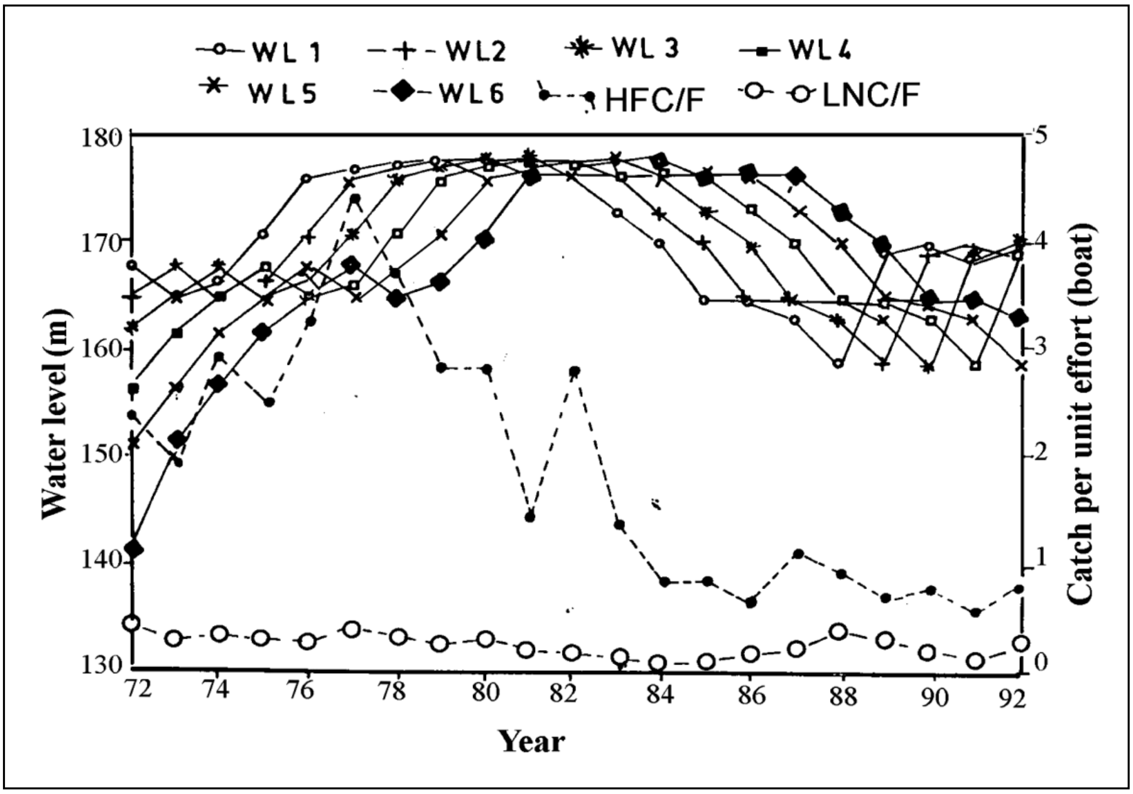


Fig. 197 **The relationship between the catch per unit effort of *Hydrocynus* spp. (HFC/F)and *Lates niloticus* (LC/F) and water level (WL1 - WL6) of Lake Nasser in 1972-1992. (Mekkawy 1996).**

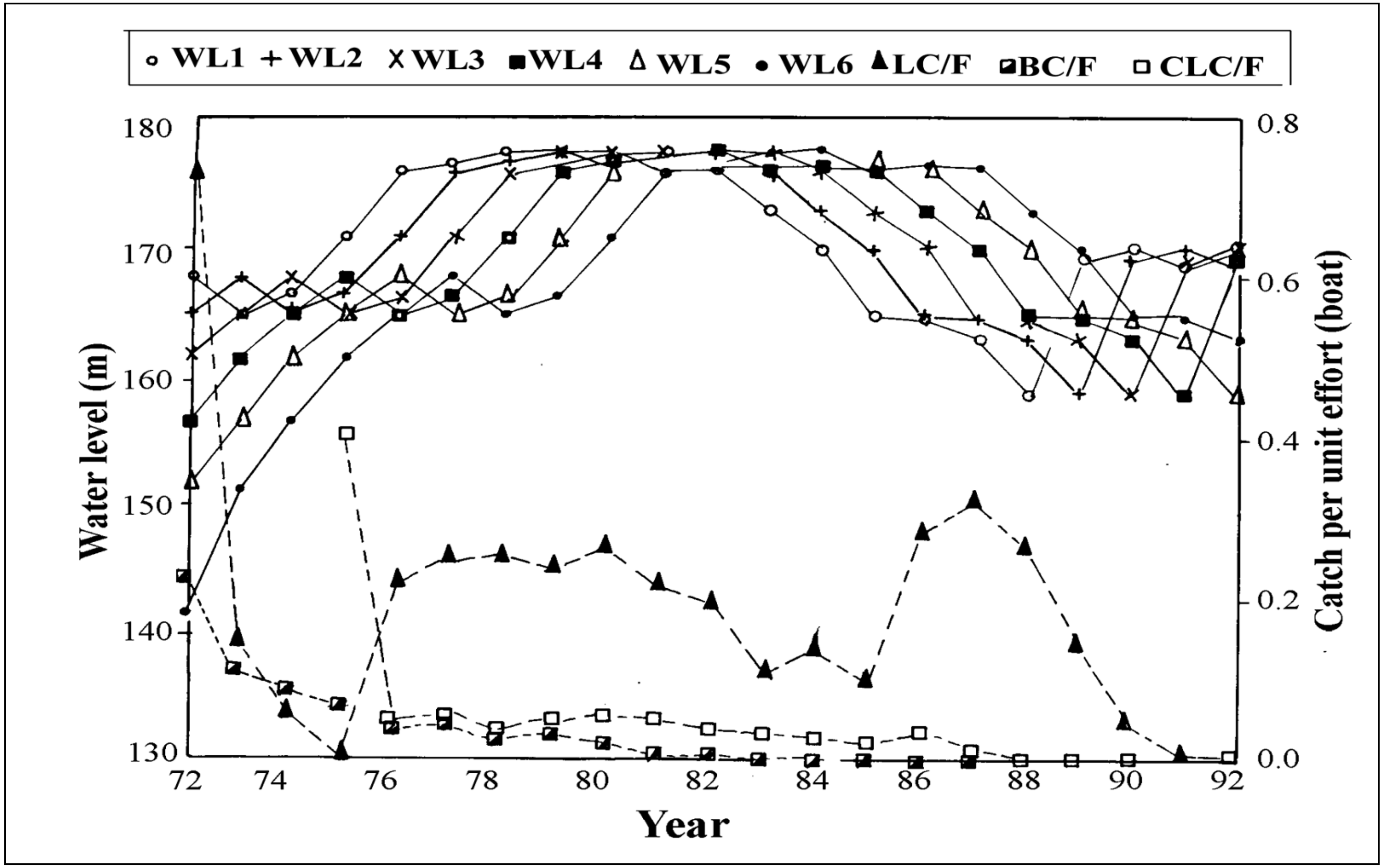


Fig. 198 **The relationship between the catch per unit effort of *Labeo* spp. (LC/F), *Bagrus* spp. (BC/F) and *Clarias* spp. (CLC/F) and water level (WL1 - WL6) of Lake Nasser in 1972-1992. (Mekkawy 1996).**

Relationships between CPUE and effort

The CPUE-effort relationships of *O. niloticus* and S. *galilaeus* (Fig. 201) indicate that the general trends of the relationships with respect to total catch and tilapiine catch were directed towards increase with time throughout 1966-1992. However, excluding the increased CPUE data of the initial years of Lake formation (1966-1972), CPUE decreased with the increased effort (Figs. 200 and 201). Mekkawy (1996) mentioned that the CPUE-effort relationships of *Hydrocynus* spp., *Lates niloticus*, *Labeo* spp. *Bagrus* spp., and *Clarias* spp. showed decreased trends in spite of the variable fluctuation throughout 1966-1992 (Figs 202 - 206). These trends were due to the continuous decline in their catch, thus no catch of *Bagrus* and *Clarias* spp. was recorded in recent years.

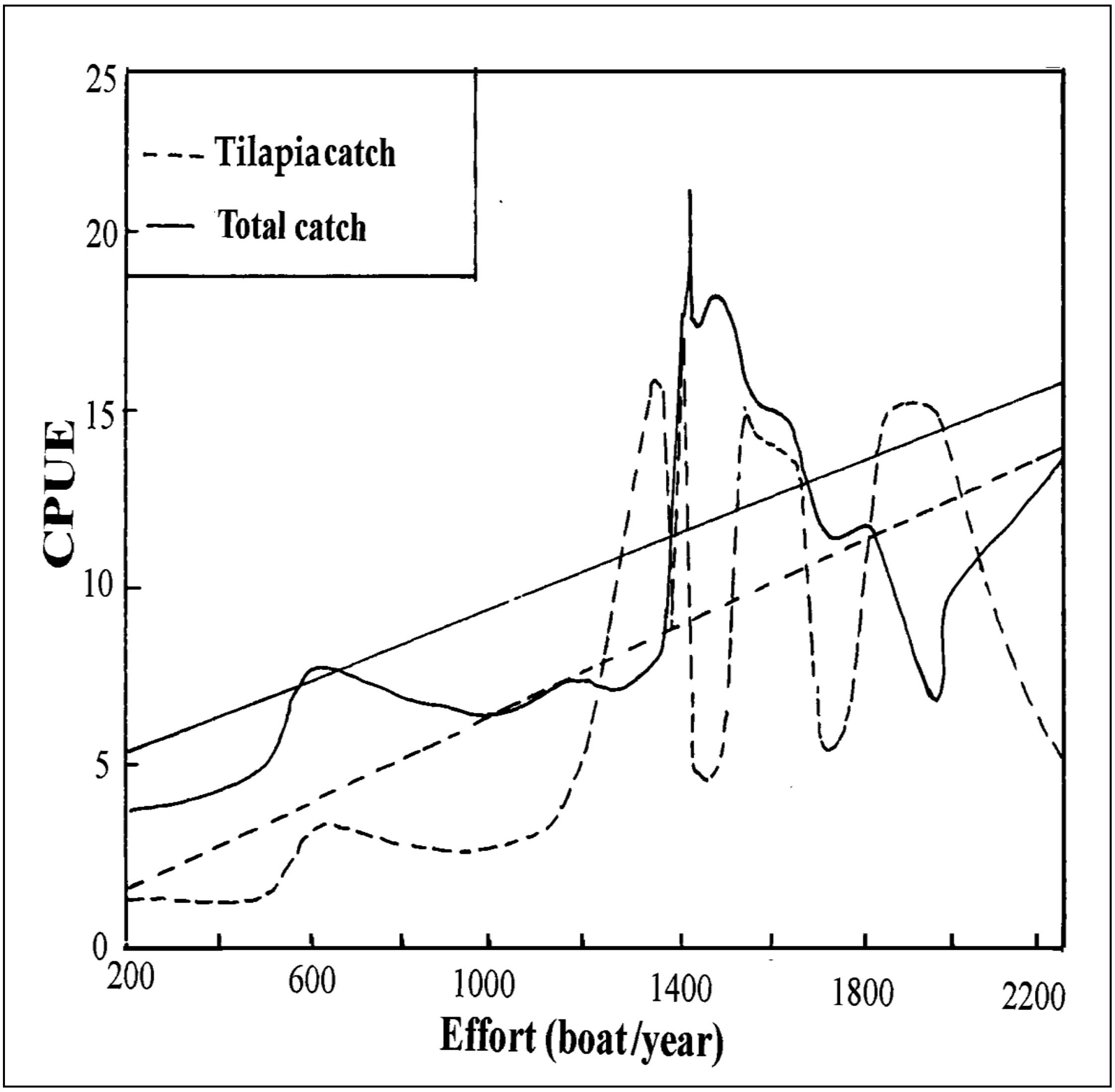


Fig. 199 **CPUE-effort relationship of total catch and *Tilapia* spp. catch of Lake Nasser (1966-1992) (Mekkawy 1996).**

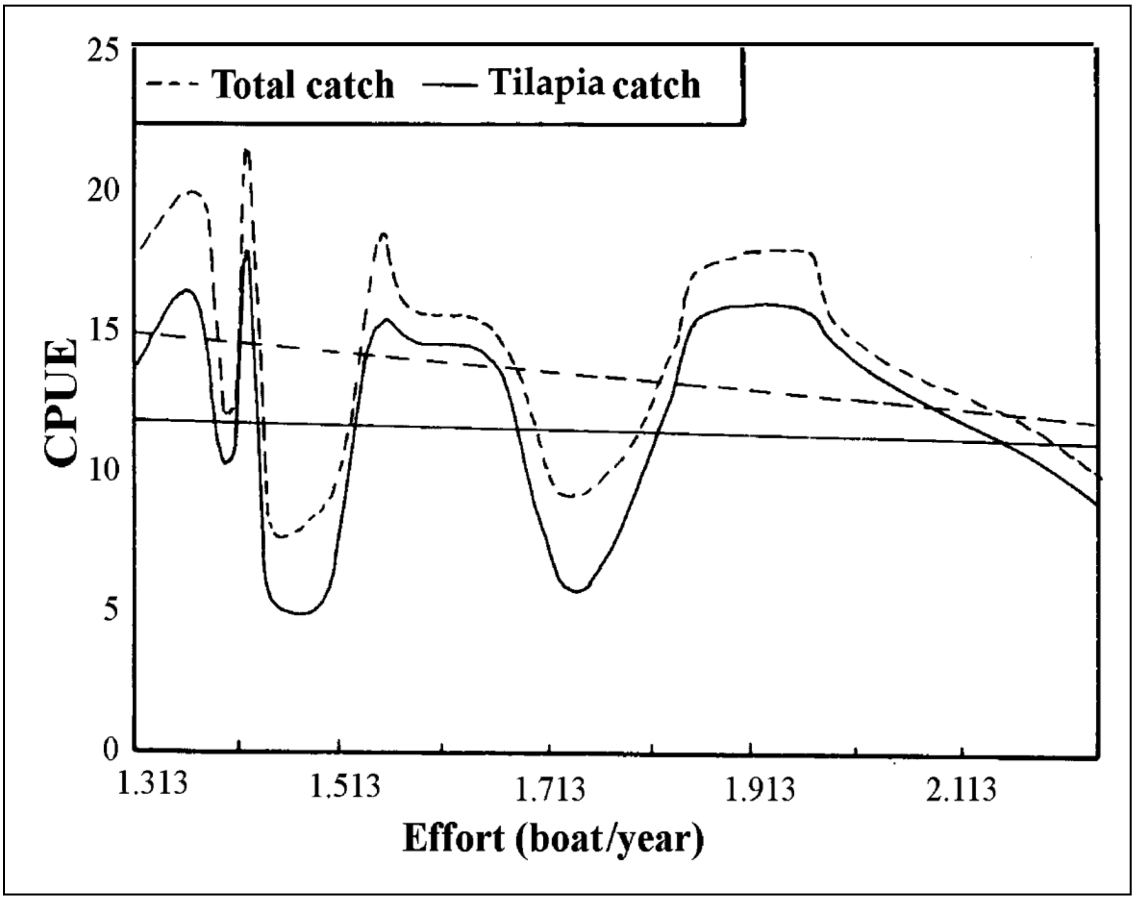


Fig. 200 **CPUE-effort relationship of total catch and *Tilapia* spp. catch (1973-1992) (Mekkawy 1996).**

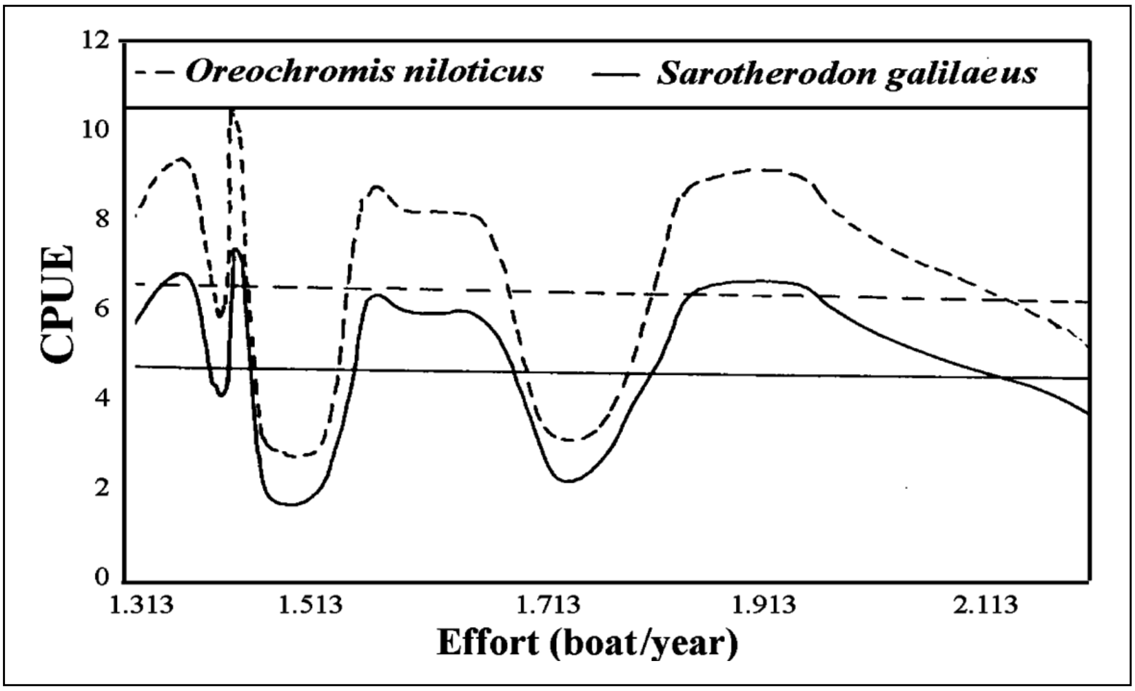


Fig. 201 **CPUE-effort relationship of *Oreochromis niloticus* and *Sarotherodon galilaeus* (1973-1992) (Mekkawy 1996).**

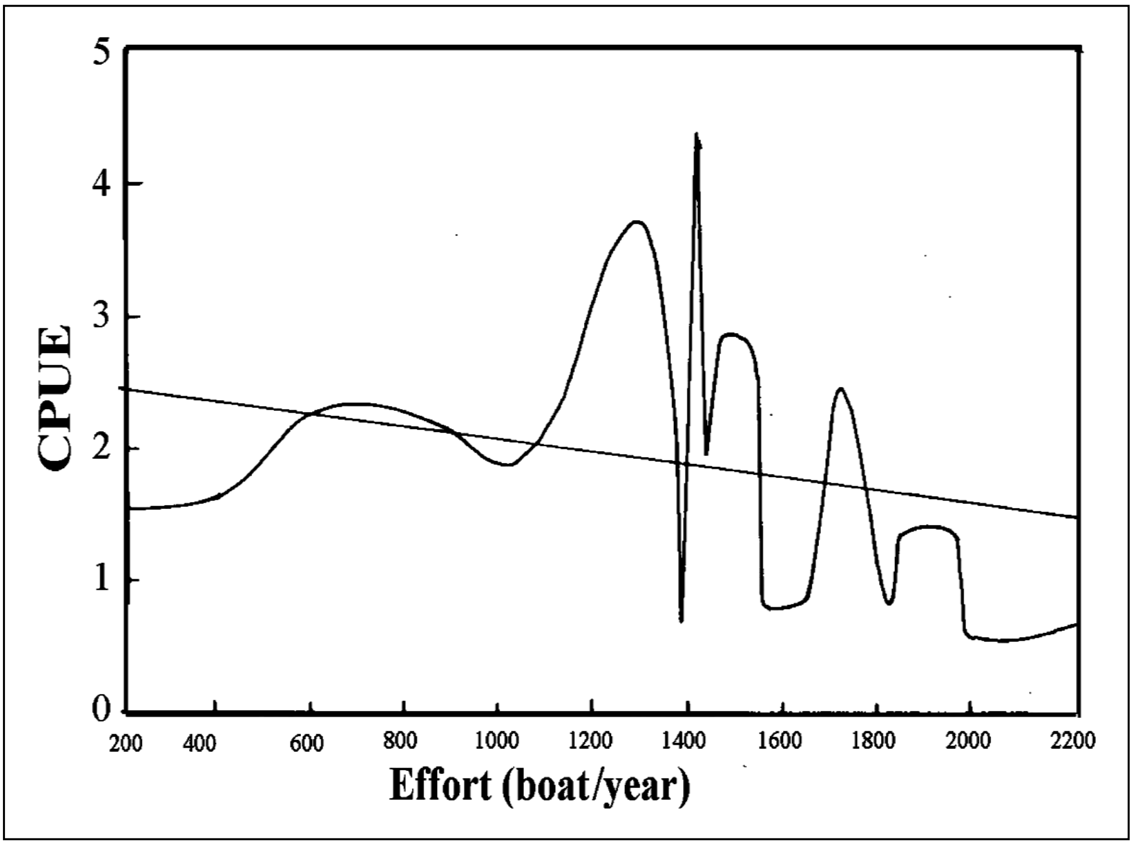


Fig. 202 **CPUE-effort relationship of *Hydrocynus* spp. of Lake Nasser (1966-1992) (Mekkawy 1996).**

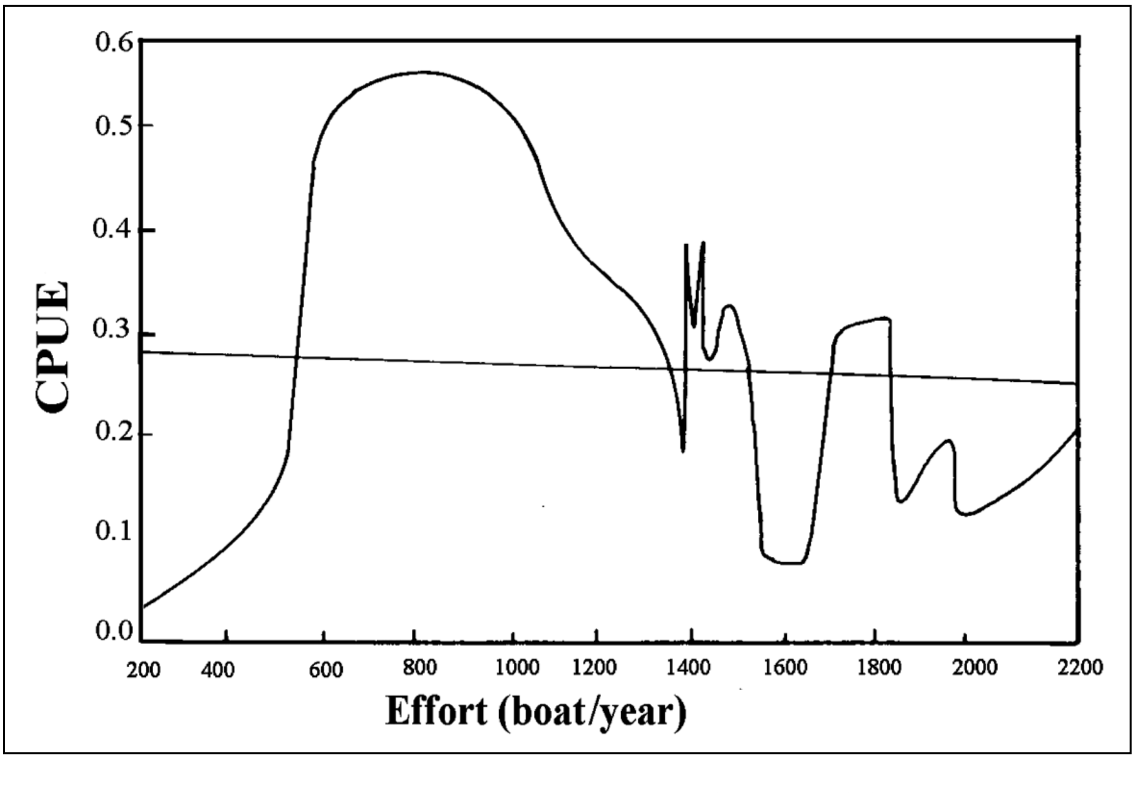


Fig. 203 **CPUE-effort relationships of *Lates niloticus* (1966-1992) (Mekkawy 1996).**

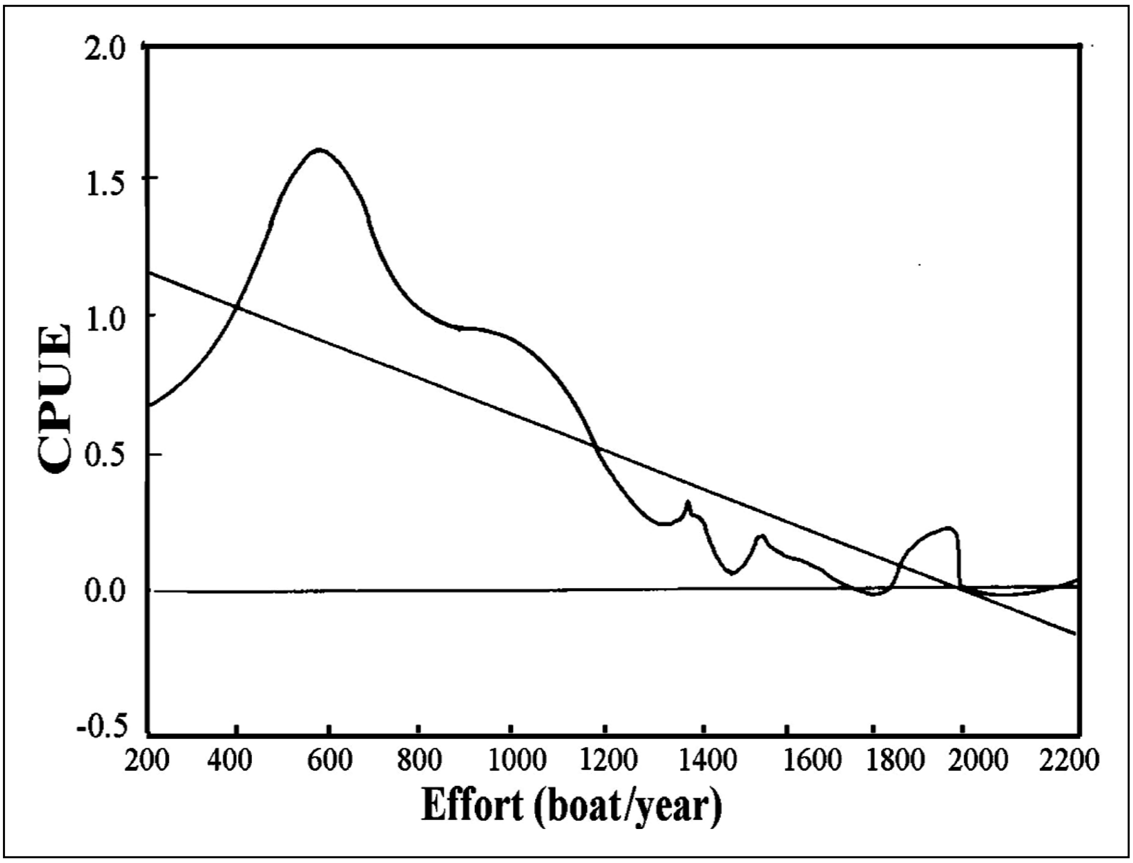


Fig. 204 CPUE-effort relationship of *Labeo* spp. (1966-1992) (Mekkawy 1996).

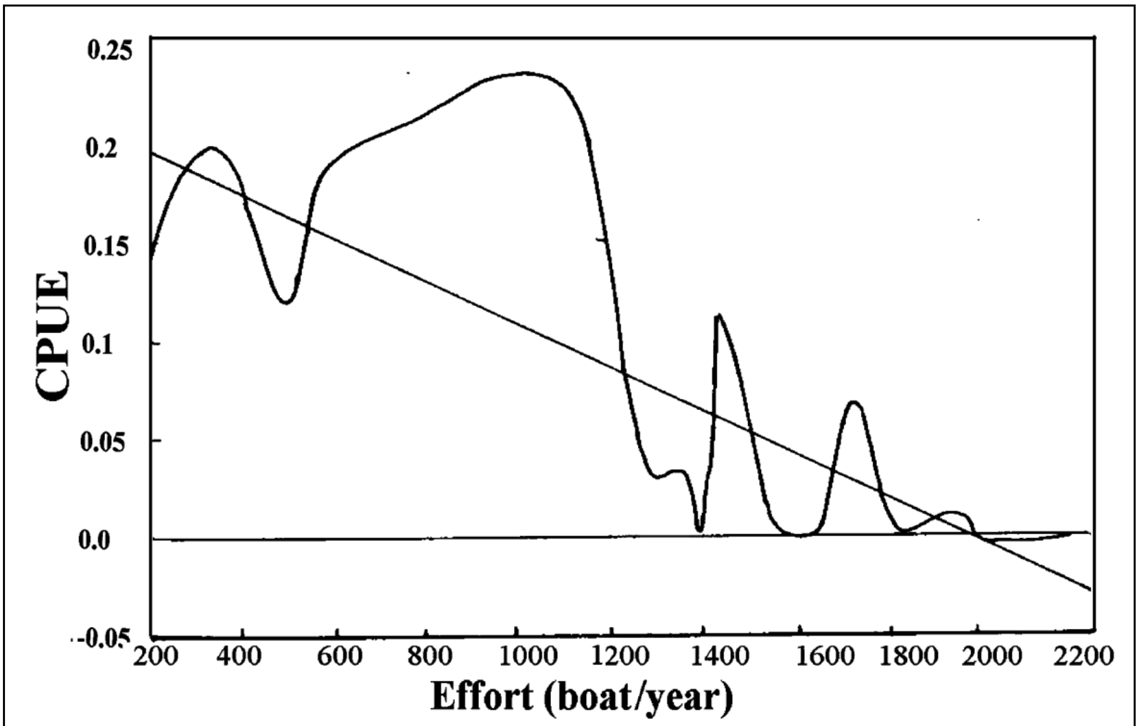


Fig. 205 CPUE-effort relationship of *Bagrus* spp. (1966-1992) (Mekkawy 1996).

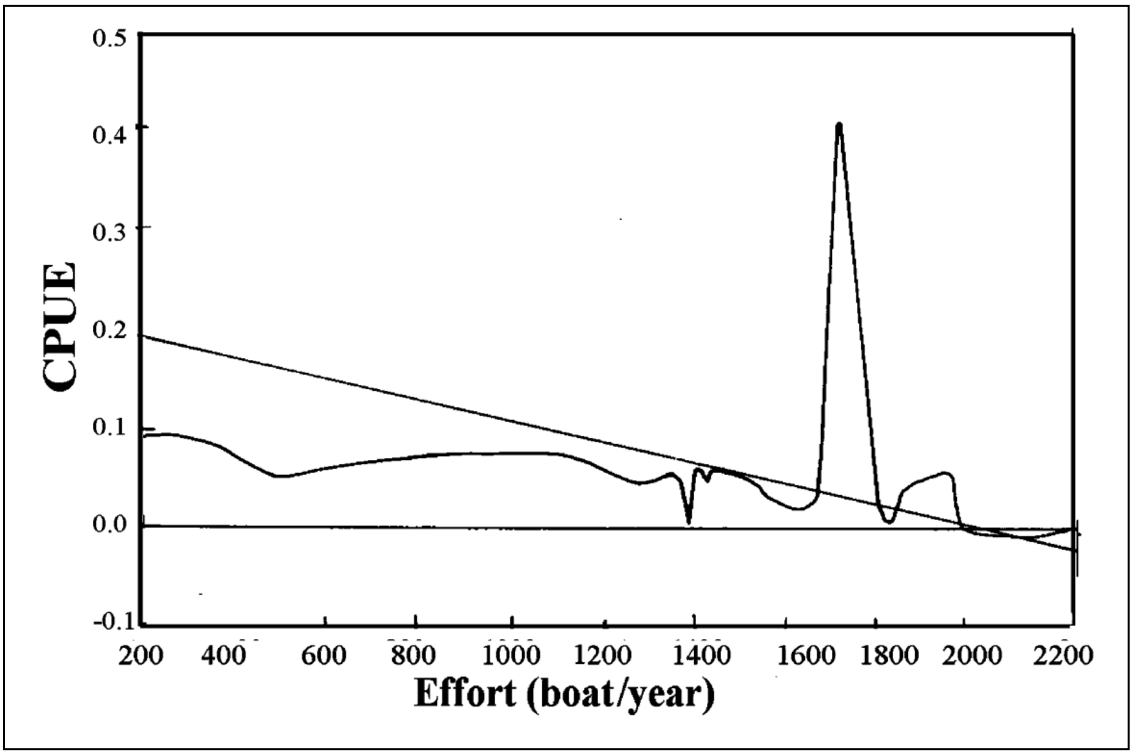


Fig. 206 **CPUE-effort relationship** ***of Clarias*** **spp. (1966-1992) (Mekkawy 1996).**

RECRUITMENT

Recruitment is the process of becoming catchable, for an individual fish it is the moment or interval during which it becomes in some degree vulnerable to capture by the fishing gear in use. Of most interest in practical fishery work is the number of recruits to the usable stock.

Mekkawy (1998) studied the effect of water level in Lake Nasser on recruitment, stock-recruitment relationships and the yield/recruitment curves (Y/R) of both *0. niloticus* and *S. galilaeus.*

Effect of water level on recruitment

Mekkawy (1998) estimated the yearly recruits (R) of *O. niloticus* and *S. galilaeus* using VPA for 1966-1992. The trends of recruitment variations with time (Y) (Fig. 207) are represented by the following equations:

For *0. niloticus* :

R = 1.658103E + 07 + 1056089Y (r = 0.41)

For *S. galilaeus:*

R= 0.443341E +07+448154.3Y (r=0.50)

Two major peaks (Fig. 207) in 1979 and 1989 were observed. The maximum numbers of recruits of *0. niloticus* were 6.089192 E + 07 and 5.66906 E

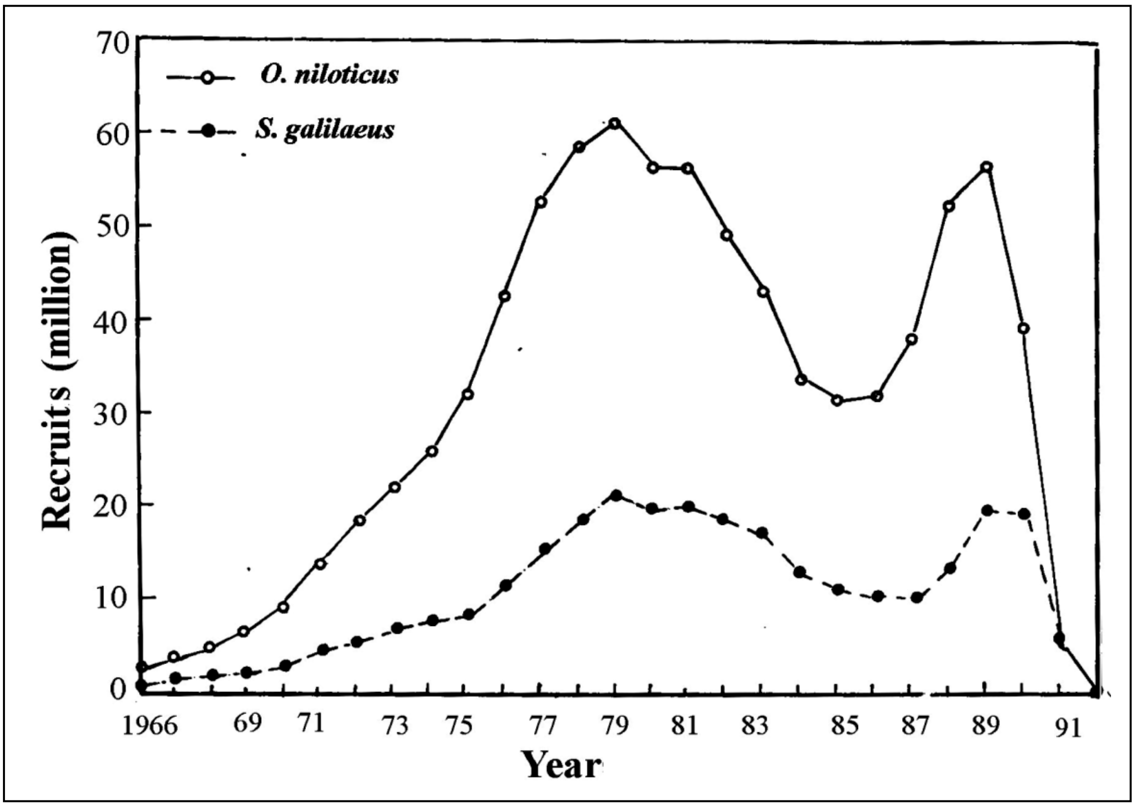


Fig. 207 **The pattern of variations of recruits of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser in 1966 - 1992 (Mekkawy 1998).**

+ 07, whereas those of *S. galilaeus* were 2.167091 E + 07 and 1.976774 E + 07 in 1979 and 1989 respectively (Mekkawy 1998).

Figs. 208 and 209 show the relationships between recruits of tilapiine species and water levels of the preceding year (WL1). The general trends were described by the following equations:

For *O. niloticus* :

R = -2.11296 E + 08 + 1459529 WL1 (r = 0.7062)

For *S. galilaeus:*

R = -1.069818 E + 08 + 745125WL1 (r = 0.7601)

Mekkawy (1998) concluded that the water level of the preceding year affects the recruits of *O. niloticus* and *S. galilaeas* by 49.88 and 57.78%, whereas the other factors control them by 50.12 and 42.22% respectively. Such water-level low effects were emphasized by the correspondence of high recruitment with low values of water level (Figs. 208 and 209 - Mekkawy 1998). In some years, there was a decline in recruits in spite of high water level (Figs. 208 and 209 - Mekkawy 1998). Accordingly, the relatively high significant R-WL1 correlations of the two tilapiine species could not be reflected by their catch-WLl relationship (Mekkawy 1998).

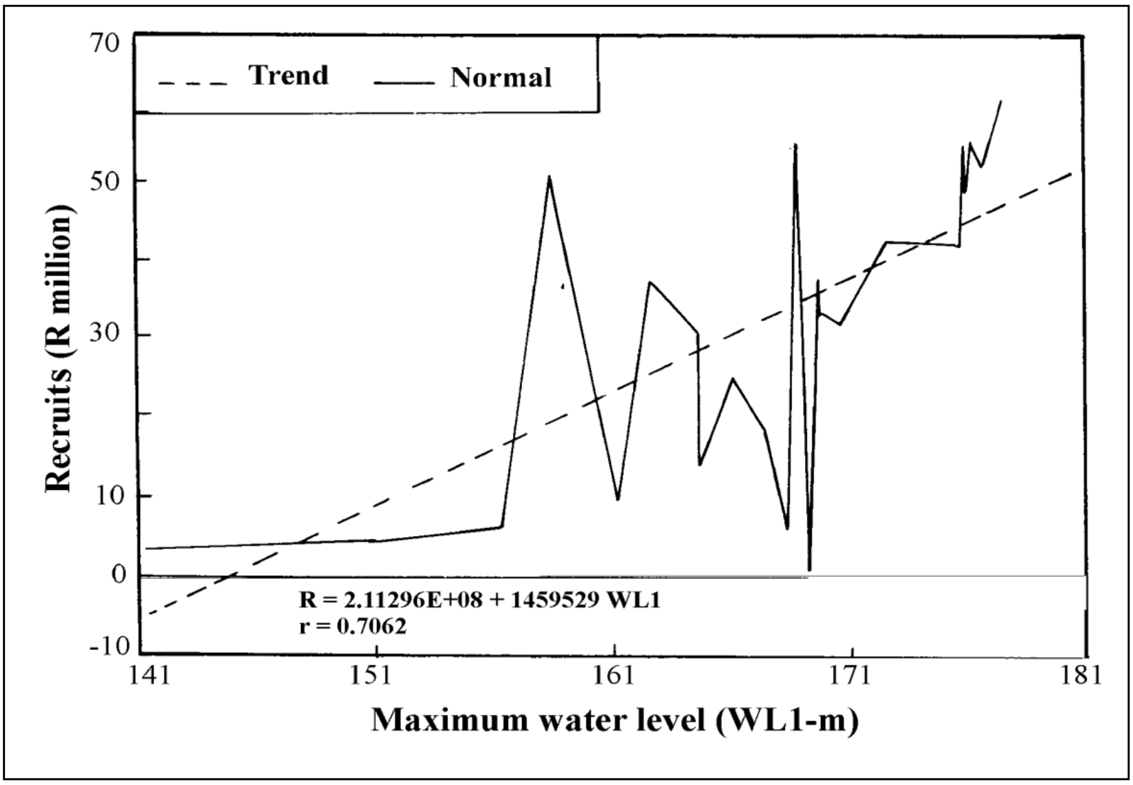


Fig. 208 **The relationship between recruits of *Oreochromis niloticus* and Lake Nasser water level of the preceding year in the 1966-1992 (Mekkway 1998).**

Stock-recruitment relationship

Mekkawy (1998) used the data of Abdel-Azim (1974) and Adam (1994) and estimated the number (mean ±SD) of eggs per gram of body weight of *O. niloticus* and *S . galilaeus* to be 2.675 ± 3.96E-01 and 5.119 ± 9.15E-01 respectively. Combination of these values with VPA results exhibits a new pattern of variations in their spawning potentials (Table 137 - Mekkawy 1998).

The latter author postulated two assumptions : either the spawning stock includes all age groups (i.e I-V or VI) or comprises only age groups III - VI and III-V for *O. niloticus* and *S. galilaeus* respectively. Accordingly, for *0. niloticus* the range of eggs / recruitment (E/R) was 1579 to 3262 and 308 to 1357 for age groups 1-VI and III-VI respectively. In case of S. *galilaeus,* it was 2690 to 6035 and 498 to 2480 for age groups I-V and III - V respectively. Such figures reflect the great loss in the eggs and pre-recruit-stage productions with respect to the two assumptions. Similar variations were recorded in the mature or spawning stock/recruitment (S/R). (Table 137 -Mekkawy, 1998).

The latter author fitted Beverton & Holt's (1957) S/R-model to stock-recruitment data of *0. niloticus* and *S. galilaeus* (Figs. 210-213) and the estimates of its parameters are given in Table 138. According to the first assumption, the S/R-relationships reflect the weak importance of density-dependent effects (and the increased density-independent effects) on the mortality, fecundity and growth of these species (Figs. 210 and 211 and the corresponding equations). In the absence of such density-dependence, the number of recruits will be an increasing function of the abundance of the parental cohorts (the proposed steady state in the figures). Such weak density-dependent effects on populations of *O. niloticus* and *S. galilaeus* make fishing, to some extent, an additional burden of mortality imposed on these populations. Therefore, the reproductive rates of these tilapiine populations must be sufficiently high to cover this extra burden.

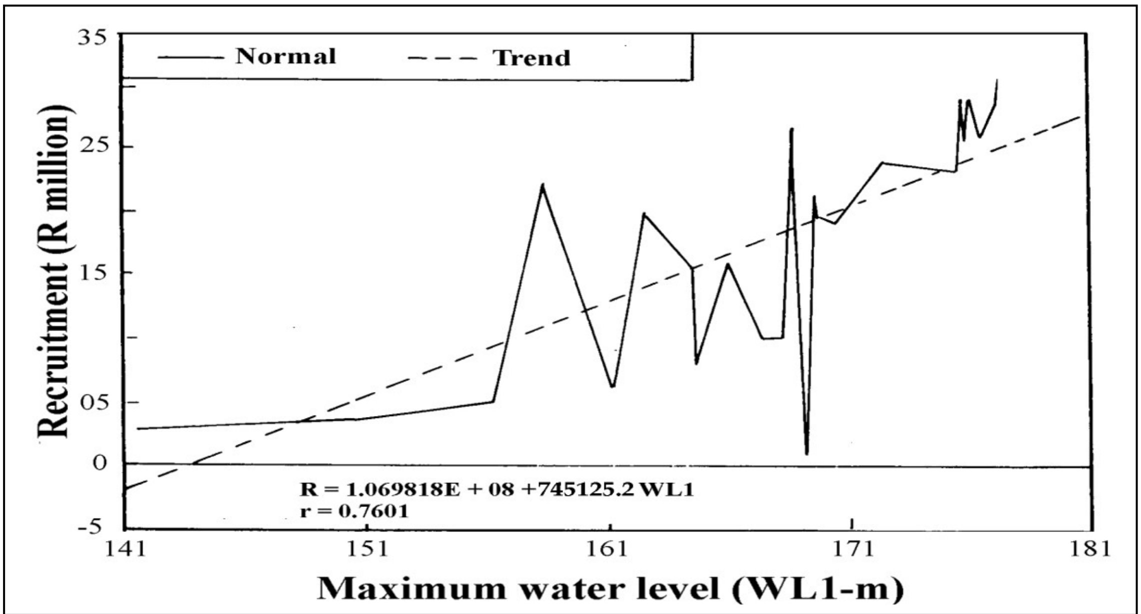


Fig. 209 **The relationship between recruits of *Sarotherodon galilaeus* and Lake Nasser water level of the preceding year in 1966-1992 (Mekkawy 1998).**

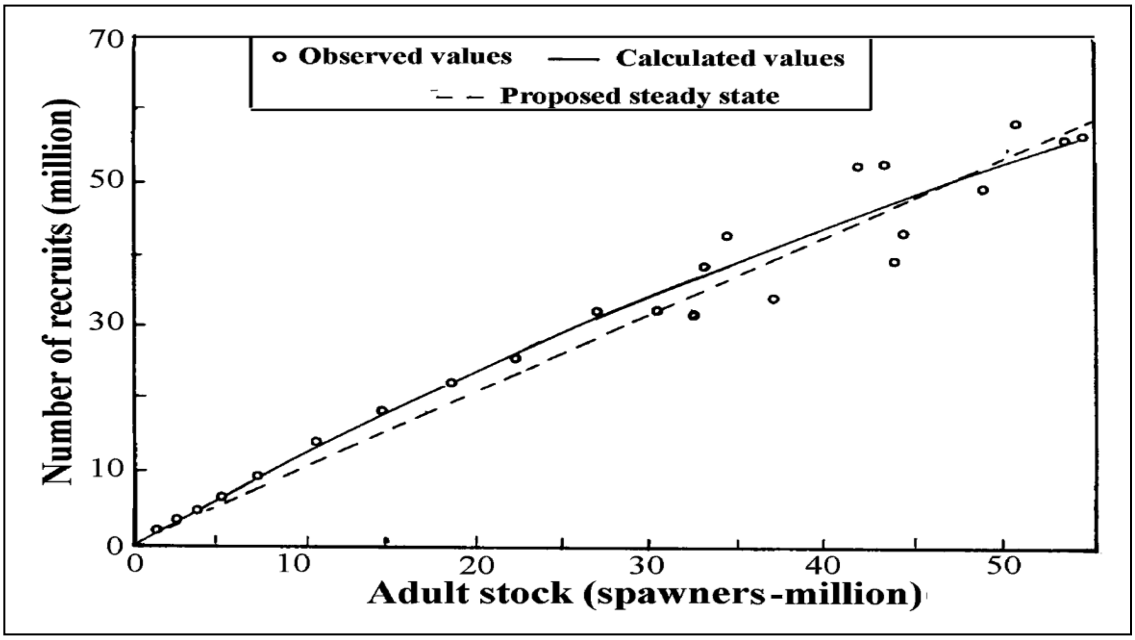


Fig. 210 **Recruitment-spawners (age groups I-VI) relationship for *Oreochromis niloticus* of Lake Nasser fitted to Beverton & Holt's S/R-model (Sparre *et al.* 1992) (Mekkawy 1998).**

Table 137 **The pattern of variations in egg production / recruitment and mature stock / recruitment of *0 . niloticus* and *S . galilaeus* of Lake Nasser in 1966-1992 with two assumptions for age groups shared (Mekkawy 1998).**

Year	Egg production/ recruitment				Mature stock /recruitment			
	O. niloticus		*S . galilaeus*		*O. niloticus*		*S. galilaeus*	
	Age groups shared							
	I-VI	III-V	I-V	III-V	I-VI	III-VI	I-V	III-V
1966	1579.7	307.7	3187.9	681.5	0.71	0.11	0.92	0.27
1967	1629.9	324.8	2690.1	498.3	0.72	0.12	0.80	0.20
1968	1867.6	436.3	3255.7	570.6	0.79	0.16	0.94	0.23
1969	1935.8	538.7	3902.8	1093.8	0.79	0.20	1.07	0.43
1970	1831.9	465.1	3744.9	988.8	0.77	0.17	1.04	0.39
1971	1787.4	430.4	3389.5	832.5	0.76	0.16	0.95	0.33
1972	1902.8	475.4	3770.6	902.2	0.79	0.18	1.05	0.36
1973	2077.8	595.2	4044.6	1190.8	0.83	0.22	1.10	0.47
1974	2192.7	678.7	4153.6	1164.6	0.86	0.25	1.13	0.46
1975	2127.2	662.9	4449.8	1388.9	0.84	0.24	1.19	0.55
1976	1986.5	564.9	3834.2	1105.6	0.80	0.21	1.06	0.44
1977	2036.8	566.3	3656.4	902.7	0.82	0.21	1.02	0.36
1978	2243.8	698.6	4070.8	1132.7	0.87	0.26	1.11	0.45
1979	2419.7	825.5	4250.2	1274.5	0.91	0.30	1.15	0.51
1980	2683.1	990.4	5007.1	1599.6	0.97	0.36	1.33	0.64
1981	2667.9	1039.7	4994.5	1818.3	0.96	0.38	1.31	0.72
1982	2795.7	1056.3	4959.8	1581.9	1.00	0.39	1.31	0.63
1983	2996.8	1252.6	5327.3	1969.5	1.03	0.46	1.39	0.78
1984	3201.9	1356.9	5875.9	2107.8	1.09	0.49	1.52	0.84
1985	2981.8	1298.4	6035.4	2497.9	1.02	0.47	1.54	0.99
1986	2554.1	949.0	5001.1	1708.0	0.93	0.35	1.32	0.68
1987	2274.2	776.3	4988.2	1712.9	0.87	0.28	1.31	0.68
1988	1972.3	570.1	4008.3	1237.1	0.80	0.21	1.09	0.49
1989	2177.2	614.9	3492.9	834.6	0.86	0.23	0.99	0.33
1990	3261.8	1265.9	4520.3	1267.2	1.12	0.47	1.22	0.50
1991	2371.8	1141.6	4769.2	1938.4	0.84	0.34	1.23	0.62
1992	2025.6	905.3	4088.6	1744.6	0.79	0.26	1.09	0.54

Table 138 **The parameters (α and β) of Beverton & Holt's (1957) S/R - model, fitted to stock-recruitment data of *O. niloticus* and *S. galilaeus* of Lake Nasser, the maximum number of recruits (R max) and the stock-recruitment correlation ($r_{R\&S}$) (Mekkawy 1998).**

Parameter	*O. niloticus*		*S. galilaeus*	
	Age groups shared			
	I-VI	III-VI	I-V	III-V
α	4.095846E-08	1.34011E-08	1.402931E-08	3.312858E-08
β	0.75104	0.06779	0.96316	0.14971
R max	244,149,804	74,620,740	71,279,343	30,185,417
$r_{R\&S}$	0.98	0.82	0.67	0.78

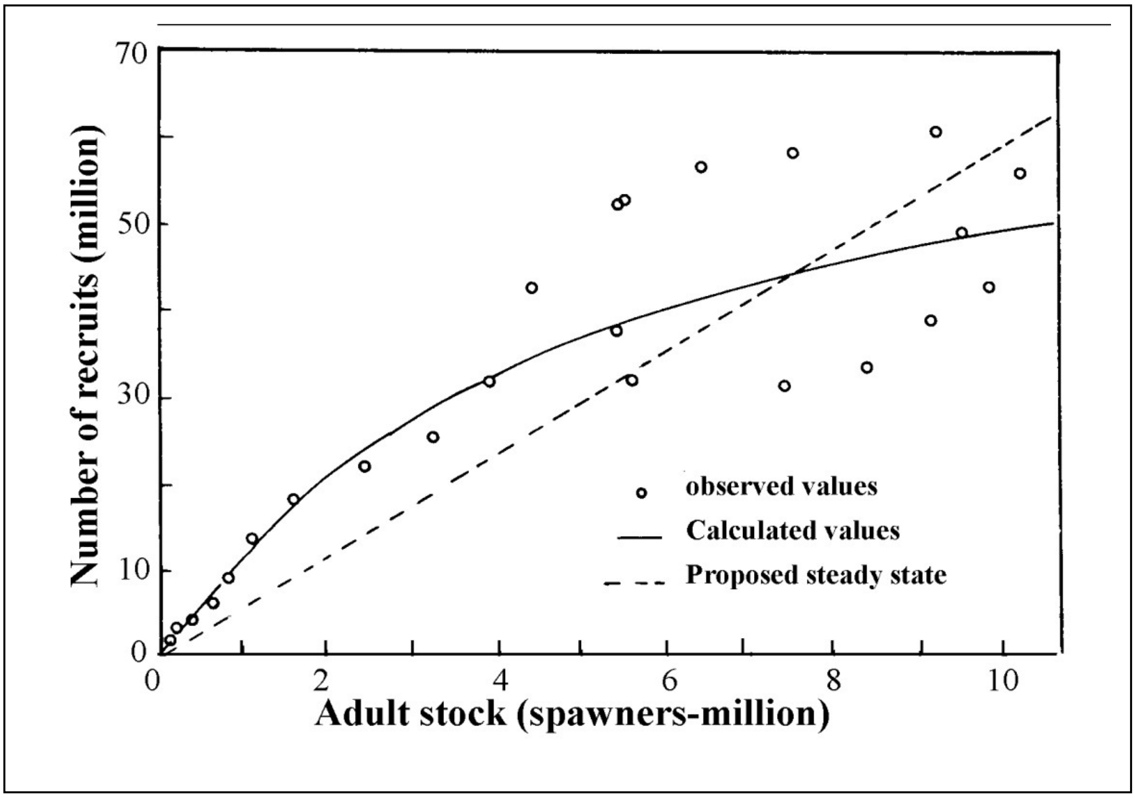


Fig. 211 **Recruitment-spawners (age groups III-VI) relationship for *Oreochromis niloticus* of Lake Nasser fitted to Beverton & Holt's S/R-model (Sparre *et al.* 1992) (Mekkawy 1998).**

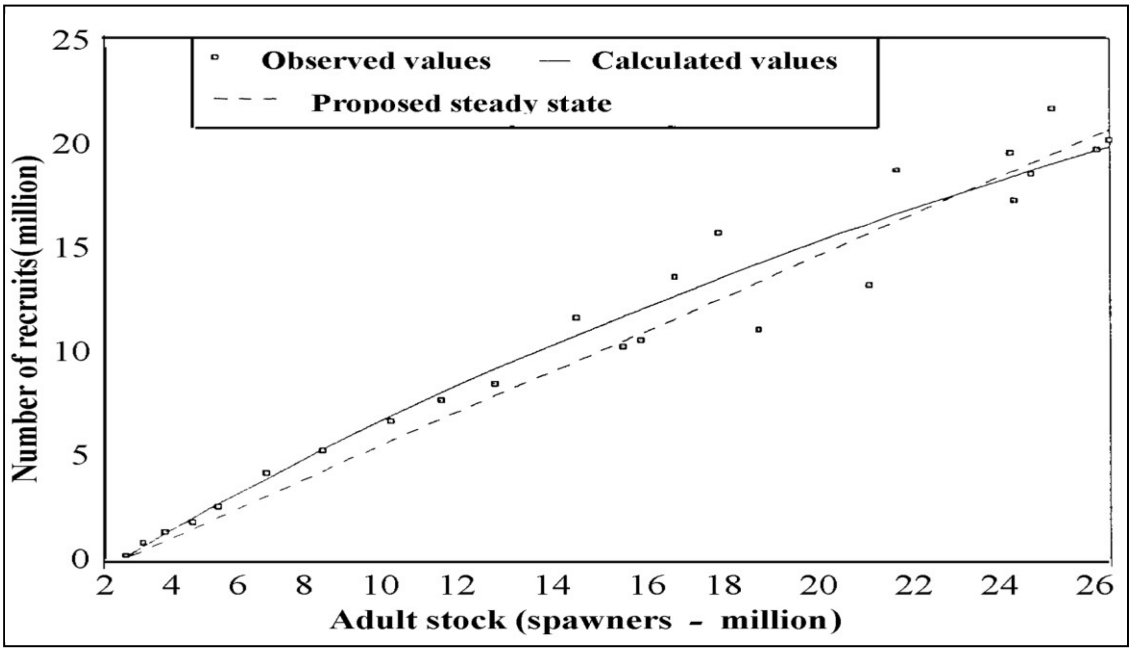


Fig. 212 **Recruitment-spawners (age groups I-V) relationship for *Sarotherodon galilaeus* of Lake Nasser fitted to Beverton & Holt's S/R-model (Sparre *et al.***

1992) (Mekkawy 1998).

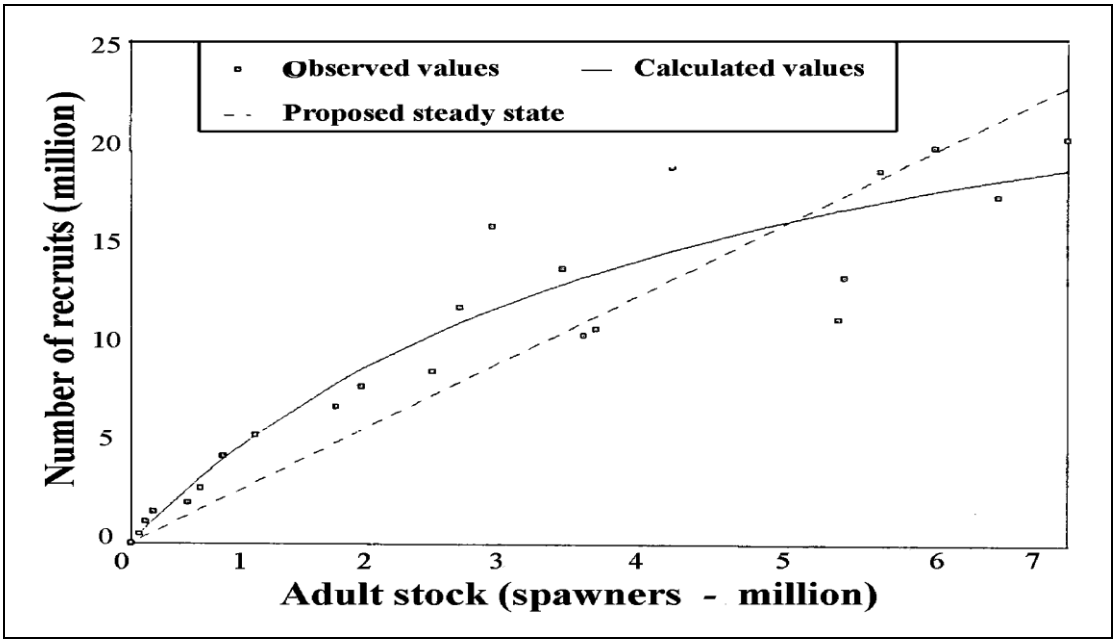


Fig. 213 **Recruitment-spawners (age groups III-V) relationship for *Sarotherodon galilaeus* of Lake Nasser fitted to Beverton & Holt's S/R-model (Sparre *et al.* 1992) (Mekkawy 1998).**

The importance of density-dependent effects increases (Figs. 211 and 213) and that of density-independent effects decreases, if the second assumption is considered (Mekkawy 1998). Consequently, the pattern of stock-recruitment relationship becomes highly different from the proposed steady state. The spawning contribution of age groups I and II cannot be excluded, because they together with age group III were represented by the highest values in the sampling process through 1965-1990 (Table 123), and some of the population characteristics of *O. niloticus* and *S. galilaeus* (e.g. early maturity) were directed towards r-selection (Mekkawy 1998). Hence, the latter author mentioned that the first assumption represents the actual status of these species in the Lake.

Although Fig. 207 indicates that recruitment of *O. niloticus* and *S. galilaeus* are variable from one year to the next, the relationship between stock and recruitment showed a pronounced trend towards increase. Such variations may be caused partially by environmental factors affecting the pre-recruit stages, and this is emphasized by low natural mortality of *O. niloticus* and *S. galilaeus,* which implies that the density-dependent factors, regulating their populations, operate before recruitment.

Mekkawy (1998) pointed out that S/R-model of Beverton & Holt (1957) supports the assumption that within a limited range of stock, recruitment appears to be independent of stock, and such a case has not been reached yet by those of *O. niloticus* and *S. galilaeus.* Using the Beverton & Holt's (1957) model, Mekkawy (1998) recorded the highest values of recruitment (24.6%) for *O. niloticus,* and 29.6%

for *S. galilaeus* of their maximum requirements during 1966-1992.

COMPUTATION OF FISH YIELD

Estimation of the fish yield (kg/ha/yr) for Lake Nasser is necessary to compare the productivity of the Lake with other African reservoirs. Hence, the total fish production from the Lake in different years and also the corresponding surface area should be calculated and /or volume based on mean water level. The relation between mean water level, average area and total volume of Lake Nasser is shown in Fig. 214. The total fish production is estimated by adding to the total landings: 10% as adjustment for self-consumption by fishermen plus 5% as adjustment for post-harvest losses (Table 139). The fish yield (kg/ha/yr) from Lake Nasser during 1968-1999 was calculated by dividing the total fish production in kilogrammes on the surface area in hectares (Table 139).

According to Baranov (1961), loeffe (1961) and Tyurin (1962), large reservoirs can be placed in one of five categories, using fish production or benthic levels as criteria (Table 140). On the basis of the aforementioned table for classification of reservoirs and according to the estimated fish yields during the whole period (1968-1999), it can be said that Lake Nasser has passed over three successive trophic states (Table 141).

1. The first trophic state is called mesohumic-mesotrophic with a fish production ranging from 15 to 30 kg/ha/yr and this happened during 1968-1971, when the minimum and maximum estimated fish yields were 18.01 and 27.52 kg/ha/year respectively.

2. The second trophic state is the mesotrophic-eutrophic (i.e. fish production 30-60 kg/ha/yr - Table 140) and this state occurred during 1972-1977, when the estimated fish yields ranged between 31.98 and 52.45 kg/ha/yr .

3. The third trophic state is eutrophic (i.e. > 60 kg/ha/yr) and occurred during 1978-1999. During this last period Lake Nasser is considered very productive so far as the fish yield increased greatly and reached 116.99 kg/ha/yr in 1985 (Table 139). Only in few years (1989, 1993, 1996 - 1999), the estimated fish yield was lower than 60 kg/ha/yr (Table 139). It is worth mentioning that in 1977, 1998 and 1999 there was a sharp drop in the estimated fish yield as it reached only 44.08, 40.11 and 28.28 kg/ha/yr respectively. This is mainly attributed to that, a high percentage of the catch is sold in the black market at high prices, and hence not recorded in the official catches. Accordingly, the true annual catches particularly those of 1997, 1998 and 1999 are not known, and so the low figures of the estimated fish yield do not represent the actual yield. Therefore, it can be said that during the period 1968-1999, Lake Nasser has gradually changed over from the mesohumic-mesotrophic state to the highly eutrophic one, if compared with the other man-made lakes of Africa as Lake Kariba (30 - 57 kg/ha/yr) or Lake Volta (43.4 kg/ha/yr).

As early as 1967, Lagler & El-Zarka, based on yield per unit surface area, placed the eventual yield at 25,000 ton. Entz (1970) suggested that fish potential

Table 139 **Estimated fish yield based on catch statistics for Lake Nasser (1968 – 1999).**

Year	Fish landings (ton)		Total fish landings (ton)	Plus adjustment for self consumption by fishermen (10% of total landings)	Plus adjustment for post-harvest losses (5% of total landings)	Total fish production (ton)	Surface area of Lake Nasser (ha)	Estimated fish yield (kg/ha/yr)
	Fresh fish	Salted fish						
1968	1152	1510	2662	266	133	3061	170000	18.01
9	2802	1868	4670	467	234	5371	220000	24.41
1970	3370	2306	5676	568	284	6528	252500	25.85
1	4316	2503	6819	682	341	7842	285000	27.52
2	5303	3040	8343	834	417	9594	300000	31.98
3	8027	2560	10587	1059	530	12176	282500	43.10
4	8030	4225	12255	1226	613	14094	320000	44.04
5	10384	4251	14635	1464	732	15831	370000	42.79
6	10929	4862	15791	1579	790	18160	405000	44.84
7	12279	6192	18471	1847	924	21242	405000	52.45
8	17852	4873	22725	2273	1137	26135	412500	63.36
9	22649	4372	27021	2702	1351	31074	405000	76.73
1980	26344	3872	30216	3022	1511	34749	400000	86.87
1	31295	2911	34206	3421	1710	39337	385000	102.17
2	25979	2688	28667	2867	1434	32968	375000	87.91
3	28885	2397	31282	3128	1564	35974	337500	106.59
4	22069	2465	24534	2453	1227	28214	325000	86.81
5	24975	1475	26450	2645	1323	30418	260000	116.99
6	15023	1292	16315	1632	816	18763	262500	71.48
7	15287	1528	16815	1682	841	19338	240000	80.58
8	14579	1309	15888	1589	795	18272	257500	70.96
9	14031	1619	15650	1565	783	17998	330000	54.54
1990	20129	1753	21882	2188	1094	15164	327500	76.84
1	29642	1196	30838	3084	1542	35464	317500	111.70
2	24721	1498	26219	2622	1311	30152	332500	90.68
3	16723	1208	17931	1793	897	20621	370000	55.73
4	20491	1583	22074	2207	1104	25385	395000	64.27
5	19692	2366	22058	2206	1103	25367	514000	61.13
6	18160	2381	20541	2054	1027	23622	425000	55.58
7	16644	3957	20601	2060	1030	23691	537500	44.08
8	15013	4190	19203	1920	960	22083	550600	40.11
1999	9876	4106	13983	1398	699	16080	568700	28.28

of Lake Nasser may be of a magnitude comparable to Lake Volta, since fertility in Lake Nasser is considerably greater than it is for Lake Volta. Samaan (1971) considered Lake Nasser as highly eutrophic, since primary productivity ranged from 5.23 to 3.21 g C/m²/day in May. Bazigos (1972), on the basis of the trends of the catch, demonstrated mathematically that the total landings could reach

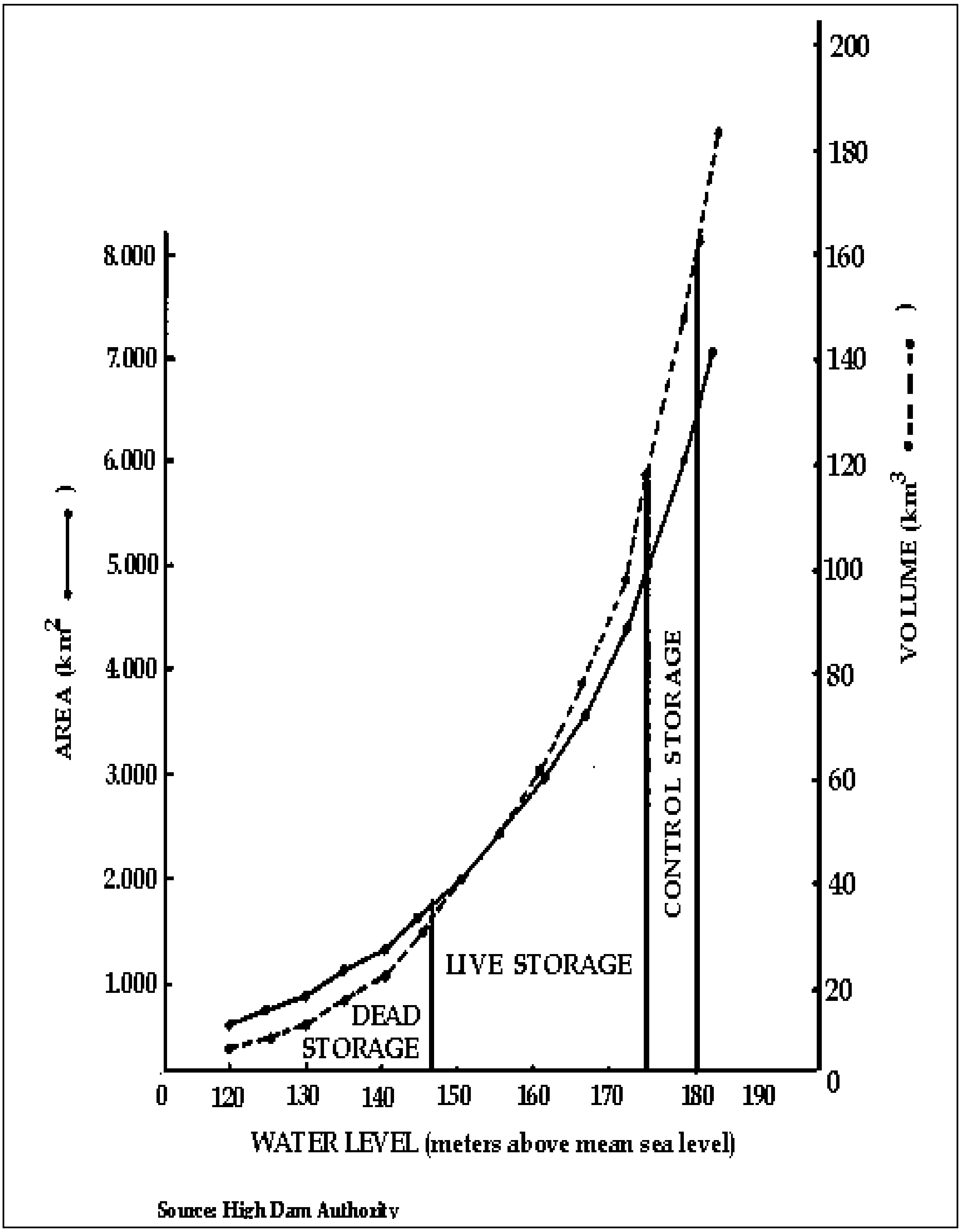


Fig. 214 **Relation between mean water level (m), average area (km^2) and volume (km^3) of Lake Nasser.**

about 20,000 ton by the year 1976 or 42 kg/ha/year, if the Lake area reached 4750 km^2. Using the morphoedaphic index, Ryder & Henderson (1974) estimated the potential fish yield at 160 and 180 m water levels of the High Dam Lake at 39 and 36 kg/ha/yr respectively. Corresponding fish yields were 12000 and 23000 ton/yr respectively. The actual fish landings increased from about 2662 ton in 1968 to 22,725 ton in 1978. Latif *et al.* (1979) mentioned that along the different years, the increase in fish production was from about 16kg/ha/yr for 1969-1971, 24 kg/ha/yr in 1972, about 38-40 kg/ha/yr for 1973-1976, about 44 kg/ha/yr in 1977 and ultimately 52.9 kg/ha/yr in 1978. The fish production per unit area, as it reached 55.58 kg/ha/yr in 1996, is higher than the figures recorded for other man-made lakes of Africa such as Lake Volta (43.4 kg/ha/yr) or Lake Kariba (30 - 57 kg/ha/yr). The following is a comparison between the fish yields of some African lakes.

Lake	Fish yield (kg/ha/yr)	Year
Nasser	55.58	(1996)
Albert	47-65	(1991)
Chilwa	77	(1989)
Chiala	75	(1989)
Edward	61-70	(1989)
Kariba	30-57	(1995)
Kivu	27-42	(1991)
Malawi	35-45	(1990)
Mweru	60	(1989-1990)
Tanganyika	90	(1990-1991)
Turkana	9-16	(1991)
Victoria	29-59	(1990-1991)
Volta	43.4	(1984)

Table 140 **Classification of reservoirs by fish production and by benthic production. (Baranov, 1961; Ioeffe, 1961 & Tyurin, 1962).**

Trophic state of reservoir	Fish production (kg/ha/yr)	Benthic biomass production (kg/ha/yr)
Oligotrophic	2-7	<15
Oligotrophic - mesohumic	7-15	15-30
Mesohumic - mesotrophic	15-30	30-60
Mesotrophic - eutrophic	30-60	60 - 120
Eutrophic	>60	>120

Table 141 **Classification of Lake Nasser according to the estimated fish yields (kg/ha/yr) into trophic states (1968 -1996).**

Period	Trophic states of Lake Nasser according to estimated fish yields (kg/ha/yr)		
	Mesohumic-mesotrophic (15-30 kg/ha/yr)	Mesotrophic-eutrophic (30-60 kg/ha/yr)	Eutrophic (>60 kg/ha/yr)
1968-1971	(18.01-27.52)	--	--
1972-1977	--	(31.98-52.45)	_
1978-1996	--	--	(63.36-116.99)

Prediction of potential annual yield using morphoedaphic index (MEI)

Potential fish yields from reservoirs and/or lakes were related to the morphoedaphic index (Ryder 1965) and many other investigators including Henderson & Welcomme (1974), Toews & Griffith (1979), Bernacsek & Lopes (1984), Marshall (1984) and Bishai & Khalil (1987). A review on MEI was made by Schlesinger & Regier (1982). The yield models based on MEI for African lakes and reservoirs are given in Crul (1992). Analyses of data sets used for these models revealed that data for the lakes and reservoirs selected by Henderson & Welcomme (1974) are used in most models developed later. Catch figures of some of these models were updated with data published after 1974 (Crul, 1992).

Several estimations of potential annual yield of Lake Nasser fisheries have been made. Table 142 shows mean electrical conductivity (Latif 1984b), morphoedaphic index and potential yield of certain khors and sites of open water in 1970-1977. These estimates exhibited khor-to-khor and khor-to-open water variations.

Ryder & Henderson (1975) estimated the potential yield on the basis of morphoedaphic index (Ryder 1965) as modified for tropical lakes (Regier *et al.* 1971) (10,000 ton, 39 kg/ha/y at 160 m; 19,000 ton, 36 kg/ha/y at 180 m), Rawson's (1952) mean depth model (10,000 ton, 37 kg/ha/y at 160m; 16,000 ton, 30kg/ha/y at 180 m) and Gulland's (1970) equation (11,000 ton). Vanden-Bossche & Bernacscek (1991) gave an account of some other estimations, notably by Sadek (1984) (30,000 ton, 67kg/ha/y) and Entz (1984) (35,000 ton, 78 kg/ha/y). Mekkawy (1998) applied some models (Henderson & Welcomme's 1974 and Marshall's 1984 Models) on Lake Nasser data and showed different results. After updating Marshall's (1984) Model, higher values of potential yield were obtained. This means that MEI-models must be updated before their application. However,

Table 142 **Mean conductivity (µmhos/cm) (derived from Latif 1984b), Morphoedaphic Index (MEI) and the potential yield of certain khors and open water stations in 1970-1977 at water levels 160 m (mean depth 21.6 m) and 180m (mean depth 25m) (Mekkawy 1998).**

Parameter	I-Khors							
	High Dam	Kalabsha	Garf Hussein	Madiq	Amada	Tushka	Adindan	Range
Conductivity	242.3	245.7	234.4	229.7	221.4	226.6	217.5	217.5-245.7
	According to Henderson & Welcomme's (1974) Model							
MEI at 160 m	11.22	11.37	10.85	10.63	10.24	10.49	10.07	10.07-11.37
Pot. yield	44.38	44.66	43.69	43.27	42.25	43.01	42.19	42.19-44.66
MEI at 180m	9.69	9.83	9.38	9.19	8.86	9.06	8.7	8.70-9.83
Yield (kg/ha)	41.44	41.72	40.81	40.43	39.74	40.16	39.40	39.40-41.72
	According to Marshall's (1984) Model							
MEI at 160 m	11.22	11.37	10.85	10.63	10.24	10.49	10.07	10.07-11.37
Pot. yield	68.60	69.01	67.58	66.97	65.85	66.57	65.37	65.37-69.01
MEI at 180 m	9.69	9.83	9.38	9.19	8.86	9.06	8.7	8.70-9.83
Yield (kg/ha)	64.25	64.67	63.33	62.75	61.73	62.35	61.23	61.23-64.67

Parameter	II-Open water stations (relative to the High Dam) at distance (km)							
	3	**50**	**100**	**140**	**200**	**250**	**290**	**Range**
Conductivity	239.5	241.8	235.0	230.6	227.0	222.9	211.8	211.8-241.8
	According to Henderson & Welcomme's (1974) **Model**							
MEI at 160 m	11.09	11.19	10.88	10.68	10.51	10.32	9.81	9.81-11.19
Pot. yield	44.14	44.33	43.75	43.37	43.05	42.7	41.68	41.68-44.33
MEI at 180 m	9.58	9.67	9.4	9.22	9.08	8.92	8.47	8.47-9.67
Yield (kg/ha)	41.22	41.40	40.85	40.49	40.20	39.87	38.91	38.91-41.40
	According to Marshall's (1984) Model							
MEI at 160 m	11.09	11.19	10.88	10.68	10.51	10.32	9.81	9.81-11.19
Pot. yield	68.24	68.52	67.67	67.11	66.63	66.09	64.66	64.66-68.52
MEI at 180 m	9.58	9.67	9.4	9.22	9.08	8.92	8.47	8.47-9.67
Yield (kg/ha)	63.93	64.19	63.39	62.84	62.41	61.92	60.50	60.50-64.19

Vanderpuye (1984) considered such application to underestimate the potential yield in Volta Lake by as much as two folds. The latter author pointed out that the true value of MEI could be more or less 2-folds. Mekkawy (1998) estimated the average MSY

(Maximum Sustainable Yield) by different methods and also found that they were nearly two folds the higher values estimated by the most recent MEI-based models.

Table 143 **Lake Nasser total conductivity (Vanden-Bossche & Bernacsek 1991) and the corresponding potential yield according to Henderson & Welcomme's (1974) and Marshall's (1984) Models (Mekkawy 1998).**

Mean depth (m)	Potential yield at: Conductivity range 190-300 μmhos/cm	Potential yield at: Mean conductivity 260 μmhos/cm
According to Henderson & Welcomme's (1974) Model		
25 at 180 m	36.98-45.81 kg/ha	42.84 kg/ha
	19,374.17-23,992.69 ton	22,438.18 ton
21.6 at 160m	39.61-47.05kg/ha	45.87 kg/ha
	10,238.49-12,679.21 ton	11,857.70 ton
According to Marshall's (1984) Model		
25 at 180m	57.64-70.70kg/ha	66.32 kg/ha
	30,191.93-37,030.63 ton	34,736.10 ton
21.6 at 160m	61.53-75.47kg/ha	70.79 kg/ha
	15,906.12-19,508.98 ton	18,300.14 ton

The MEI- based models reflect only one of the aspects produced by the variable ecological, environmental and fishery factors. Their validity for application is limited by their continuous updating. Therefore, administrators and fishery managers usually seek other models to obtain more precise predictions and in turn to make definitive plans for the future.

Predicting *Tilapia* spp. catch from water level and length of shoreline

The annual changes of water level, catch and the number of fishing boats are given in Fig. 215 (Yamaguchi *et al.* 1996) .The latter authors introduced a regression model for predicting tilapia catch from the water level and length of shoreline of the Lake. Tables 144 and 145 show the relation between water level and shoreline and annual changes in shoreline length during 1964-1987.

A detailed method adopted by Yamaguchi *et al.* (1996) will be given :

The following cubic equation was used for measuring the relationship between water level (H) and shoreline (L).

$L = LO + a\,(H\text{-}HO) + b\,(H\text{-}HO)^2 + c\,(H\text{-}HO)^3 + e$ .... (1)

where, a, b and c are constants, e is an error, HO and LO are water level and shoreline length before building the High Dam. The constants a, b and c were obtained by using the least square method. The result of calculation is shown in the following equation:

$$L = 625 + 177.8\ (H\text{-}112) - 5.054\ (H\text{-}112)^2 + 0.0587\ (H\text{-}112)^3 \quad \ldots\ldots\ldots\ldots (2)$$

Using this equation, the shoreline length for every year was estimated (Table 145).

Table 144 **Relation between water level and shoreline (Yamaguchi *et al.* 1996)**

Water level (m)	Shoreline (km)
112	660
150	3852.2
160	4300.4
165	4439.8
170	4625.35
175	5842
180	7859.5

Yamaguchi *et al.* (1996) found a relation between logarithm of tilapia catch and shoreline length at 1-3 years before High Dam construction. Consequently, they proposed a multiple regression formula of natural logarithm of the index of stock abundance [L_n (C_t NL_t / B_t] on the shoreline length at 0, 1, 2 and 3 years before building the Dam (equation 3).

$$L_n\ (C_t\ NL_t\ /\ B_t = b_0 + b_1NL_t + b_2NL_{t-1} + b_3NL_{t-2} + b_4NL_{t-3} \quad \ldots\ldots\ldots\ldots (3)$$

Where b_o, b_1, b_2, b_3 and b_4 are regression coefficients. Table 146 shows the results of regression analysis, using the full model (equation 3).

Yamaguchi *et al.* (1996) noticed that the variance inflation factor (VIF) at L_{t-2} was very high (i.e. 32), and this value suggested that multi-collinearity, using the full model (equation 3), was so strong that the latter authors selected explanatory variables by using Ridge's regression method (Chatterjee 1981-cit. Yamaguchi *et al.* 1996) (Fig. 216). Therefore, Yamaguchi *et al.* (1996) selected L_{t-3} and they made up a reduced model in the following equation:

$$L_n\ (C_t\ NL_t\ /\ B_t = b_o + b_2NL_{t-1} + b_4NL_{t-3} \quad \ldots\ldots\ldots\ldots (4)$$

Table 145 **Annual changes in shoreline length. (Yamaguchi *et al.* 1996).**

Year	Water level* (m)	Shoreline (km)
1964	116.4	1314
1965	123.0	2047
1966	130.0	2530
1967	138.5	2880
1968	148.5	3236
1969	153.5	3495
1970	158.5	3867
1971	163.2	4358
1972	165.5	4660
1973	161.7	4814
1974	164.0	4458
1975	169.0	5210
1976	174.5	6326
1977	174.4	6303
1978	174.8	6397
1979	175.5	6566
1980	173.6	6121
1981	172.0	5778
1982	171.5	5677
1983	169.5	5298
1984	167.3	4929
1985	160.3	4037
1986	161.2	4130
1987	158.8	3894

* Values of May of that year

The result of multiple regression analysis by using the reduced model (equation 4) is shown in Table 147. Multi-collinearity in the reduced model is small enough and adequate (VIF = 3.5).

Yamaguchi *et al.* (1996) analysed the residuals of the reduced model (Figs. 217 and 218) and they observed that the reduced model (equation 4) is reasonable and is applicable for predicting the catch and equation 4 may be transformed into the following:

$$C_t = B_t / L_t \, \mathrm{Nexp.} \, (b_o + b_2NL_{t-1} + b_4NL_{t-3})$$

Fig. 219 shows a comparison between the estimated and the actual catches, and it is obvious that there is almost no difference between them (Yamaguchi *et al.* (1996).

Tilapia growth curve (Yamaguchi *et al.* 1996) indicated that *0. niloticus* and *S. galilaeus* recruit catch resources at 2 or 3 years old and the spawning area of tilapia is greatly affected by the shoreline length. Therefore, Yamaguchi *et al.* (1996) concluded that shoreline length at 3 years before (L_{t-3}) was selected as one of explanatory variables.

Table 146 **Result of multiple regression analysis with full model (equation [3]) (Yamaguchi *et al.* 1996).**

Variable	β*[1]	Standard error of β	VIF*[2]
L_t	-9.106E-05	1.076 E-04	8.6
L_{t-1}	3.459 E-04	1.734 E-04	26.2
L_{t-2}	- 1.483 E-04	1.732 E-04	32.2
L_{t-3}	5.803 E-04	9.674 E-05	13.0
Constants	7.217	0.182	
	N*[3] = 21	R*[4] = 0.987	

*1 Regression coefficient. *2 Variance inflation factor.
*3 Number of data. *4 Multiple correlation coefficient

Table 147 **Result of multiple regression analysis with reduced model (equation [4]) (Yamaguchi *et al.* 1996).**

Variable	β*[1]	Standard error of β	VIF*[2]
L_{t-1}	1.783 E-04	6.212 E-05	3.5
L_{t-2}	5.280 E-04	4.933 E-05	3.5
Constants	7.163	0.1653	
	N*[3] = 21	R*[4] = 0.987	

*1 Regression coefficient. *2 Variance inflation factor.
*3 Number of data. *4 Multiple correlation coefficient

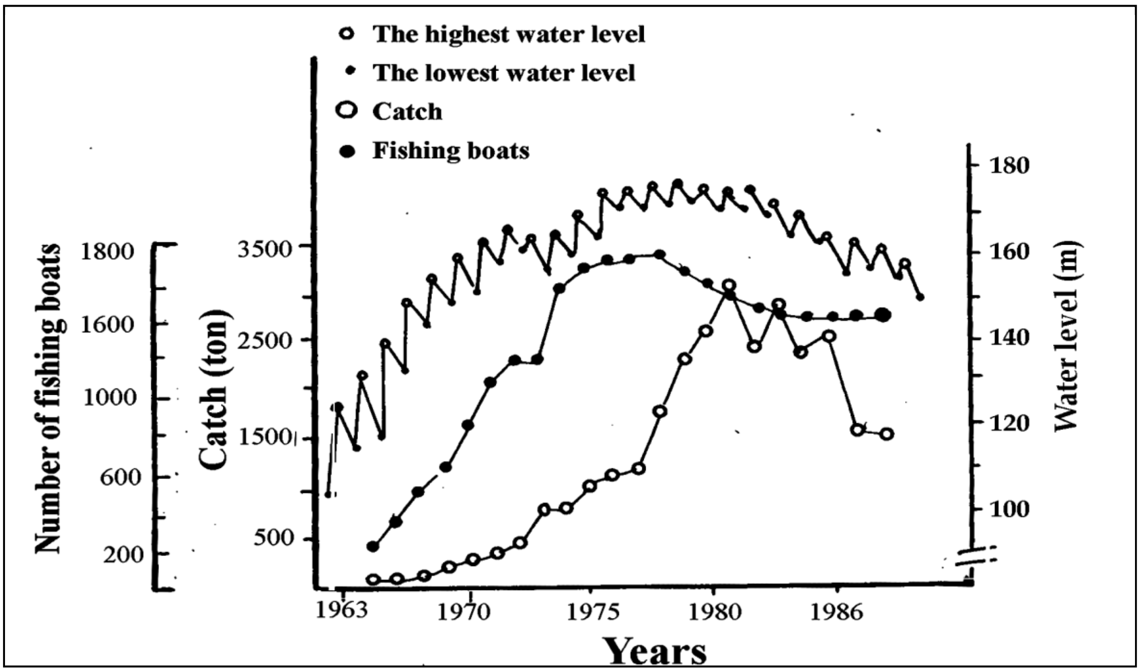


Fig. 215 **Annual changes of water level, catch and the number of boats (Yamaguchi *et al.* 1996).**

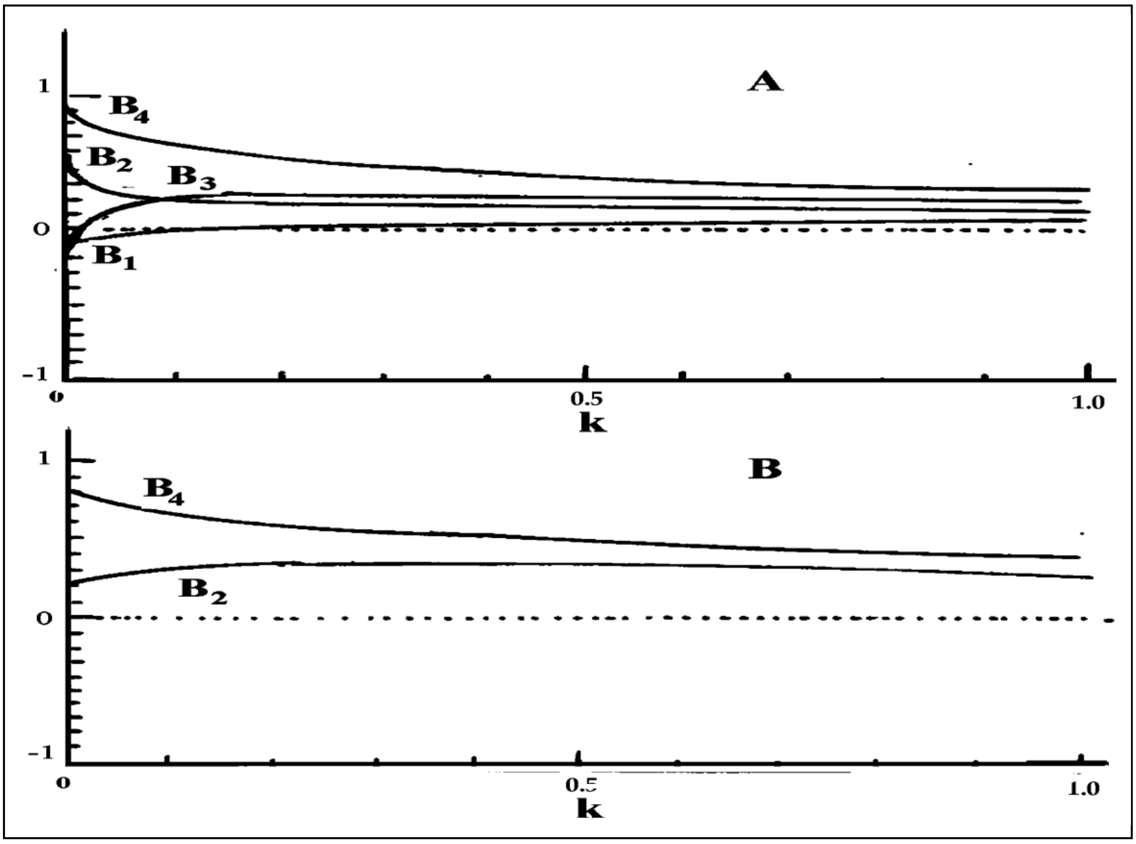


Fig. 216 **Ridge's locus**

A : Full model. B : Reduced model, β^{*1} : Ridge's regression coefficient

K : Ridge's parameter (Yamaguchi *et al.* 1996).

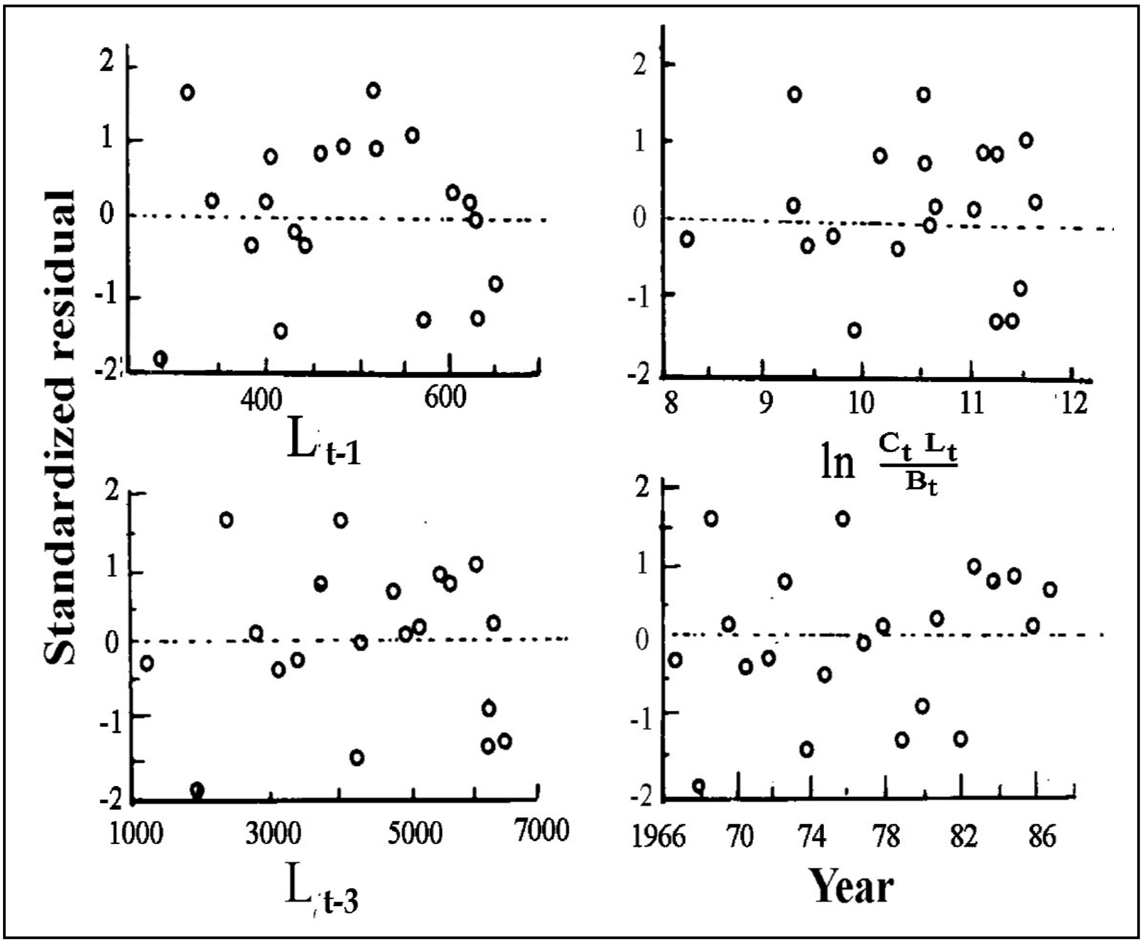


Fig 217 **Standardized residuals shown against explanation variables L_{t-1} , L_{t-3} In (C_t L_t/B_t) and year t (Yamaguchi *et al.* 1996).**

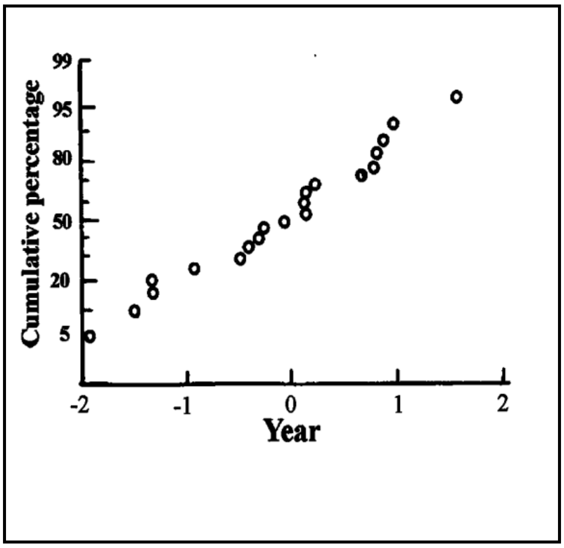


Fig 218 **Test of normality of residuals by normal probability paper,**

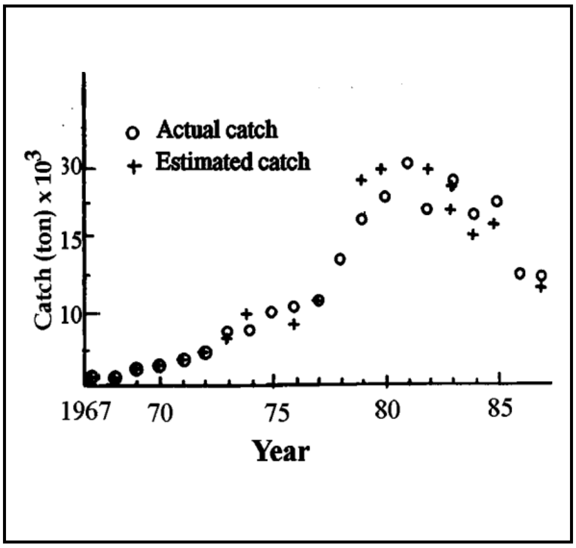


Fig 219 **Relation between actual and estimated catch.**

(Yamaguchi *et al.* 1996)

Tentative estimation of fish production from phytoplankton primary production.

Habib & Aruga (1987) calculated the primary net production of phytoplankton in the different fishing areas of Lake Nasser (Table 148), and in the entire Lake at 160 and 180 m above Sea level (Fig. 149).

Table 148 **Primary net production of phytoplankton in different fishing areas of Lake Nasser (for areas refer to Fig. 149) (Habib & Aruga 1987).**

Fishing area	Primary net production [kg (d.w.) /m²/year]
1	2.88
2	5.02
3	3.83
4	5.28
5	4.51
6	2.51
Average	**4.01**

Table 149 **Primary net production of phytoplankton in the entire lake (Habib & Aruga 1987).**

Water level (m)	160	180
Surface area (km²)	2562	5237
Surface area (m²)	$2.56x10^9$	$5.24x10^9$
Annual net production [kg (d.w.) / year]	10.3×10^9	21.0×10^9
Annual net production [ton (d.w.) / year]	10.3×10^6	21.0×10^6

d.w. = dru weight.

For estimation of fish production, Habib & Aruga (1987) assumed that one half of primary production is consumed directly by fish (one trophic level) and the other half, indirectly by fish (two trophic levels), at a conversion efficiency of 10% (Table 150).

Table 150 **Fish production (dry weight) from Lake Nasser (Habib & Aruga 1987).**

Assumption	Water level (m)	
	160	**180**
Half of primary production consumed directly by fish	$5.15 \times 10^6 \times 0.1 =$ 5.15×10^5	$10.5 \times 10^6 \times 0.1 =$ 10.5×10^5
Half of primary production consumed indirectly by fish.	$5.15 \times 10^6 \times (0.1)^2 =$ 0.52×10^5	$10.5 \times 10^6 \times (0.1)^2 =$ 1.05×10^5
Total	5.67×10^5	11.55×10^5

The latter authors assumed that the fish dry weight is about 25% of the fish fresh weight and consequently the fish production could be calculated as shown in Table 151.

Table 151 **Calculated fish production (fresh weight) from Lake Nasser (Habib & Aruga 1987).**

	Water level (m)	
	160	**180**
Fish production (Fresh weight) (ton/year)	$5.67 \times 10^5/0.25$ = 22.7×10^5	$11.55 \times 10^5/0.25$ = 46.2×10^5

Assuming that the habitat of tilapia is only 10% of the total Lake area along the shore, tilapia production will be as follows:

	Water level (m)	
	160	**180**
Tilapia production (ton/year)	$22.7 \times 10^5 / 10$ 22.7×10^4	$46.2 \times 10^5 / 10$ 46.2×10^4

Assuming that only 10% of tilapia are caught, the tilapia catch will be as follows:

	Water level (m)	
	160	180
Tilapia catch	22.7×10^4 / 10 22.7×10^3 ton / year	46.2×10^4 / 10 46.2×10^3 ton / year

ESTIMATION OF MAXIMUM SUSTAINABLE YIELD (MSY)

Estimation of maximum sustainable yield (MSY) using some population characteristics

Mekkawy (1998) calculated some population characteristics of *O. niloticus, S. galilaeus* and *Lates niloticus*. The latter author estimated the maximum sustainable yield of the aforementioned fish species of Lake Nasser during 1966-1992 (Tables 152-154). The MSY was roughly estimated according to Cadima's estimator (Troadec, 1977). However, these yearly variable MSY's values were overestimated since they were influenced only by yearly catch and total mortality and not by long-term data (Mekkawy 1998).

Estimation of maximum sustainable yield (MSY) using yield / recruitment and biomass/recruitment relationships

Sparre *et al.* (1992) mentioned that yield per recruit (Y/R) model of Beverton & Holt (1957) is in principle a "steady state model". This model can be written according to Gulland (1970) in the following form:

$$Y/R = F *\exp [- M^* (Tc - Tr)] *W_\infty^* [1/Z - 3S/(Z + k) + 3S^2 (Z + 2k) - S^3/(Z + 3k)]$$

Where $S = \exp [-K^* (Tc - To)$; k = von Bertalanffy growth parameter,
Tc = age at first capture; Tr = age at recruitment;
$W\infty$ = asymptotic body weight; F = fishing mortality;
M = natural mortality; Z = total mortality; Z = F + M.

Mekkawy (1998) used the aforementioned model in calculating Y/R with varying inputs of different values of Tc and F. The latter author used also Beverton & Holt's biomass per recruit (B/R) and relative Y/R models (Sparre *et al.* 1992) in estimating MSY/R and the relative MSY/R for different values of Tc.

The yield / recruitment curves (Y/R) of *0. niloticus* differed in shape and characteristics from those of *S. galilaeus* (Fig. 220 and 221). Thus, Y/R - curves of the latter species had pronounced maximum values and correspondingly lower values of fishing mortality, F_{MSY} in comparison with those of the first species (Mekkawy 1998). The lower value of the natural mortality rate (M) of *S. galilaeus* produced the lower F_{MSY} and higher MSY/R. The latter author mentioned that this situation pays to let *S. galilaeus* to grow to a large size and this means that for a biological optimum exploitation, fishing mortality should be low.

Table 152 **Certain population characteristics and the maximum sustainable yield (MSY) of *Oreochromis niloticus* of Lake Nasser in 1966-1992 (Mekkawy 1998).**

Year	Population characteristics *					MSY** (ton)
	F	Z	μ	E	V	
1966	0.144	0.765	0.189	0.101	0.434	2554.5
1967	0.253	0.873	0.289	0.169	0.414	2823.2
1968	0.361	0.982	0.368	0.230	0.395	3362.6
1969	0.432	1.053	0.411	0.267	0.384	8353.8
1970	0.589	1.210	0.487	0.342	0.360	8490.5
1971	0.750	1.371	0.547	0.408	0.338	10005.4
1972	0.819	1.440	0.569	0.434	0.329	12636.6
1973	1.047	1.667	0.628	0.509	0.302	19832.2
1974	1.078	1.698	0.635	0.518	0.299	19797.3
1975	1.255	1.875	0.669	0.566	0.280	25040.1
1976	1.040	1.660	0.626	0.507	0.303	29134.2
1977	1.039	1.659	0.626	0.507	0.303	31028.4
1978	0.948	1.568	0.604	0.478	0.313	48588.9
1979	0.990	1.611	0.615	0.492	0.308	63040.6
1980	1.027	1.647	0.623	0.503	0.304	70793.9
1981	1.431	2.051	0.697	0.608	0.264	75906.5
1982	1.127	1.747	0.645	0.533	0.293	63771.5
1983	1.346	1.966	0.684	0.589	0.271	71513.9
1984	1.135	1.755	0.646	0.535	0.292	61332.7
1985	1.197	1.817	0.659	0.552	0.286	61298.3
1986	1.010	1.631	0.619	0.498	0.306	41804.2
1987	1.010	1.631	0.619	0.498	0.306	40734.6
1988	1.014	1.635	0.620	0.499	0.306	38848.6
1989	1.626	2.247	0.724	0.647	0.247	31167.9
1990	1.626	2.247	0.724	0.647	0.247	46874.1
1991	1.437	2.058	0.698	0.609	0.263	72962.1
1992	1.333	1.953	0.682	0.586	0.273	61352.7

**** roughly estimated according to Cadima's estimator (Troadec, 1977).**

F= fishing mortality, Z = total mortality, μ & E = ratio and rate of exploitation, V = expectation of natural death.

Table 153 **Certain population characteristics and the maximum sustainable yield (MSY) of *Sarotherdon galilaeus* of Lake Nasser in 1966-1992 (Mekkawy 1998).**

Year	Population characteristics *					MSY** (ton)
	F	Z	μ	E	V	
1966	0.277	0.345	0.803	0.234	0.057	365.1
1967	0.484	0.552	0.877	0.372	0.052	566.4
1968	0.692	0.760	0.911	0.485	0.048	825.8
1969	0.829	0.897	0.924	0.547	0.045	2257.1
1970	1.129	1.197	0.943	0.658	0.040	2665.6
1971	1.438	1.505	0.955	0.743	0.035	3486.9
1972	1.570	1.638	0.959	0.772	0.033	4561.9
1973	2.006	2.074	0.967	0.846	0.029	7828.9
1974	2.066	2.133	0.968	0.854	0.028	7891.5
1975	2.405	2.472	0.973	0.891	0.025	10476.3
1976	1.992	2.060	0.967	0.844	0.029	11472.7
1977	1.991	2.059	0.967	0.844	0.029	12215.7
1978	1.817	1.884	0.964	0.818	0.031	18524.8
1979	1.898	1.966	0.965	0.830	0.030	24412.8
1980	1.967	2.035	0.967	0.840	0.029	27758.0
1981	2.742	2.810	0.976	0.917	0.023	32994.9
1982	2.160	2.228	0.970	0.865	0.027	25795.8
1983	2.579	2.647	0.974	0.905	0.024	30547.9
1984	2.175	2.243	0.970	0.867	0.027	24865.8
1985	2.294	2.362	0.971	0.880	0.026	25276.4
1986	1.936	2.003	0.966	0.836	0.029	16299.3
1987	1.936	2.003	0.966	0.836	0.029	15882.3
1988	1.944	2.012	0.966	0.837	0.029	15169.4
1989	3.117	3.185	0.979	0.938	0.020	14018.8
1990	3.117	3.185	0.979	0.938	0.020	21083.1
1991	2.755	2.823	0.976	0.918	0.023	31754.9
1992	2.554	2.622	0.974	0.903	0.024	26133.6

Refer to table 152 for abbreviations ** roughly estimated according to Cadima's estimator (Troadec, 1977).

Table 154 **Certain population characteristics and the maximum sustainable yield (MSY) of *Lates niloticus* of Lake Nasser in 1966-1992 (Mekkawy 1998).**

Year	Population characteristics *					MSY**
	F	Z	μ	E	V	(ton)
1966	0.062	0.284	0.218	0.054	0.193	172.2
1967	0.108	0.330	0.328	0.092	0.189	617.9
1968	0.154	0.376	0.410	0.129	0.185	1297.3
1969	0.185	0.407	0.455	0.152	0.182	4766.1
1970	0.252	0.474	0.532	0.201	0.177	6359.3
1971	0.312	0.543	0.591	0.248	0.171	6557.6
1972	0.351	0.573	0.612	0.267	0.169	5522.7
1973	0.448	0.670	0.669	0.327	0.162	4418.5
1974	0.461	0.683	0.675	0.334	0.161	5442.7
1975	0.537	0.759	0.708	0.376	0.155	5564.5
1976	0.445	0.667	0.667	0.325	0.162	4675.9
1977	0.445	0.666	0.667	0.325	0.162	6340.9
1978	0.406	0.628	0.646	0.301	0.165	4849.7
1979	0.424	0.646	0.656	0.312	0.163	4238.9
1980	0.439	0.661	0.664	0.321	0.162	4887.5
1981	0.612	0.834	0.734	0.415	0.150	4076.7
1982	0.482	0.704	0.684	0.346	0.159	3000.4
1983	0.576	0.798	0.722	0.397	0.153	2659.7
1984	0.486	0.708	0.686	0.348	0.159	1464.1
1985	0.512	0.734	0.698	0.363	0.157	1386.6
1986	0.432	0.654	0.661	0.317	0.163	2837.5
1987	0.432	0.654	0.661	0.317	0.163	3484.4
1988	0.434	0.656	0.662	0.318	0.163	6199.4
1989	0.696	0.918	0.758	0.455	0.145	7012.4
1990	0.696	0.918	0.758	0.455	0.145	4707.9
1991	0.615	0.837	0.735	0.417	0.150	2561.5
1992	0.570	0.792	0.720	0.394	0.153	6083.9

Refer to table 152 for abbreviations ** roughly estimated according to Cadima's estimator (Troadec 1977).

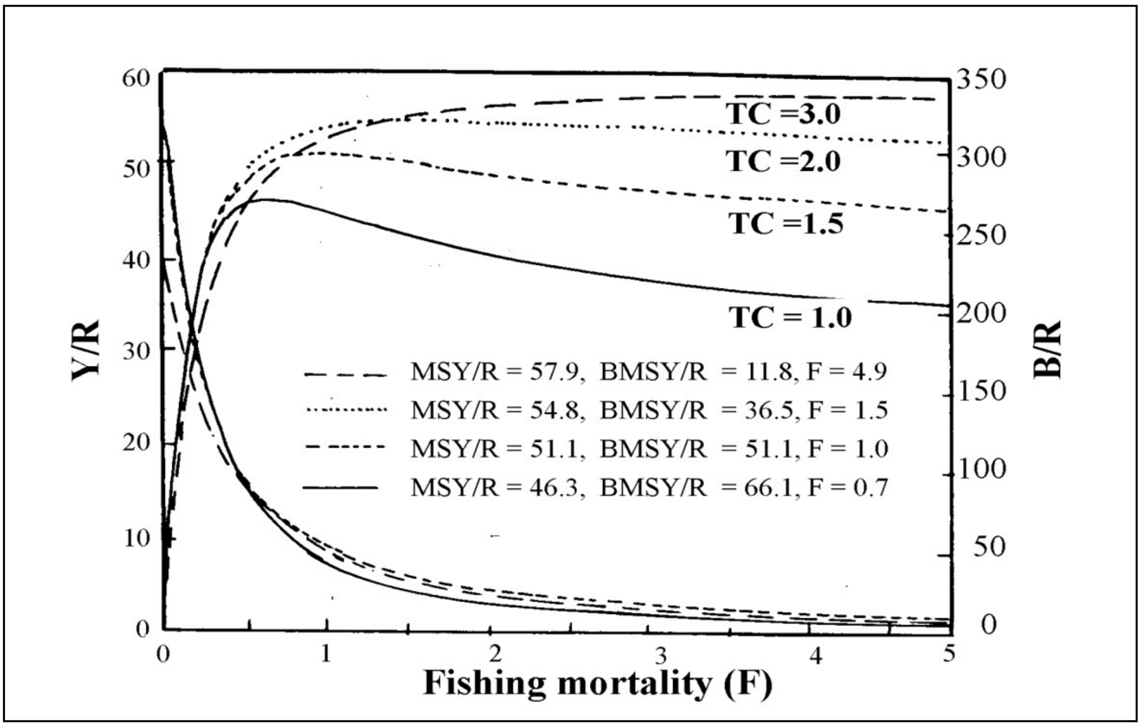


Fig. 220 **Yield/recruit (Y/R) and biomass/recruit (B/R) curves with different ages at first capture (TC) of** ***Oreochromis niloticus*** **of Lake Nasser (Mekkawy 1998).**

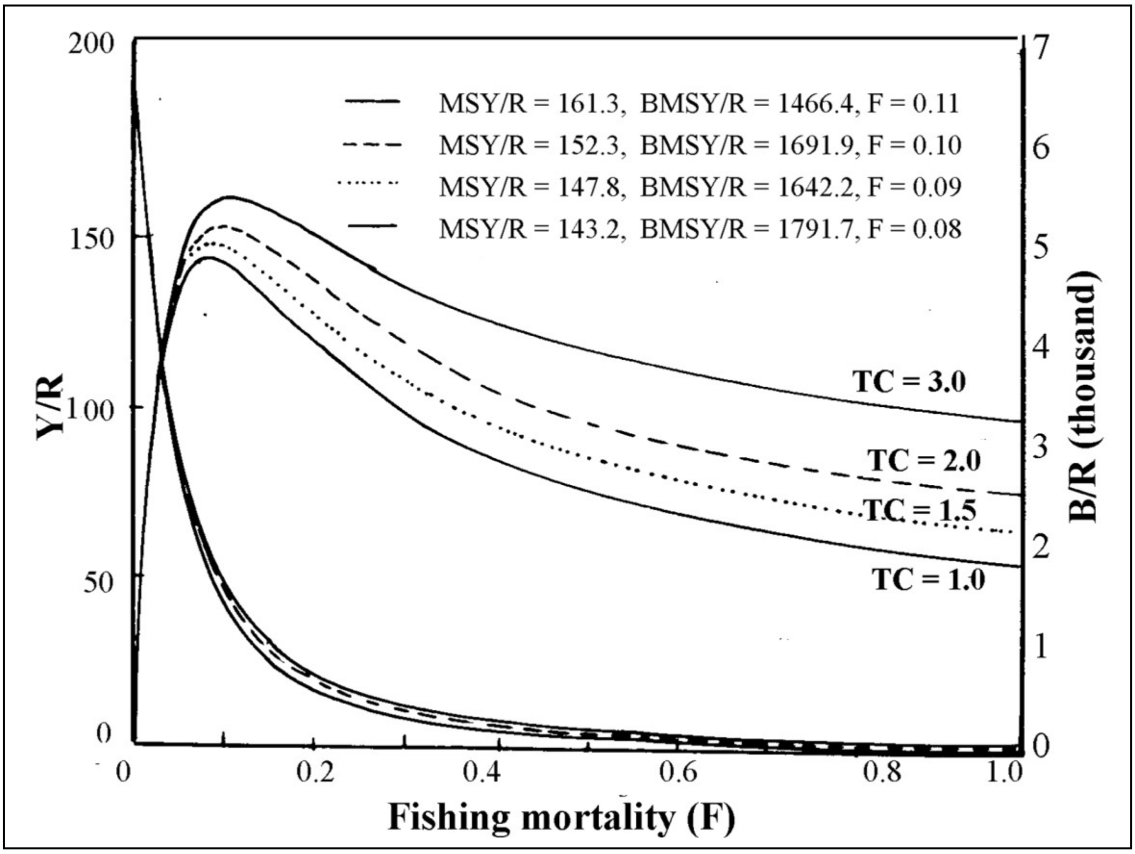


Fig. 221 **Yield/recruit (Y/R) and biomass/recruit (B/R) curves with different ages at first capture (TC) of** ***Sarotherodon galilaeus*** **of Lake Nasser (Mekkawy 1998).**

The MSY/R of both *0. niloticus* and *S. galilaeus* increases with the increase of age at first capture, Tc (Figs. 220 and 221). The recruits required to obtain MSY of F_{MSY} (30,000 ton) are 647,948,164 and 518,134,715 for Tc = 1 and 3 respectively. When comparing these values with those of 1979-cohort, Mekkawy (1998) concluded that the environmental and biological conditions of the Lake should be controlled to multiply the current recruits of *O. niloticus*, at least by a factor of 9-11 for MSY (30,000 ton) at Tc = 1 – 3). The latter author postulated that those of *S. galilaeus* should be multiplied by at least a factor of 5 - 6 for MSY (17,000 ton) at Tc = 1 - 3.

Figs. 220 and 221 show that the annual average biomass of the survivors was expressed as a function of fishing mortalities of tilapiine species considered. The biomass of these species declines with the increase of fishing effort. In other words, their biomass per recruit (B/R) curves were proportional to CPUE, which means that one should expect a decrease in CPUE and their biomass when effort increases (Mekkawy 1998).

Therefore, a decrease in CPUE is not per se an indication that a stock is overfished. In fact, overfishing occurs when the effort becomes so high that the growth curve cannot balance the death process.

Table 155 shows that the percentages of biomass corresponding to the biologically optimum F-level, (B_{MSY}) relative to the virgin stock biomass (Bv), the biomass of unexploited stock, at different ages of first capture were represented by 5.02-19.92% for *O. niloticus* and 21.95-26.37% for *S. galilaeus.* The reduction in the spawning stock biomass of these species will influence the productivity of their stocks. Below such a level of reduction (B_{MSY}) the stock of *O. niloticus* and *S. galilaeus* will be recruitment - overfished (Mekkawy 1998).

Two types of Y/R-curves are observed (Figs. 220 and 221). Fig. 220 shows a plateau type of curve, which is virtually asymptotic for most purposes. At Tc > 2, *0. niloticus* Y/R increases to a plateau with increasing fishing mortality. Beyond its first part, a large increase in fishing mortality produces only a very small increase in yield. In the remaining curves, especially those of *S. galilaeus,* a definite peak of yield is reached at a relatively low fishing mortality. At first sight, the management policies suggested by the two types of curves are very different (Mekkawy 1998). The first seems to indicate maximum yields from heavy fishing, whereas the second advocates low to moderate fishing mortality. The latter author mentioned that this conclusion is misleading and in fact, the actual shape of these Beverton & Holt yield curves varies according to the relationship between growth rate and age at first capture, Tc.

Table 155 **Optimum fishing mortality (F_{MSY}), maximum sustainable yield per recruit (MSY/R), corresponding biomass per recruit (B_{MSY}/R) virgin stock per recruit (Bv/R) and the percentage of B_{MSY} relative to Bv at different ages of first capture, Tc, and according to the current growth characteristics of *O. niloticus* and *S. galilaeus* of Lake Nasser (Mekkawy 1998).**

F_{MSY}	MSY/R	B_{MSY}/R	B_V/R	B_{MSY} /B_V (%)	Tc
		O. niloticus			
0.7	46.3	66.1	332.0	19.92	1.0
1.0	51.1	51.1	313.8	16.28	1.5
1.5	54.8	36.5	290.4	12.58	2.0
4.9	57.9	11.8	234.9	5.02	3.0
		S. galilaeus			
0.08	143.3	1791.7	6793.9	26.37	1.0
0.09	147.8	1642.2	6773.6	24.24	1.5
0.10	152.3	1691.9	6748.4	25.07	2.0
0.11	161.3	1466.4	6681.9	21.95	3.0

Mekkawy (1998) mentioned that S. *galilaeus,* which is of a slow growing nature, and is caught early in life, has a lot of potential weight to put on, and this brings about a maximum yield at low fishing rates. Such low rates allow fish to escape the gear and therefore realize some of their growth potential. On the other hand, *0. niloticus* tends to be fast-growing and producing Y/R-curve of the plateau type even at lower rates of Tc.

Mekkawy (1998) considered the relative Y/R-concept of Beverton & Holt (1966), and his results concerning MSY/R, E_{MSY}, F_{MSY}, Tc, Lc and the corresponding mesh size for these tilapiine species are presented in Table 156. For *0. niloticus,* if Tc increases above 3, it will be difficult to determine E_{MSY}, except at very heavy fishing.

Estimation of maximum sustainable yield (MSY) using Schaefer's Model

Mekkawy (1998) fitted khor's catch-effort data of 1988-1994 to Schaefer's Model and estimated the MSY per month per fishing area, and presented also the effort and CPUE ranges in Tables 157 and 158. Using khor's MSY, Mekkawy (1998) estimated the total MSY of the Lake as 59,742.24 ton, 52.14% (= 31,150.2 ton) of that value was contributed by the northern part of the Lake and 47.86%

(= 28,592.4 ton) by the southern part. The average MSY per fishing area was 798.72 and 722.75 ton per year for the northern and southern parts respectively. Three khor fishing areas were out of calculations due to the positive CPUE-effort correlations (Table 157 and 158).

Table 156 **Relative maximum sustainable yield [(MSY/R)] and the corresponding optimum exploitation rate (E_{MSY}), and optimum fishing mortality rate (F_{MSY}) at different ages of first capture, Tc, and the corresponding total length, Lc and mesh size and according to the current characteristics of *O. niloticus* and *S. galilaeus* of Lake Nasser (Mekkawy 1998).**

(MSY/R)	E_{MSY}	F_{MSY}	Tc	Lc	Mesh size
		O. niloticus (selection factor = 1.93)**			
0.005619	0.492	0.60	1.0	11.88	6.15
0.008450	0.617	1.00	1.5	14.64	7.58
0.012378	0.733	1.70	2.0	17.28	8.95
0.017675	0.869	4.90	2.5	19.81	10.26
0.024649	0.981	31.6	3.0	22.23	11.52
		***S. galilaeus* (selection factor = 2.03)**			
0.10535	0.588	0.10	1.0	12.26	6.05
0.11093	0.632	0.12	1.5	13.42	6.62
0.11707	0.650	0.13	2.0	14.52	7.16
0.17375	0.680	0.15	2.5	15.58	7.69
0.13113	0.695	0.16	3.0	16.59	8.18
0.13922	0.731	0.19	3.5	17.55	8.66
0.14810	0.759	0.22	4.0	18.48	9.11
0.15786	0.788	0.26	4.5	19.36	9.55
0.16860	0.816	0.31	5.0	20.20	9.96

**** For Tc > 3, $E_{MSY} \approx 1.0$ and (MSY/R)-increase requires very high F_{MSY}.**

Mekkawy (1998) mentioned that the total-catch-effort data of the whole period (1966-1992) were fitted to the power function equation (Fig. 222). These data were best described by the following equation:

$$\text{Catch (C)} = 0.148928\ f^{1.5975378}$$

which may also take the form :

$$\text{CPUE} = 0.148928\ f^{1.5975378}$$

The power function model has no maximum and therefore, maximum sustainable yield (MSY) and the corresponding fishing effort (f_{MSY}) cannot be determined. This model could be considered here as a descriptive one (Mekkawy 1998).

The total-catch-effort data of the fluctuated period (1973-1992) were fitted to the hyperbolic model (Fig. 223) and was described by the following equation:

Table 157 **Estimation of maximum sustainable yield (MSY) per month and the related optimum effort (f_{MSY}) of the fishing grounds of the northern part of Lake Nasser based on the data of Mohamed, M. (1993a, b, 1995a, b) for 1988-1994. Monthly effort and catch per unit effort (CPUE) ranges are given. (Mekkawy 1998).**

Fishing ground	No.	Effort range (boat)	CPUE range (ton/boat/month)	MSY (ton)	f_{MSY} (boat)
El Ramla*	1	86-120	0.45-1.18	+	+
Dihmit (east)	2	10-19	0.87-1.57	20.84	22
Dihmit (east)	3	13-49	0.89-1.52	60.35	97
Dihmit (west)	4	18-31	0.69-1.61	273.96	693
Amberkab (east)	5	13-17	0.39-1.71	13.52	16
Amberkab (east)	6	6-16	0.56-1.46	10.12	13
Amberkab (west)	7	2-12	0.12-0.99	4.85	9
Amberkab (west)	8	6-14	0.23-1.89	10.09	14
Rahma (east)	9	7-34	0.69-1.58	32.82	36
Rahma (east)	10	5-25	0.69-1.92	48.69	87
Kalabsha	11	18-31	0.41-1.93	17.09	33
Gazal (north)	12	11-34	0.23-1.44	31.72	62
Gazal (north)	13	11-40	0.36-1.71	45.75	95
Gazal (north) inter	14	12-30	0.40-1.86	25.32	50
Gazal (north)	15	6-37	0.22-1.05	38.97	96
Gazal (inter)	16	3-20	0.15-0.93	7.59	19
Kalabsha (south)	17	3-39	0.23-1.25	22.78	44
Gazal (south)	18	13-39	0.21-1.08	38.94	91
Merwaw (east)	19	7-24	0.57-2.00	20.28	20
Fallahin (west)	20	15-34	0.59-0.98	113.37	295
Merwaw (west)	21	7-17	0.44-1.96	23.70	11
Merwaw (west)	22	15-27	0.33-1.16	15.58	34
Merwaw (east)	23	19-27	0.56-1.25	24.07	48
Wadi Abyad (east)	24	20-29	0.40-1.11	38.74	124
Wadi Abyad (east)	25	14-31	0.43-1.42	119.82	237
Wadi Abyad	26	8-28	0.53-1.99	20.16	27
Wadi Abyad	27	21-29	0.55-1.55	28.58	19
Galal	28	8-25	0.36-1.59	23.36	34
Mariya	29	10-24	0.52-1.63	18.37	20
Garf Hussein (west)	30	12-38	0.54-1.41	152.26	267
Garf Hussein	31	11-70	0.47-1.19	957.35	344
Garf Hussein (west)	32	6-29	0.44-1.07	117.21	215
Gersha	33	9-28	0.66-2.92	22.93	18
Gersha (east)	34	5-30	0.36-2.05	17.86	17
Abesko (east)	35	5-29	0.74-1.65	23.64	36
Abesko (east)	36	21-32	0.66-2.62	33.29	11
Abu-Derwa (west)	37	17-30	0.59-9.42	23.00	20
Abu-Derwa (west)	38	21-42	0.40-1.36	42.10	59
Allaqi (north)	39	10-41	0.42-2.46	31.03	22
Allaqi (south)	40	7-26	0.53-1.86	25.75	45

***Data for Khor El Ramla are based on years 1991,1993, 1994; + means positive correlation between effort & CPUE.**

Table 158 **Estimation of maximum sustainable yield (MSY) per month and the related optimum effort (f_{MSY}) of the fishing grounds of the southern part of Lake Nasser based on the data of Mohamed, M. (1993a, b, 1995a, b) for 1988-1994. Monthly effort and catch per unit effort (CPUE) ranges are given. (Mekkawy 1998).**

Fishing ground	No.	Effort range (boat)	CPUE range (ton/boat/month)	MSY (ton)	f_{MSY} (boat)
Allaqi	41	2-30	0.47-2.27	16.18	23
Allaqi	42	10-24	0.83-3.97	36.53	20
Allaqi	43	13-24	0.57-2.44	30.48	27
Allaqi (east)	44	28-45	0.63-1.85	36.62	63
Korta (west)	45	9-28	0.67-1.54	404.36	840
Moharrka	46	9-31	0.89-1.44	60.87	99
Sayala (west)	47	9-31	0.72-2.93	26.73	24
Sayala (west)	48	18-39	0.34-1.69	27.5	36
Sayala (west)	49	15-26	0.47-1.52	31.67	50
Sayala (west)	50	17-27	0.37-2.71	55.5	95
Sayala (west-east)	51	11-25	0.57-2.61	23.21	14
Madiq (east)	52	12-25	0.44-1.44	15.57	20
Madlq (east-west)	53	28-37	0.32-2.07	47.69	74
El Soboui (east)	54	3-27	0.52-5.06	22.35	18
El Soboui (east-west)	55	12-22	0.40-2.15	45.41	22
Wadi El Arab	56	7-32	0.58-1.92	65.15	153
Malki-Singary	57	20-30	0.42-2.36	29.21	20
Malki	58	8-28	0.79-6.23	16.54	10
Korosko (east)	59	8-48	0.77-2.14	38.97	21
Korosko (inter)	60	9-22	0.43-3.92	27.95	12
Korosko	61	8-56	0.61-5.55	59.90	33
Abu Handal (east-west)	62	9-65	0.67-2.01	50.42	46
Abu Handal (east-west)	63	10-36	0.59-1.97	48.46	72
Thomas, Afia (east-west)	64	7-54	0.99-2.11	427.67	618
Ebrim Afia	65	5-35	0.56-2.72	41.19	46
Shebbak	66	9-51	0.70-3.83	50.90	53
Masmas (west)	67	11-36	0.56-2.49	40.87	40
Masmas (inter)	68	8-29	0.85-1.80	37.00	49
Tushka (west)	69	28-36	0.99-2.90	+	+
Tushka (west)	70	21-56	0.75-3.08	73.56	67
Tushka (west)	71	13-52	0.94-3.27	42.56	44
Tushka (west)	72	7-28	0.86-2.63	59.52	51
Forgondy (west)	73	5-20	0.85-2.68	+	+
Forgondy (west)	74	7-28	0.65-1.67	46.21	58
Hamido (east)	75	10-63	0.76-1.56	73.82	165
Hamido (east)	76	2-37	0.91-2.27	56.90	59
Khor-Bateakh	77	7-61	0.86-5.47	73.11	50
Abu Simbel (east)	78	3-25	0.33-1.15	35.99	14
Abu Simbel (west)	79	2-39	0.41-1.11	96.89	204

+ means positive correlation between effort & CPUE.

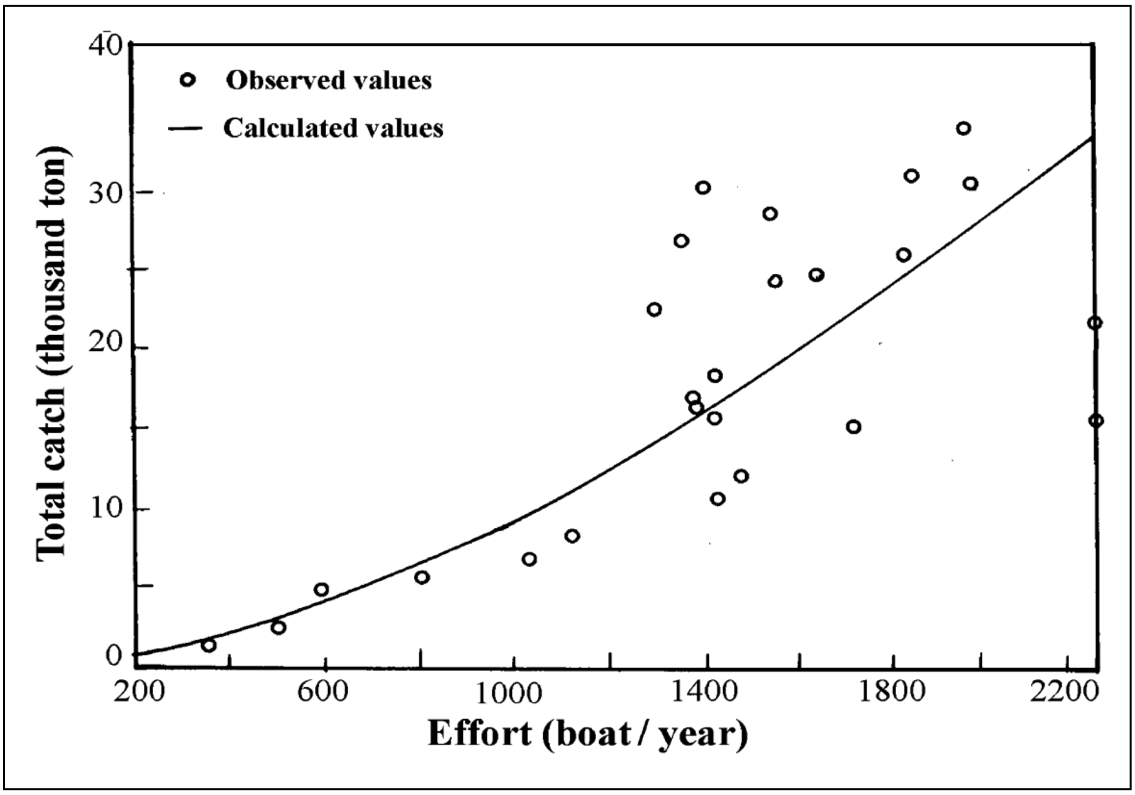


Fig. 222 **Total catch-effort data of Lake Nasser for 1966-1992 period fitted to power function equation. (Mekkawy 1996).**

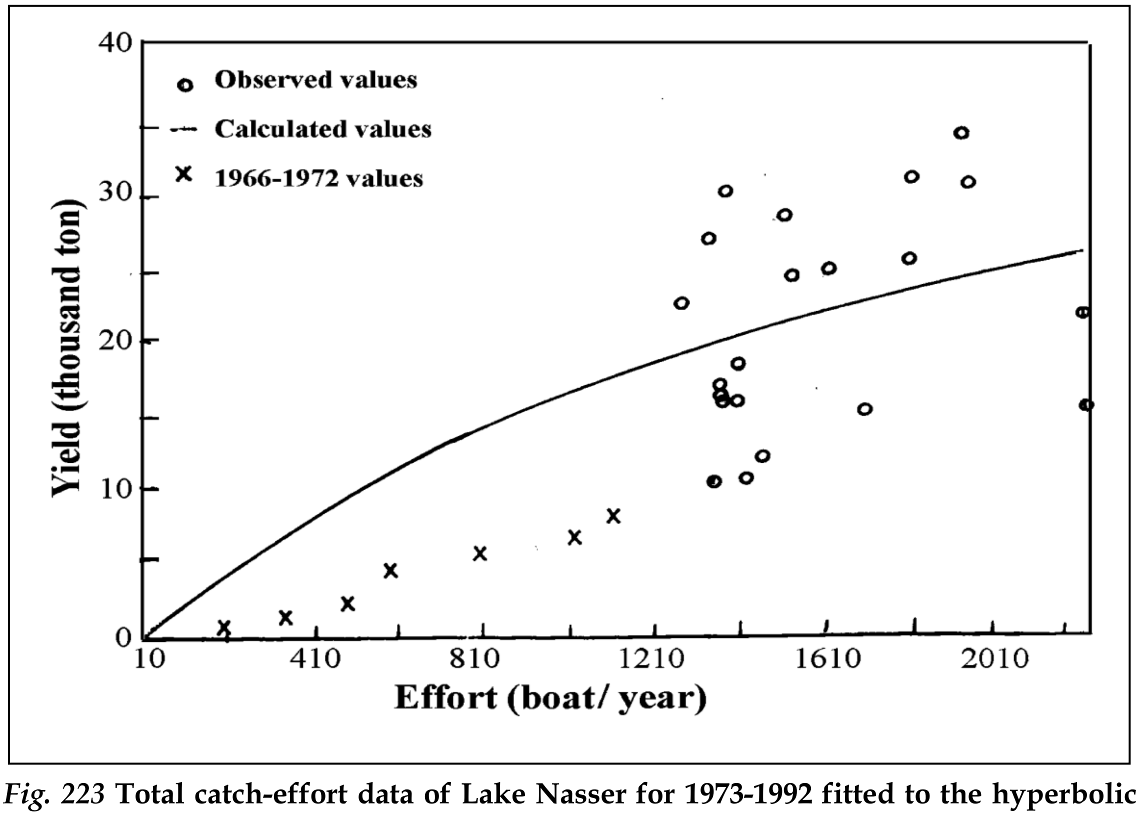


Fig. 223 **Total catch-effort data of Lake Nasser for 1973-1992 fitted to the hyperbolic model 1966-1972 yield values were estimated according to such model (x) (Mekkawy 1996).**

Catch (C) = 1.0 / (0.00002 + 0.04089/E)

Such a hyperbolic model determines (MSY) with infinite effort. The MSY (after its multiplication by 1.11233919 to convert from harmonic to arithmetic mean) was 55,616.69 ton.

Fig. 223 shows that the fitted data of the initial years of Lake formation (1966 -1972, denoted by x) were away of the corresponding expected values of the model used. Mekkawy (1998) found that it was impossible to fit data of the total period (1966-1992) to that model due to the negative values of the constant parameters which in turn were due to the increased CPUE of the initial years of Lake formation.

Since the CPUE of 1973-1992 for tilapiines and of 1966-1992 for other groups of fishes had undergone relatively substantial changes, the holistic model of Schaefer (1954), Schaefer's Model, was applied by Mekkawy (1998) and fitted to describe the CPUE-effort relationship of different fish groups of Lake Nasser. The parameter estimates of such a model and the corresponding MSY and f_{MSY} are given in Table 159 and Fig. 224.

$Y_{(i)}/f_{(i)} = a\ bf_{(i)}$ if $f_{(i)} \leq -a/b$

where, $Y_{(i)}$ = catch, $f_{(i)}$ = effort, a and b are constants.

$f_{(MSY)} = -0.5\ a/b$

$MSY = 0.25\ a^2/b$

Table 159 **Maximum sustainable yield (MSY) and the corresponding fishing effort [f_{MSY}] for fish groups of Lake Nasser (Mekkawy 1998).**

Species	**a**	**b**	**f_{MSY} (boats)**	**MSY (ton)**
Tilapia **spp.**	12.3794	- 0.00068495	9037	55934.57
0. niloticus	7.15774	- 0.000396027	9037	32342.01
S. galilaeus	5.221626	- 0.000288916	903	23592.82
Hydrocynus **spp.**	2.552008	-0.000484051	2636	3363.67
Lates niloticus	0.2807073	-1.322234	1061	1489.84
Labeo **spp.**	1.297548	- 0.000656976	988	640.67
Bagrus **spp.**	0.2201915	-0.000111074	991	109.13
Clarias **spp.**	0.2113117	- 0.000104679	1009	106.64

a and b are constants.

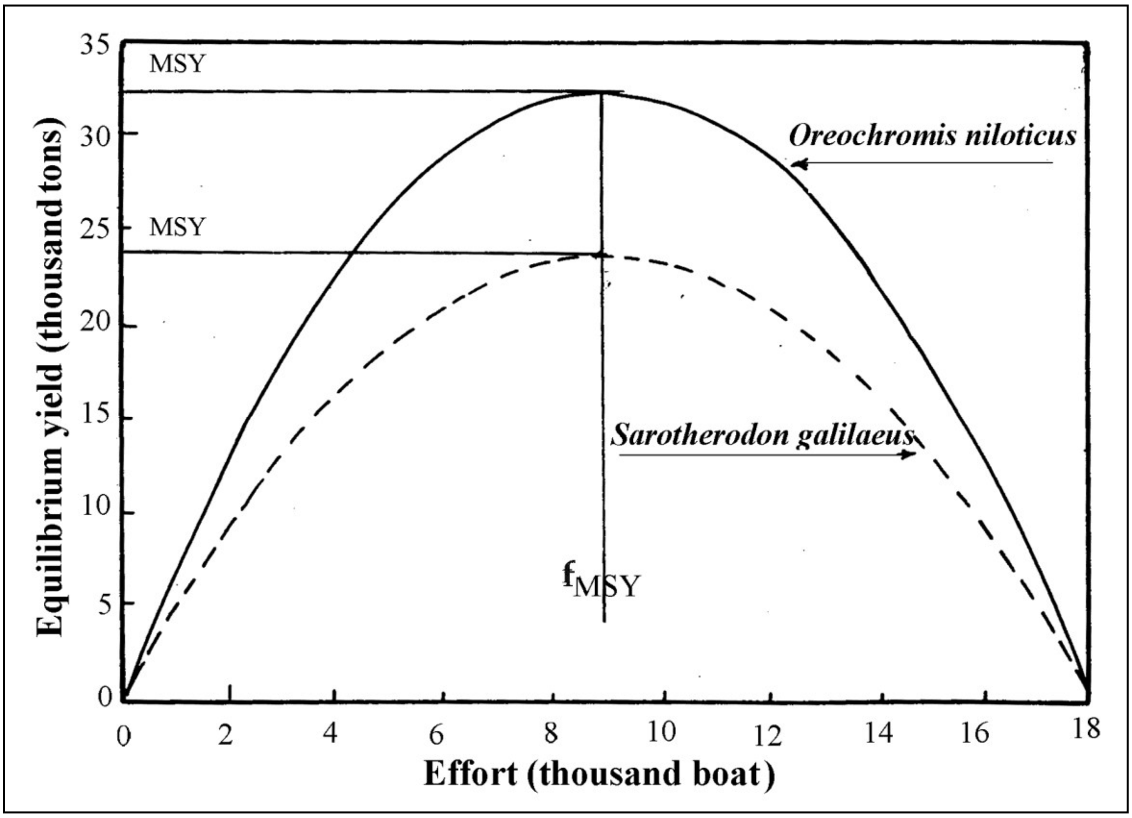


Fig. 224 **Equilibrium yield-effort relationships (Schaefer model) for *O. niloticus* *and S.galilaeus* of Lake Nasser (1973-1992) (Mekkawy 1998).**

Table 159 shows that the MSY for the tilapiines was found to be equal to both MSY for *O. niloticus* and *S. galilaeus.* The total MSY of the Lake was 61,644.78 ton, tilapiines MSY represented 90.74% of it (Table 159). The MSY's of other fish groups were low and reflected the severe condition that controlled their production (Mekkawy 1998).

Proposed modification of Schaefer's Model. One can take Lake area (A) in consideration due to its effect as spawning grounds on the catch. Therefore, Schaefer's Model and MSY can be written in the forms:

$$Y(i)/f_{(i)} * A_{(i)} = a + bf_{(i)}$$

$$MSY = (-0.25\ a^2/b) * A_{(i)}$$

where $A_{(i)}$ is the average Lake area in the six preceding years. In such a model, f_{MSY} is not affected by Lake area. Mekkawy (1998) fitted such a model to 1981- and 1989-total-catch-effort data, taking the effect of lake area (as spawning grounds) on the catch into consideration. The following equations were derived:

$$Y_{(i)}/ f_{(i)} * A_{(i)} = 0.070079269 + - 2.669437\ E\text{-}05 * f_{(i)}$$

$$MSY = 45.993817\ A$$

Accordingly, the total MSY of the Lake with maximum area of 1,250,000 feddans (505868 ha) was estimated to be 57,492.27 ton with f_{MSY} =1313 boats. Since the average tilapia catch of 1991-1992 represented 93.5% of the total catch, the tilapiine MSY can be estimated to be 53,755.27 ton (Mekkawy 1998).

Estimation of maximum sustainable yield (MSY) **using Graham's Model in relation to biomass**

According to Ricker (1975), Mekkawy (1998) fitted a Graham curve from the relation of surplus production to biomass, to catch-effort data of *O. niloticus* and *S. galilaeus* using the formula:

$Y_E/B=k-(k/B_\infty)*B$ ...... (Ricker 1975)

where, Y_E is the yield when the stock is in equilibrium, B is the mean stock biomass. B_∞ is the maximum stock size and k is a constant

The results (Table 160) show that the MSY of the two tilapiine species (54,107.07 ton) was nearly similar to that determined by Schaefer's Model, while f_{MSY} was different. Since the average tilapiine catch of the years 1991-1992 represented 93.5% of the total catch, the total MSY can be estimated to be 57,868.52 ton (Mekkawy 1998).

Table 160 **Results of fitting Graham's curve to catch-effort data of *0. niloticus* and S. *galilaeus* in relation to their biomass (Mekkawy 1998).**

Parameter	*O. niloticus*	*S. galilaeus*
Intercept (K)	1.40544	2.51893
Slope ($-K/B_\infty$)	-1.838254 E-05	-5.822434E-05
Maximum stock size (B_∞)	76455.16	43262.49
Optimum stock size (Bs)	38227.57	21631.25
Maximum sustainable yield (ton)	26863.28	27243.79
Optimum fishing effort (f_{MSY})	937	910
Fishing mortality rate (F)	0.70272	1.259465
Catchability coefficient (q)	7.2188706 E-04	1.3835616 E-03

Estimation of maximum sustainable yield (MSY) using Surplus Production Model

Mekkawy (1998) calculated the catchability coefficient (q) of *0. niloticus* and *S. galilaeus* (Table 160) using the natural death rate (Z) and Silliman's Method (Ricker, 1975). The latter author also calculated the surplus biomass production and consequently the parameters recorded in Table 160. Mekkawy (1998) used the following equation:

$Y_E/\overline{B} = k - (k/B_\infty)\,\overline{B}$ .... Ricker (1975)

where Y_E = surplus production, $\overline{B}$ = mean stock size

B_∞ = maximum stock size, k = constant

Figs. 225 and 226 explain the surplus production / biomass and biomass relationships of *O. niloticus* and *S. galilaeus*.

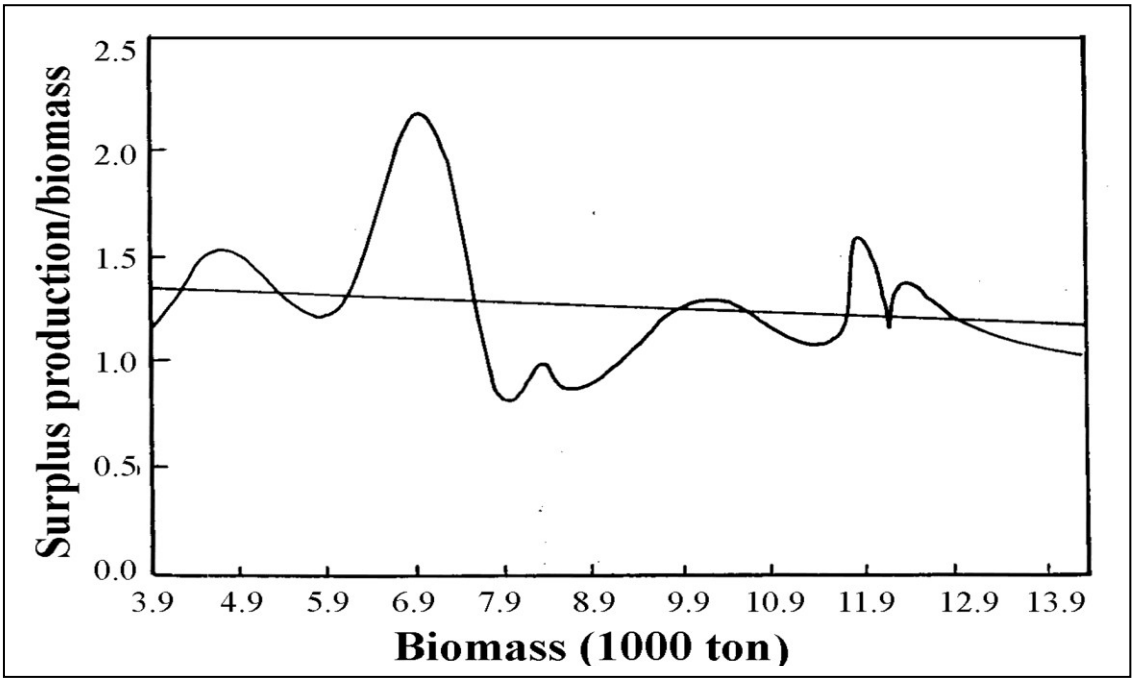


Fig. 225 **Surplus production/biomass-biomass relationship of *Oreochromis niloticus* of LakeNasser (1973-1992) (Mekkawy 1998).**

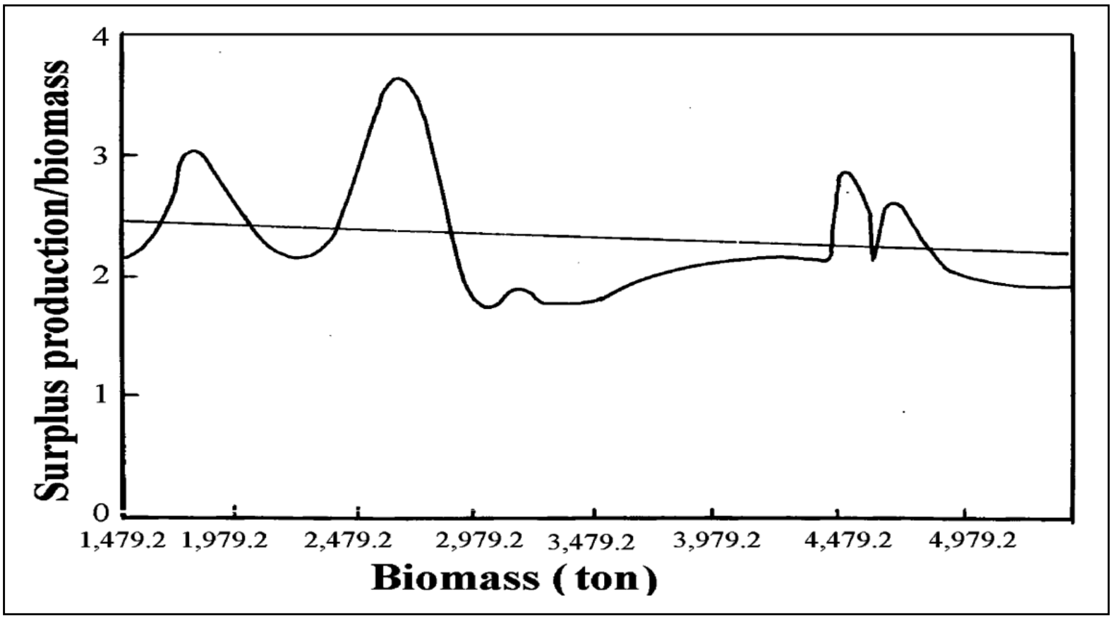


Fig. 226 **Surplus production/biomass-biomass relationship of *Sarotherodon galilaeus* of Lake Nasser (1973-1992) (Mekkawy 1998).**

Estimation of maximum sustainable yield (MSY) using the Generalized Stock Production Model (Fox 1975)

Fox (1975) mentioned that catch-effort data usually do not represent equilibrium conditions. Accordingly, catch-effort data of Lake Nasser were adjusted to approximate these conditions, and hence the Generalized Stock Production Model of Fox (1975) was fitted (Mekkawy 1998). The results of fitting the aforementioned model to catch data of *O. niloticus* and *S. galilaeus* are presented in Table 161 and Figs. 227 and 228. The catchability coefficients of both tilapiine species estimated by the Generalized Stock Production Model are shown in Table 162. MSY was estimated to be 25,336.9; 15,614.1 and 15,347.5 ton for *O. niloticus* and to be 32,970.0; 16,542.7 and 13,657.7 ton for *S. galilaeus* according to Asymptotic, Gompertz and Logistic Models respectively (Mekkawy 1998). The latter author mentioned that except for those estimated by Asymptotic Model, the other MSY's in comparison with the above estimated ones showed considerable variations and were underestimated. Mekkawy (1998) estimated the total MSY of Lake Nasser to be 62,360.32 ton according to the Asymptotic Model considering the average percentage of tilapiine catch during 1991-1992 (93.5%).

Estimation of maximum sustainable yield (MSY) using age-based Thompson & Bell Model

Mekkawy (1998) calculated the yield, value of yield and biomass of *O. niloticus* and *S. galilaeus* by the age based Thompson & Bell Model (Sparre *et al.* 1992). Figs. 229 and 230 show the yield, economic value of the yield and biomass curves of these species. MSY's of *O. niloticus* and S. *galilaeus* were 30,127.64 and 17,692.34 ton at a multiplication factor of 1.7 and 0.48 respectively. This means that the 1979-cohort fishing pattern should be highly increased to obtain MSY of *O. niloticus* and be decreased to achieve MSY of *S. galilaeus.* When the price per kilogram is 2 LE, (the fixed price by the authorities; the market price is not less than 9 L.E/kg) the maximum sustainable economic yield value (MSE) will be 60,254,380 LE and 35,384,670 LE for *O. niloticus* and *S. galilaeus* respectively (Mekkawy 1998 Figs. 229 and 230).

Table 161 **Results of fitting Generalized Stock Production Model (Fox, 1975) to catch data of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser for 1966-1992. (Mekkawy 1998).**

Parameter	*Oreochromis niloticus*			*Sarotherodon galilaeus*		
	M*=			**M*=**		
	0	**1**	**2**	**0**	**1**	**2**
Pre-exploitation catch/effort	16.09	13.07	11.34	7.92	7.53	7.28
Optimum catch/effort		4.81	5.67	--	2.74	3.64
Optimum fishing effort	--	3245	2706	--	6030	3751
Maximum sustainable yield (ton)	25336.9	15614.1	15347.5	32970.0	16542.7	13657.7
By geometric mean						
Virgin population size (ton)	194019	130531	110722	159916	135870	115951
Optimum population size (ton)	--	48043.8	55361.0	--	50008.8	57975.7
By arithmetic mean						
Virgin population size (ton)	79947.5	60636.7	51673.1	75152.5	67596.9	57901.1
Optimum population size (ton)	--	22318.1	25836.5	--	24879.9	28950.5

*** M =0, according to the Asymptotic Yield Model. M =1, according to the Gompertz Model, M =2, according to the Logistic ModeL**

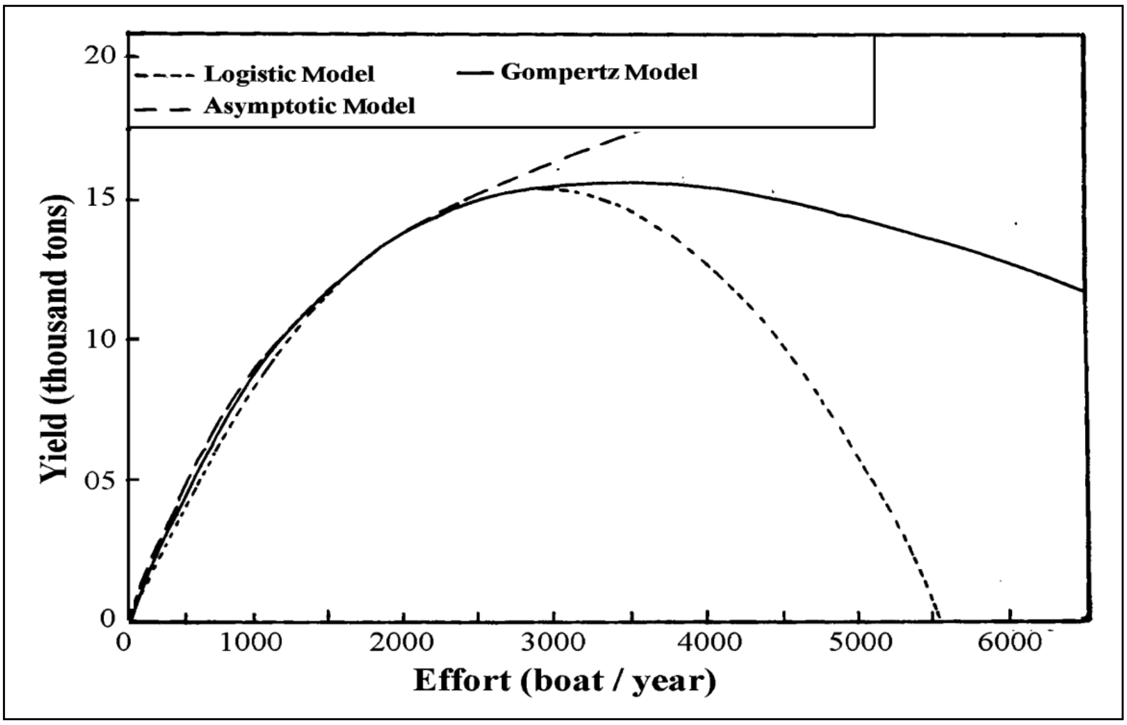


Fig. 227 **Catch-effort data of *Oreochromis niloticus* of Lake Nasser for 1966-1992 fitted to the Generalized Stock Production Model* (Mekkawy 1998).**

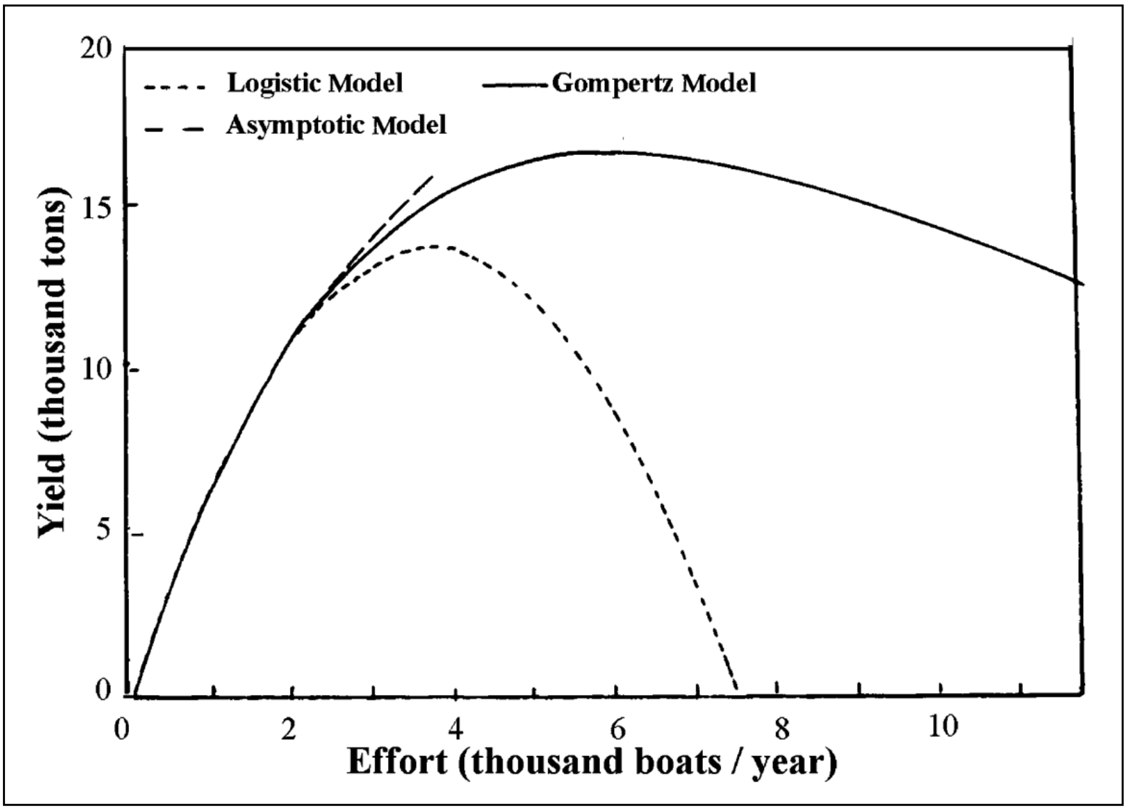


Fig. 228 **Catch-effort data of *Sarotherodon galilaeus* of Lake Nasser for 1966-1992 fitted to the Generalized Stock Production Model* (Mekkawy 1998).**

***(Fox 1975)**

Table 162 **Catchability coefficients of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser estimated by the Generalized Stock Production Model** (Mekkawy 1998).**

Years	Catchability coefficient					
	Oreochromis niloticus			*Sarotherodon galilaeus*		
	M*= 0	M*= 1	M*= 2	M*= 0	M*= 1	M*= 2
1973 & 1974	0.342721E-05	0.578748E-05	0.780571E-05	0.196079E-05	0.322847E-05	0.518372E-05
1974 & 1975	0.259511E-04	0.490654E-04	0.575256E-04	0.146985E-04	0.235925E-04	0.374827E-04
1975 & 1976	0.747395E-04	0.109466E-03	0.136376E-03	0.426454E-04	0.605548E-04	0.876032E-04
1976 & 1977	0.226919E-04	0.298569E-04	0.335309E-04	0.133309E-04	0.171691E-04	0.227856E-04
1977 & 1978	0.435108E-03	0.473898E-03	0.464885E-03	0.297584E-03	0.318066E-303	0.353474E-03
1978 & 1979	0.178489E-03	0.170935E-03	0.104870E-03	0.855421E-04	0.703247E-04	0.442098E-04
1979 & 1980	0.239989E-03	0.200931E-03	0.139865E-03	0.974938E-04	0.803967E-04	0.729503E-04
1980 & 1981	0.244411E-03	0.224022E-03	0.181249E-03	0.134481E-03	0.117625E0303	0.110824E-03
1981 & 1982	0.288206E-04	0.276371E-04	0.239768E-04	0.168248E-04	0.153623E-04	0.150980E-04
1982 & 1983	0.842603E-05	0.807143E-05	0.692804E-05	0.465112E-05	0.423564E-05	0.417849E-05
1983 & 1984	0.119790E-03	0.116328E-03	0.102207E-03	0.662916E-04	0.610731E-04	0.611060E-04
1984 & 1985	0.310136E-03	0.308226E-03	0.267033E-03	0.119256E-03	0.109431E-03	0.113531E-03
1985 & 1986	0.119623E-02	0.117835E-02	0.120476E-02	0.406355E-03	0.392886E-03	0.437950E-03
1986 & 1987	0.218525E-04	0.239755E-04	0.234119E-04	0.139633E-04	0.150766E-04	0.170181E-04
1987 & 1988	0.372923E-04	0.417163E-04	0.413309E-04	0.234248E-04	0.257679E-04	0.296414E-04
1988 & 1989	0.254674E-03	0.342742E-03	0.386160E-03	0.139413E-03	0.178973E-03	0.241897E-03
1989 & 1990	0.187736E-03	0.288424E-03	0.356481E-03	0.943128E-04	0.131544E-03	0.195688E-03
1990 & 1991	0.240750E-04	0.902049E-04	0.202893E-03	0.766035E-04	0.122068E-03	0.180329E-03
1991 & 1992	0.409764E-03	0.413130E-03	0.432860E-03	0.354375E-03	0.347695E-03	0.358573E-03

***M = 0, according to the Asymptotic Yield Model; M=1, according to the Gompertz Model; M=2 according to the Logistic Model.**

**** (Fox 1975).**

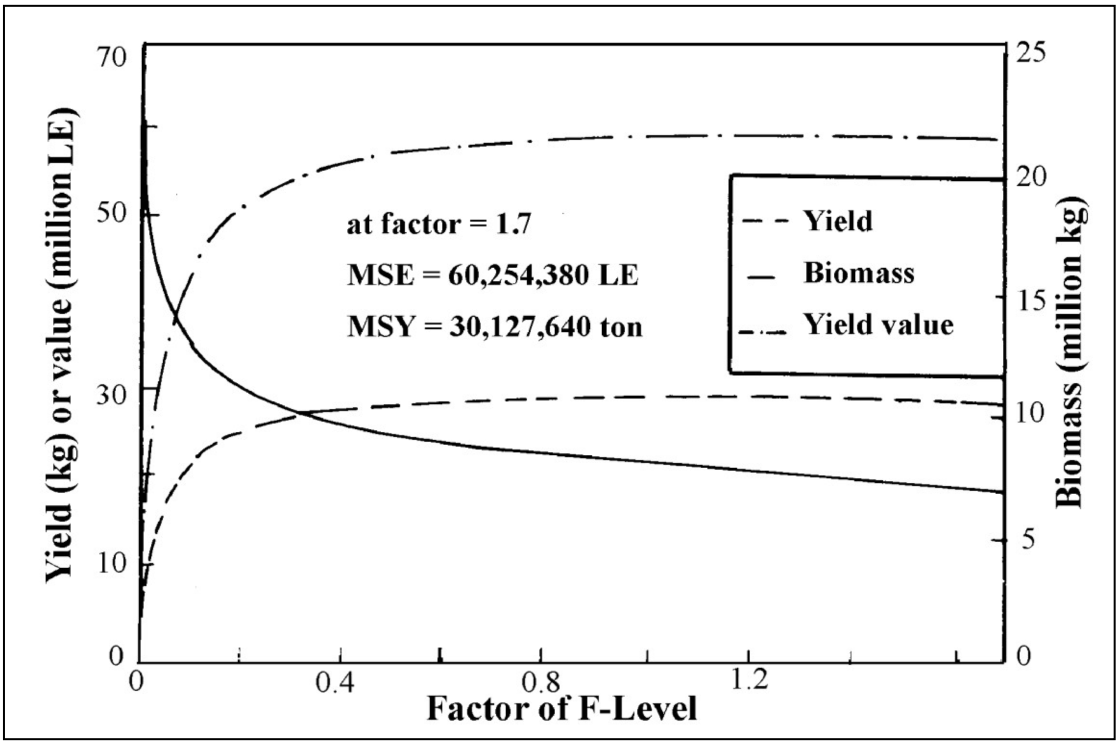


Fig. 229 **Yield, value of yield and biomass of** ***Oreochromis niloticus*** **calculated by the age based Thompson & Bell Model (Sparre** ***et al.*** **1992) (MSY = Maximum Sustainable Yield, MSE = Maximum Sustainable Economic Yield (value) (Mekkawy 1998).**

Table 163. **Maximum Sustainable Yield (MSY) of tilapiine spp.** ***(0. niloticus*** **and** ***S. galilaeus)*** **from Lake Nasser, estimated by Mekkawy (1998) using various methods.**

Method of estimating	MSY of tilapiine spp. (ton)		
MSY	*O. niloticus*	*S. galilaeus*	Total
Schaefer's Model	32,342.01	23,592.82	55,934.83
Proposed modification of: Schaefer's Model	-	-	53.755.27
Graham's Model	26,863.28	27,243.79	54,107.07
Generalized Stock Production Model:			
Asymptotic Yield Model	25,336.9	32,970.0	58,306.9
Gompertz Model	15,614.1	16,542.7	32,156.8
Logistic Model	15,347.5	13,657.7	29,005.2
Age-based Thompson & Bell Model	30,127.64	17,692.34	47,819.98

A comparison between the maximum sustainable yield (MSY) of tilapiine spp. *(O. niloticus* and *S. galilaeus)* from Lake Nasser, estimated by different methods is given in Table 163. The highest MSY of tilapiine spp is 58,306.9 ton and is obtained by using the Generalized Stock Production Model "Asymptotic Yield Model"; while the lowest one (29,005.2 ton) is obtained by using the Logistic Model. It is obvious that the possible maximum sustainable yield of tilapiine spp. from Lake Nasser is around 55,000 ton**.**

ESTIMATION OF FOOD QUANTITIES REQUIRED TO OBTAIN MAXIMUM SUSTAINABLE YIELD (MSY)

Lake Nasser fishes belong to different trophic levels (Latif 1984a, Rashid 1995). *Brycinus nurse, Alestes baremoze, A. dentex, Labeo coubie, L.horie, L.niloticus, L. victorianus* and *Tilapia zillii* are primary consumers feeding on bottom deposits, filamentous algae and higher plants. *Synodontis schall, S. clarias, S. serratus, Mormyrus kannume, M. caschive, Chrysichthys auratus* and *C. rueppelli* are secondary consumers feeding mainly on insect larvae, molluscs and crustaceans. *Hydrocynus forskalii, Bagrus bajad, B. docmak, Schilbe mystus, Schilbe (Eutropius) niloticus* and *Lates niloticus* are tertiary consumers (mainly piscivores). *O. niloticus* and *S. galilaeus* can be identified as bacterial, phytoplankton filter and plankton feeders, these fishes can be considered predator fishes on rotifers, copepods and ostracods. Therefore, we can say that *O. niloticus* and *S. galilaeus* feed at more than one trophic level. In his work, Mekkawy (1998) analyzing the commercial catch, as a function of abundance, refers to the fact that Lake Nasser ecosystem is in favour of those species exhibiting more flexibility in their diets, which may cross trophic level boundaries, viz., *O. niloticus* and *S. galilaeus.* Economically, the dominance and increased abundance of both tilapiine species is considered more suitable because they can use 10% of the available potential energy, the other species of higher trophic levels use only 1% of such energy. A fishery based on herbivorous fish will therefore be more productive than one based mainly on predators.

Mekkawy (1998) mentioned that in later years, the herbivorous *Tilapia zillii* spread in Lake Nasser. Hickling (1961) recorded that *T. zillii* plays a multiple role as a plant feeder by making nutrient material available for plankton or making its faecal masses available for other fishes. The latter author pointed out that the ability of such species to bring back into circulation the plankton nutrients locked up in tissues of water plants has led to successful introduction of that species in Lake Victoria. Further studies on the biology of *T. zillii* and its impacts on Lake Nasser ecosystem should be carried out in the near future. Also, it is required to investigate the trophic level interactions and to determine food requirements for different species inhabiting Lake Nasser.

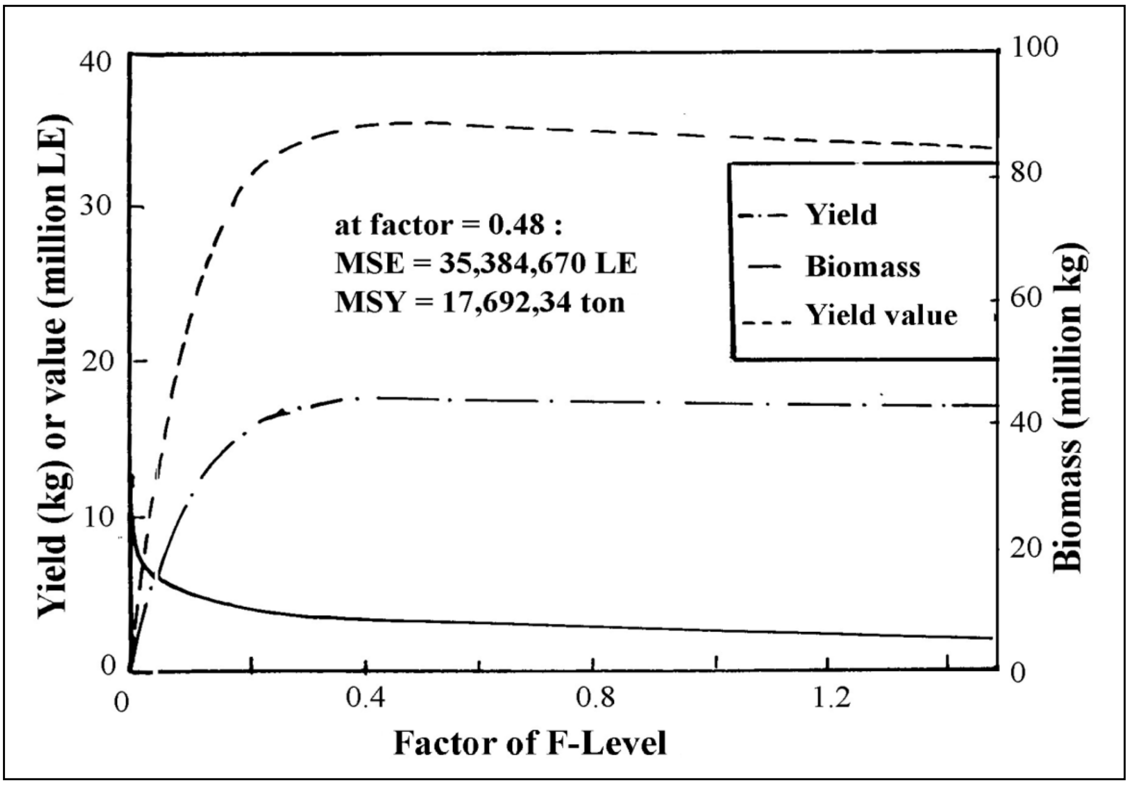


Fig. 230 **Yield, value of yield and biomass of *Sarotherodon galilaeus* calculated by the age based Thompson & Bell Model (Sparre *et al.* 1992) (MSY = Maximum Sustainable Yield, MSE = Maximum Sustainable Economic Yield value) (Mekkawy 1998).**

The relationship between feeding rates and growth has been investigated by several authors including Ivlev (1961) and Winberg (1960) using predator oriented approach. Conover (1978) studied the feeding rate in relation to body size and temperature. According to Ssentongo & Welcomme (1985), Conover's study leads to two main conclusions: an increase in water temperature increases the feeding rate, and small fish require a bigger ration under given conditions than larger fish. Caddy (1983) has examined series of data from Conover (1978) for a range of bottom dwelling fish and established the following relationship:

$$\text{In}\ (r_{T,W}) = 1.841 - 0.286\ \text{In}\ (W) + 0.048T$$

where $(r_{T,W})$is the feeding rate (as a percent of body weight per day), W is the mean body weight in gram and T is the mean water temperature.

Using Caddy's (1983) equation, Ssentongo & Welcomme (1985) determined the food requirements to obtain MSY of *Lates niloticus* in Lake Victoria. Accordingly, such equation can be applied to Lake Nasser fish species and hence their food requirements to obtain the maximum sustainable yield.

Mekkawy (1998) determined the food requirements for *O. niloticus* in Lake Nasser. According to Mekkawy *et al.* (1994), the mean weights (W) of *O. niloticus* caught in trammel nets are 33 ; 290 and 801 g for length groups (standard length) 30-90, 91-200 and 201-450 mm respectively. The mean ambient temperature of Lake Nasser is 22 ºC. Using Caddy's equation, Mekkawy (1998) determined the feeding rates of *O. niloticus* as 6.67, 3.58 and 2.68 % for length groups 30-90, 91-200, 201-450 mm respectively. The latter author determined the total annual food (X) required to obtain the mean MSY of *O. niloticus* (30,000 ton) using Caddy's (1983) estimator.

$$X=365(r_{T,W})B/100$$

where B is the mean biomass which can be derived from the following equation, the generalized version of Gulland's estimator proposed by Cadima (Troadec 1979):

$$MSY=0.5ZB$$

where Z = 1.95, the total mortality of year 1992. B was estimated to be 30,769.23 ton. This value was distributed for the three length groups of *O. niloticus* by percentages derived from Abdel-Azim (199la) and Mekkawy *et al.* (1994). Table 164 shows the annual food required to obtain maximum sustainable yield (30,000 ton) of *O. niloticus* from Lake Nasser.

Table 164 **Annual food (ton) required to obtain the maximum sustainable yield (30,000 ton) of *Oreochromis niloticus* of Lake Nasser according to length groups (based on data by Abdel-Azim (1991a), Mekkawy *et al.* (1994) and Mekkawy (1998).**

Food item	**Length group (standard length) in mm**		
	30-90	**91-200**	**201-450**
Cyanophyta	8373.06	48670.94	101043.82
Chlorophyta	7433.03	33329.01	45632.58
Diatoms	16572.63	46188.20	24907.88
Higher plant tissue	-	1689.19	7004.40
Plant detritus	473.44	3434.07	2395.18
Animal detritus	29.22	232.03	778.27
Copepoda	-	-	3478.72
Cladocera	-	412.55	975.18
Rotifera	200.88	1213.99	108.69
Inorganic particles	27.39	83.53	100.64
Total (ton)	**33,109.65**	**135,253.51**	**186,425.36**
Fish biomass (ton)	1359.99	10350.77	19058.46
%	4.42	33.64	61.94
Fish abundance (No.)	41,846,154	35,692,308	23,793,335
%	41.30	35.22	23.48
Average weight (g)*	33	290	801
Total length (mm)	50-130	131-260	261-570
Feeding rate (%)	6.67	3.58	2.68

***As previously mentioned (pp 257 & 258) the average weights given by Mekkawy *et al.*, (1994) are much lower than the actual weights recorded during recent years.**

CONCLUSIONS

Assessment of Lake Nasser fisheries is required for better development and management of the resources on which the fishery is based. This requires a certain preliminary assessment of the level of exploitation of the fishery relative to its potential. Furthermore, details of the biological and ecological constraints to the resource are needed for the effective management and monitoring.

Lake Nasser is almost lacustrine except in its southernmost part (about 50 km in length), which has riverine characteristics during the flood season. The number of important khors in Lake Nasser is 85, of which 48 are located on the eastern side and 37 on the western side. Lake Nasser is eutrophic in some areas (khors), while it is mesotrophic to oligotrophic in other parts (main channel, which constitutes 80% of the total area of the Lake proper).

As a matter of fact, remarkable changes both in environment and fishery have been occurring in Lake Nasser since the construction of the High Dam. The knowledge of all the changes in surface area and volume of water in the khors at different water levels is very important for fish stock assessment and fishery development. The length of the shoreline and its slope are important factors for the development of periphyton and littoral fauna, the main food of *Tilapia* species, as well as the littoral areas provide tilapias with suitable breeding and nursery grounds.

Unfortunately, there is a lack of adequate knowledge on the present fish stocks, under the changing environmental conditions. Lake Nasser was originally a multispecies fishery during the first period of impoundment (1966-1975). Fifty six fish species belonging to 15 families were recorded. The most common open water species were *Alestes* spp., *Hydrocynus forskalii* and *Schilbe niloticus. Sarotherodon galilaeus, Oreochromis niloticus, Brycinus nurse, Hydrocynus forskalii* and *Lates niloticus* were abundant in inshore waters. At present, fish stocks are dominated by S. *galilaeus* and *O. niloticus.* The remaining fish species have either declined to insignificant levels or are almost in their way to disappear from the Lake. There has been no continuous information on the fish stocks in offshore and inshore waters of the Lake. Recently, Mekkawy (1998) carried out a study on fish stock assessment of Lake Nasser, with emphasis on those of *O. niloticus* and *S. galilaeus.*

Fishes are usually landed either fresh or salted. The predominant marketable fresh fishes are *S. galilaeus, O. niloticus, Lates niloticus, Labeo* spp., *Bagrus* spp. and *Synodontis* spp., while the salted fishes are mostly *Hydrocynus forskalii, Alestes* spp. and *Schilbe (Eutropius) niloticus.* The salted fish composed a high percentage of the total landed fish, with an average of 51.8% during 1966-1968. Then they decreased progressively to an average of 32.7% during 1969-1978, and to about 10.3% during 1979-1998.

Commercial fishes are classified according to their feeding habits into:

a- Periphyton-plankton feeders *(S. galilaeus* and *O. niloticus)*

b- Zooplankton-insect feeders *(Alestes* spp.)

c- Omnivorous fish, feeding mostly from the bottom and or between stones *(Barbus* sp., *Labeo* spp., synodontids, schilbeids and mormyrids).

d- Carnivorous fish (*Bagrus* spp., *Lates niloticus, Hydrocynus* spp., *Clarias* spp. and *Heterobranchus* spp).

The composition of fish landings is in favour of periphyton plankton feeders being about 90-93% of the total landings by weight during recent years.

The evolution and trends of the total fish catch and the catches of different fish groups in the percentage of the total fish catch during 1966-1996 are presented.

The total fish catch per month in spring is almost twice that in summer in both northern and southern regions of the Lake. However, in spring the total catch of the southern region reached about 1.5 times that of the northern region of the Lake.

Certain correlations between the catch of the major fish group *(Tilapia* spp.) and those of other fish groups in Lake Nasser are calculated. The intercorrelation matrix of the annual catch of different fish species is presented.

The significance trend analysis parameters of different fish groups catch through 1966-1994 and the trend analysis parameters of the catch of different khors fishing groups through August and December of 1988-1992 are calculated.

Tilapia species production may affect the production of other fish species. Thus, the catch of *Hydrocynus forskalii* and *Lates niloticus* may be affected by *Tilapia* species catch when it is more than 15,000 ton of annual catch, leading to a decrease in the annual production of the former two species. The catch of *Labeo* species and *Bagrus* species show a decrease, when *Tilapia* species catch is more than 10,000 and 5,000 ton respectively.

Highest fish yields were recorded in the southern region of the Lake, particularly close to Allaqi, Korosko and Tushka, where higher mean annual values of chlorophyll *a* and zooplankton were recorded. This phenomenon suggests the possibility of developing active fisheries in the southern region of Lake Nasser.

The fish species composition of experimental catches, using floating and sinking gill nets, is presented.

Tilapia spp. catch correlated significantly with water level during preceding years (from two to six years before the catch). There was no correlation between *Tilapia* spp. catch and the catch effort. The total catch of fishes from Lake Nasser correlated with previous water levels from two to six years, and this reflected the trend in case of *Tilapia* spp. catches, the major commercial species in the Lake.

The number of fishing boats used in Lake Nasser began with 200 in 1966, and gradually increased to 1700 in 1978, while from 1979 to 1989 it gradually decreased from 1613 to 1175. Then the number of fishing boats was stable (about 1900) during the period from 1990 to 1991 and increased to 2200 since 1994.

A relationship exists between the total annual fish production of the Lake and water level, which shows remarkable fluctuations from year to year. In 1966, the total landings was 751 ton, increased to 16,000 ton in 1976 due to the increase of water level and number of fishing boats. During 1976-1981, when the mean water level attained about 174 m, and the fishing effort was constant (1600 fishing boat), the total catch increased to 34,000 ton in 1981. The water level was relatively high and so very suitable for tilapia production. An exceptional negative correlation between water level and tilapiine catch, which represents about 90 % of the total fish catch was noticed during 1991 - 1999. Thus, tha mean water level increased progressively from 165.79 m in 1991 to 178.92 m in 1999, while simultaneously tilapiine catch decreased sharply from 29,383 ton in 1991 to 8606 ton in 1999. This is mainly attributed to that, a large portion of the catch is sold illegally in the black market with high prices, and hence not recorded in the official catches which do not represent the true tilapiine production from the Lake. Generally, the fish production in Lake Nasser is affected by many factors including prohibiting of fishing from 15th March to 15th May, which was enforced since 1990.

The relations between the catches (i.e. total, *Tilapia, Hydrocynus, Lates* and *Bagrus* spp.) and water level and effort are calculated by using multiple linear regression. The obtained picture makes it possible to predict the possible catch if knowing the water level and catch effort. Not all fish species are equally affected with water level or catch effort. Some of them are affected in some years with water level. In Lake Nasser *Tilapia* spp. are mostly affected with the fluctuations of water level, and this is reflected on the size of the total catch.

The monthly catch of both tilapiine species exhibited two or three major peaks. Also, the monthly variations of gonad index of *O. niloticus* and *S. galilaeus* show two major peaks. However, the catch peaks do not coincide with those of gonad index.

The fishing gears and nets used in Lake Nasser are: floating gill-nets, trammel nets, sunken gill nets, beach seines and long-line. Mesh selectivities of trammel net for *O. niloticus* and *S. galilaeus* were determined experimentally.

The effort-biomass relationships for *O. niloticus* and *S. galilaeus* were described. Fishing cannot be considered the only factor that controls biomass. Fishing represents only 33 and 44% of the total effect for *O. niloticus* and *S. galilaeus* respectively.

Virtual Population Analysis (VPA) looks at the populations of *0. niloticus* and *S. galilaeus* in a historic perspective. The trend of increase in the yield, abundance and biomass per hectare are presented. The fish productions of both tilapiine species were determined. The ratio of production to biomass (turnover ratio) was relatively high in the first years of Lake impoundment. The Lake yield of tilapiines was lower than the biomass during 1966-1991, which means that their fisheries did not experience difficulties due to the increasing effort. However, in 1992, the biomass of both species slightly differed from the yield, which means the start of such difficulties. Hence, the fisheries of tilapiine species should be carefully monitored because higher fishing efforts together with a further series of droughts could bring ruin to these fisheries.

Trawl selection curves derived from VPA of *O. niloticus* and *S. galilaeus* as a function of body length are presented.

There are different growth patterns of *O. niloticus* and *S. galilaeus* during the period 1970-1990. Generally, the maximum length estimated for the two tilapiine species exhibited a decrease trend with the progression of years. Other population characteristics of *0. niloticus, S. galilaeus* and *L. niloticus* are presented.

The survivorship curves of 1979-cohorts of the two tilapiine species exhibited two different curves. According to Krebs (1985), type I curve represents populations with very little loss for most of the life span and then high losses of older organisms, whereas type II curve implies a constant rate of mortality independent of age. The survivorship curve of *0. niloticus* occupies an intermediate position between type I and type II curves of Krebs (1985), while that of *S. galilaeus* was close to type I curve.

Higher values of catch per unit effort, CPUE (more than 2 ton/boat/ month) are recorded from the fishing grounds located in the southern region of the Lake. The average value of CPUE in the southern region (i.e. 1.61 ton/boat/month) is about 1.45 times that of the northern region of the Lake (i.e. 1.11 ton / boat / month). The variation of CPUE for five successive years (1988 - 1992) shows remarkable annual and monthly changes in the CPUE for fishing grounds, where high catches are recorded. Generally, there is a decrease in the average CPUE in the northern as well as the southern fishing grounds. However, it seems that the southern fishing grounds are still higher in the density of fish than the northern fishing grounds.

The average CPUE during 1966 -1996 showed that it was less than one ton/boat/month during 1966 -1977, then fluctuated between about one to two ton/boat/month during 1978 - 1992. Maximum CPUE was attained in 1981 (1.90 ton / boat / month), followed by a decline to an average of 0.88 ton / boat/ month during 1993 -1997, and reached 0.64 ton/boat/month in 1999. It is worth mentioining that during the last 10 years, a part of the commercial catch was sold in the black market illegally with high prices. This leads to a drop in the figures of CPUE.

The CPUE-effort relationships of *O. niloticus* and *S. galilaeus* are presented. The general trends of the relationships with respect to the total catch and tilapiine catch were directed towards increase with time throughout 1966-1992. However, excluding the increased CPUE data of the initial years of Lake formation (1966-1972), CPUE decreased with the increased effort. The CPUE-effort relationships of *Hydrocynus, Lates, Labeo, Bagrus* and *Clarias* spp. showed decreased trends in spite of the variable fluctuation throughout 1966-1992. These trends were due to the continuous decline in their catch. Thus in recent years the caches of *Bagrus* and *Clarias* spp. were insignificant hence not recorded in the actual annual Lake prodcuction.

The yearly recruits (R) of *O. niloticus* and *S. galilaeus* using Virtual Population Analysis (VPA) for 1966-1992 are presented and the trends of recruitment variations with time (Y) are described. The relationships between recruits of tilapiine species considered and water levels of the preceding year (WL1) are presented. The water level of the preceding year affects the recruits of *O. niloticus* and *S. galilaeus* by 49.88 and 57.78%, whereas the other factors control them by 50.12 and 42.22% respectively. Such water-level low effects were emphasized by the correspondence of high recruits with low values of water level. In some years, there was a decline in recruits in spite of high water level. Accordingly, the relatively high significant R-WL1 correlations of the two tilapiine species could not be reflected by their catch-WLl relationship.

The pattern of variations in egg production/recruitment (E/R) and mature stock / recruitment (S/R) of *0. niloticus* and *S. galilaeus* of Lake Nasser in 1966-1992 period with two assumptions for age groups of the spawning stock shared are presented. Beverton & Holt's (1957) S/R model was fitted to stock-recruitment data of *O. niloticus* and *S. galilaeus* and the estimates of its parameters are given.

Lake Nasser has passed over three successive trophic states :

1- Mesohumic-mesotrophic with a fish production ranging from 15 to 30 kg/ha/yr during 1968-1971.

2- Mesotrophic-eutrophic (i.e. fish production 30-60 kg/ha/yr) during 1972-1977.

3- Eutrophic (i.e. > 60 kg/ha/yr) during 1978-1998.

Therefore, during 1968-1996, Lake Nasser has gradually changed over from the mesohumic-mesotrophic state to the highly eutrophic one, if compared with the other man-made lakes of Africa as Lake Kariba (30-57 kg/ha/yr) or Lake Volta (43.4 kg/ha/yr).

It is worth mentioning that in 1997, 1998 and 1999 there was a sharp drop in the estimated fish yield which reached 44.08, 40.11 and 28.28 kg/ha/yr respectively. This is mainly attributed to that, a large potrion of the catch is sold in the black market with high prices, and hence not recorded in the official catches. The low figures of estimated fish yield in 1997, 1998 and 1999 do not represent the actual yield.

On the basis of the Morphoedaphic Index (MEI), several estimations of potential annual yield of Lake Nasser fisheries have been made. The MEI-based models reflect only one of the aspects produced by the variable ecological, environmental and fishery factors. Their validity for application is limited by their continuous updating. Therefore, administrators and fishery managers usually seek other models to obtain more precise predictions and to make definitive plans for the future.

A regression model for predicting tilapia catch from the water level and length of shoreline of the Lake was introduced. The shoreline length at 3 years before (L_{t-3}) was selected as one of the explanatory variables.

Fish production from Lake Nasser was estimated also from the primary net production of phytoplankton.

The maximum sustainable yield (MSY) was estimated by using different methods :

The MSY for *O. niloticus, S. galilaeus* and L. *niloticus* during 1966-1992 were roughly estimated according to Cadima's estimator. However, these yearly variable MSY's values are overestimated since they are influenced only by yearly catch and total mortality and not by long-term data.

The yield per recruit (Y/R) with varying inputs of age at first capture (Tc) and fishing mortality (F) were calculated. Also, the biomass per recruit

(B/R) and relative Y/R models were used in estimating MSY/R and relative MSY/R´ for different values of Tc. The MSY/R of both *O. niloticus* and *S. galilaeus* increases with the increase of age at first capture (Tc). The recruits required to obtain MSY of F_{MSY} (30,000 ton) are 647,948,164 and 518,134,715 for Tc = 1 and 3 respectively. The environmental and biological conditions of the Lake should be controlled to multiply the current recruits of *O. niloticus*, at least by a factor of 9-11 for MSY at Tc = 1-3, those of *S. galilaeus* should be multiplied by at least a factor of 5-6 for MSY (17,000 ton) at Tc = 1-3.

S. galilaeus , which has a slow-growing nature and caught early in life, has a lot of potential weight to put on and this brings about a maximum yield at low fishing rates. Such low rates allow fish to escape the gear and therefore realize some of their growth potential. On the other hand, *O. niloticus* takes its way towards fast-growing and producing Y/R-curve of the plateau type even at lower rates of Tc.

Catch-effort data of khors in 1988-1994 were fitted to Schaefer's Model, and the MSY per month per fishing area were estimated. Subsequently, the total MSY of the Lake was found to be 59,742.24 ton. The total-catch-effort data of 1973-1992 were fitted to the hyperbolic model, and the calculated MSY was 55,616.69 ton. The holistic model of Schaefer (1954) was applied to the CPUE of 1973-1992 for tilapiines and of 1966-1992 for the other group of fishes. The total MSY was 61,644.78 ton, and tilapiines represented 90.74% of it. The MSY of other fish groups was low and reflected the severe conditions that control their production. Taking Lake area (A) in consideration, due to its effect as spawning grounds on the catch, a proposed modification of Schaefer's Model was fitted to 1981-and 1989-total catch-effort. The total MSY of the Lake with a maximum area of 1,250,000 feddan (505868 ha) was estimated to be 57,492.27 ton with f_{MSY} =1313 boat, and the tilapiine MSY was estimated to be 53,755.27 ton.

A Graham curve from the relation of surplus production to biomass was fitted to catch-effort data of *O. niloticus* and *S. galilaeus.* The MSY of the two tilapiine species (54,107.07 ton) was nearly similar to that determined by Schaefer's Model, while f_{MSY} was different. The total MSY was estimated to be 57,868.52 ton.

The surplus production/biomass and biomass relationship was used in calculating the maximum sustainable yield, which was 26,863.28 ton for *O. niloticus* and 27,243.79 ton for *S. galilaeus.*

The Generalized Stock Production Model of Fox (1975) was fitted to catch-effort data of *O. niloticus* and *S. galilaeus* of Lake Nasser for 1966-1992. The MSY was estimated to be 25,336.9, 15,614.1 and 15,347.5 ton for *O. niloticus* and

32,970.0; 16,542.7 and 13,657.7 ton for *S. galilaeus* according to the Asymptotic, Gompertz and Logistic Models respectively. Except for those estimated by the Asymptotic Model, the other MSY's in comparison with the above estimated ones showed considerable variations and were underestimated. The total MSY of Lake Nasser was estimated to be 62,360.32 ton according to the Asymptotic Model, considering the average percentage of tilapiine species (93.5%) of 1991-1992.

The yield, value of yield and biomass of *O. niloticus* and *S. galilaeus* were calculated using the age-based Thompson & Bell Model. The MSY's of *0. niloticus* and *S. galilaeus* were 30,127.64 and 17,692.34 ton respectively. When the price per kilogram is 2 LE (the fixed price by the authorities), the actual price in the market is not less than 9 LE/kg), the maximum sustainable economic yield value (MSE) will be 60,254,380 LE and 35,384,670 LE for *O. niloticus* and *S. galilaeus* respectively.

The food quantities required to obtain the MSY were estimated. *O. niloticus* and *S. galilaeus* can be identified as bacterial, phytoplankton filter and plankton feeders; also these fishes can be considered predator fishes on rotifers, copepods and ostracods. In other words, these species feed at more than one trophic level. It is obvious that Lake Nasser ecosystem is in favour of those species exhibiting more flexibility in their diets, which may cross trophic level boundaries, viz., *O. niloticus* and *S. galilaeus.*

In recent years, the herbivorous *Tilapia zillii* spread in Lake Nasser. *T. zillii* plays a multiple role as a plant feeder by making nutrient material available for plankton or making its faecal masses available for other fishes. Further studies on the biology of *T. zillii* and its impact on Lake Nasser ecosystem should be carried out in the near future. Also, it is required to investigate the trophic level interactions and to determine food requirements for different fish species inhabiting Lake Nasser. Caddy's (1983) equation shows the feeding rate in relation to body size and temperature.

The total annual food (ton) required to obtain the mean maximum sustainable yield (i.e. 30,000 ton) of *O. niloticus* was estimated using Caddy's (1983) estimator.