*Afr. J. Trop. Hydrobiol. Fish. (1998) 8: 36-44*

# Growth, mortality and recruitment of Nile tilapia *(Oreochromis niloticus)* (L.) (Cichlidae) in Lake Turkana (Kenya): Possible variations as assessed by length frequency analysis

C.O. RABUOR*, J. MOREAU**, AND J.O. MANYALA***

* *Kenya Marine and Fisheries Research Institute*
*Sangoro Research Centre*
*P.O.Box 136, PAP-ONDITI, Via Ahero - Kenya*

** *Department of Inland Fisheries,*
*INPT/ENSAT*
*145 Avenue de muret 31076 TOULOUSE. France*

*** *Kenya Marine and Fisheries Research Institute*
*Turkana Research Centre*
*P.O.Box 205 LODWAR - Kenya.*

**ABSTRACT**

Estimates of growth, mortality and recruitment pattern of Nile tilapia *(Oreochromis niloticus)* from Lake Turkana were obtained from two sets of length frequency distributions: one from HOPAON (1982) obtained in 1974 from littoral beach seining and a recent one obtained from multi-mesh size gillnet fished from April 1989 to November 1991. Data analysis was performed with the FISAT (FAO ICLARM Stock Assessment Tool, version 1.0) software. Values of $L\infty$ = 40 and 59.5 (cm TL), and K = 0.250 and 0.325 $yr^{-1}$; and the ratio of total mortality rate to the growth constant (Z/K) of 2.72 $yr^{-1}$ 5.11 $y^{r-1}$ were obtained respectively with a clear seasonal growth pattern. The total mortality estimates from the catch curve analysis were Z = 0.96 and 1.59 $yr^{-1}$ respectively with a natural mortality (M) of about 0.65 $yr^{-1}$ for a mean environmental temperature (T) of 27°C. The highest peak for recruitment was from June to September indicating recruitment of one cohort per year. The growth performance index (Ø) = Log10 + 2 Log10 $L\infty$ = 2.57 and 2.87 for the two sets of data respectively. These results are discussed and compared to available information on growth performance index for *Oreochromis niloticus* in other large African lakes.

## INTRODUCTION

### Lake Turkana and its Fisheries

The Kenyan portion of Lake Turkana is the most important one as only 2% of the lake belongs to Ethiopia (Fig 1). It comprises (7,730 $km^2$) of the entire lake. Lake Turkana lies between 2° 25' and 4° 35' North of the equator. It has an average depth of 29.7 m, elevated 73 m above the sea level. The maximum depth is about 73 m and the shoreline is about 920 km with some flat sandy beaches (WELCOMME 1972). The Kenya multi-species fishery of Lake Turkana is dominated by *Lates* species (70%): other minor predators (10%) and various benthic fishes (15%). Tilapiines mainly *Oreochromis niloticus, Sarotherodon galileus* and *Tilapia zillii* contributed about 5% (KOLDING, 1983; Kenyan Department of Fisheries pers.com) of the total landing.

*Oreochromis niloticus* (Linnaeus) pisces: Cichlidae is widely distributed within African lakes. It is indigenous in Lake George, Edward and Albert. It was introduced in Lake Victoria in the nineteen fifties and sixties (ODERO 1979) and in Lake Turkana about the same period. Information on the biology of *Oreochromis niloticus* in Lake Turkana is given by Worthing and Ricardo (1936); LOWE-McCONNELL (1953,1958); HARBOTT (1976,1982); HARBOTT and OGARI (1982); STEWART (1988) and KOLDING (1993).

Length frequency analysis on Nile tilapia specimens of Lake Turkana were performed by MOREAU *et al.* (1994) from samples collected by HOPSON (1982) which clearly showed the progression of some modes in the length frequency distributions. The aim of this work was to compare the demographical situation of the stock of Nile Tilapia in Lake Turkana in two different periods and to assess possible recent changes.

## MATERIALS AND METHODS

### Sampling Methodology

Length-frequency data for Nile Tilapia were obtained from the previous routine survey programme conducted on a monthly basis during the O.D.A. Project on Lake Turkarna Fisheries from March to December 1974 (HOPSON, 1982); (Fig.6a). Another set of data from multimesh gillnet samples were collected from April 1989 to December 1991. Total length (cm TL) measurements for the samples were grouped into 1 cm length groups ranging from 2 to 28 cm in 1974 and into 2 cm length groups ranging from 11 to 46 cm in 1989 to 1991. It has to be realised that this difference of size range might induce differences in the results obtained.

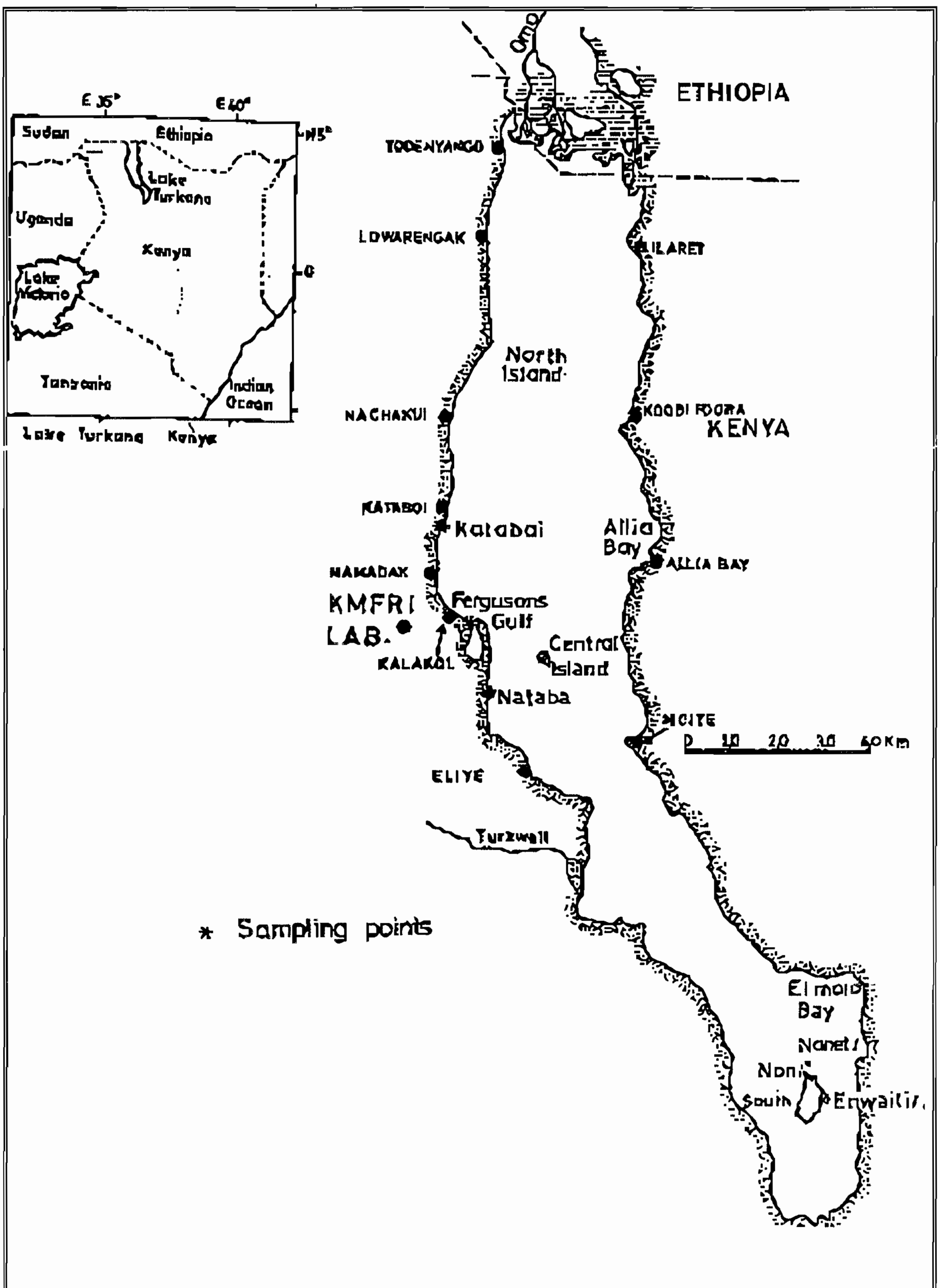



Fig. 1 Lake Turkana (Kenya) showing the position of KMFRI Field Laboratory and the sampling points.

**Data analysis**

The FAO-ICLARM Stock Assessment Tool (FISAT) Software (GAYANILO *et al.,* 1994) was utilized. The following operations were performed: To create and modify the length-frequency data for use with the program, the samples collected from 1989 to 1991 had to be merged into a single file thus constituting a single "artificial year" (Fig.6b).

**Estimation of Growth Parameters**

The estimation of the growth parameters were based on the Von Bertalanffy Growth Formula (VBGF) expressed in the form: $L_t = L\infty (1\text{-}exp(-K^*(t-t_0)))$ ..........................................................................................(1) (PAULY and GASCHUTZ, 1979)

Where:

- $L_t$ is the predicted length at age t.
- L∞ is the asymptotic length, or the mean length the fish of a given stock would reach if they were to grow forever.
- K is a growth constant, also called "Stress factors" by Pauly (1980)
- $T_0$ is the age the fish would have been at zero length predicted by the equation.

Given the sets of data and the ecological conditions of the lake, seasonality could be taken into account by using the VBGF as modified by (SOMERS, (1988), which incorporates two more parameters:

- C the value of which is between 0 and 1 and indicates the magnitude of the seasonal growth patterns.
- WP the time of the year during which growth rate is minimum. In Lake Turkana, this is usually between December and February (HOPSON, 1982).

It should be noted that FISAT has a routine which allows to improve the quality of the estimates of L∞ and K by taking into account the possible selectivity of sampling techniques towards small fishes (PAULY 1980; 1984). Preliminary trials were performed which showed that this procedure was not relevant because of the very small sizes of the smallest fish recorded in the samples.

**Estimation of Mortality rates**

To obtain an estimate of the instantaneous total mortality coefficient for definite range of sizes/ages, a length converted catch curve analysis (PAULY 1980,1983, and 1984) was performed. In order to compute the natural mortality coefficient (M) PAULY (1981)

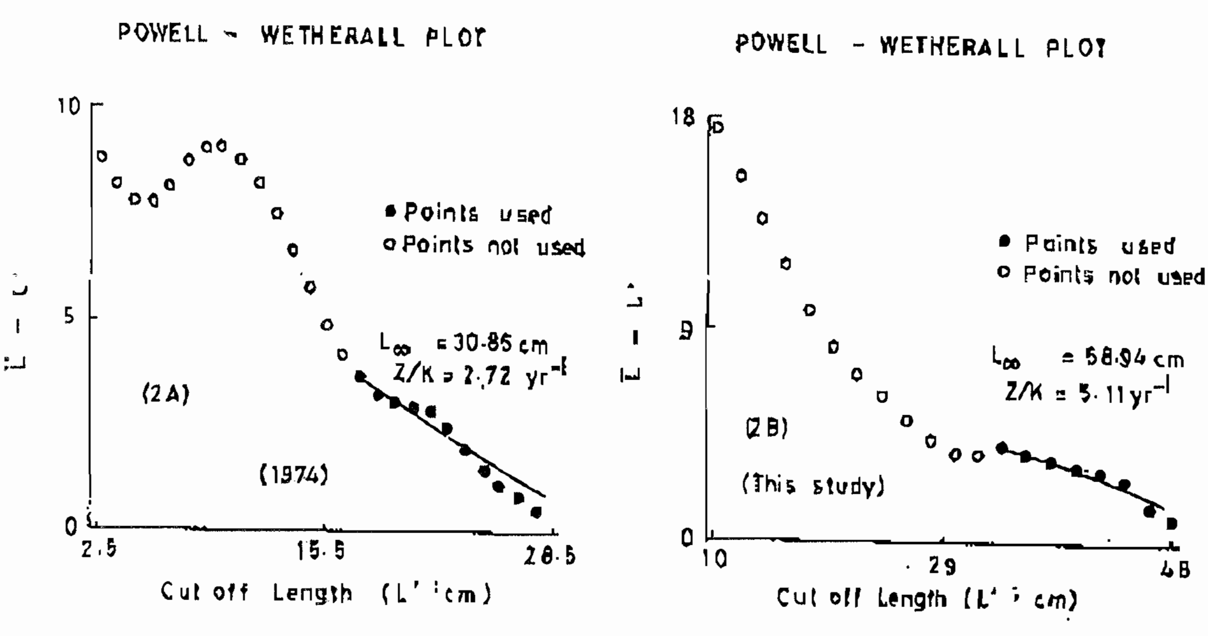



Fig. 2A, 2B: Preliminary estimates of L∞, Z/K as obtained by the method of Wetherall (1986) and modified by Pauly (1986) for *Oreochromis niloticus* in L. Turkana.

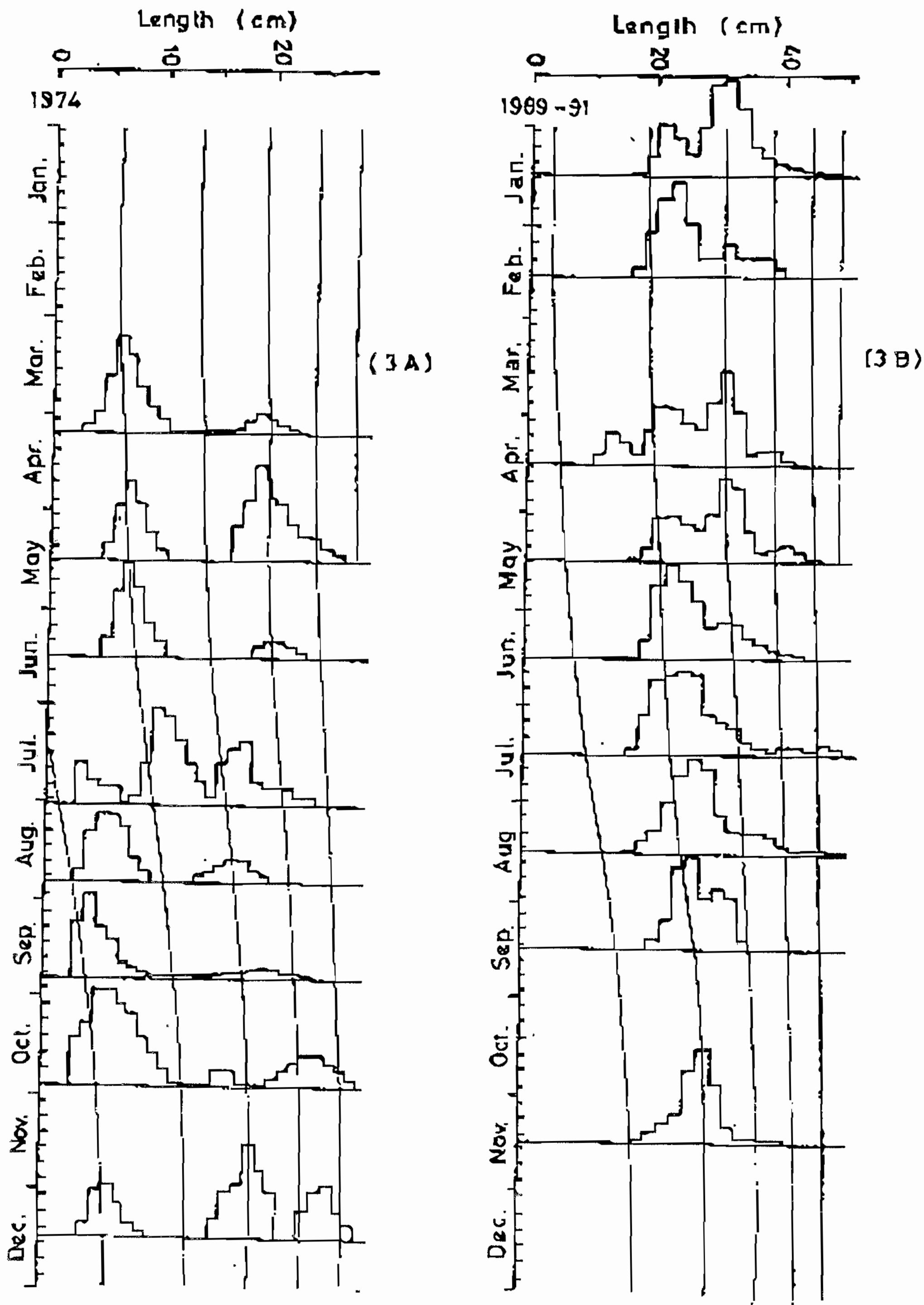



Fig. 3A, 3B : Direct fit of length at age using length - frequency distributions of *Oreochromis niloticus* in L. Turkana for 1974 (Hopson) and 1989 (This study).

(Paramteres : $L_{\infty}$ = 59. 59 cm, K = 0.325 yr$^{-1}$)
$L_{\infty}$ = 40.00 cm, K = 0.250 yr$^{-1}$)

developed a predictive formula using the multiple regression indicated below:

$$\log_{10}M = -0.0152 - \log_{10}L_\infty + 0.65431\ \log_{10}K + 0.4631\ \log_{10}T°C \quad (2)$$

This formula as used to obtain the estimate of (M), given $L_\infty$ (already given) K and T (the mean environmental temperature °C), Once (Z) and (M) were obtained, the fishing mortality (F) could be derived from the relationship:

$$Z = F + M;\ F = Z - M \quad (3)$$

and the exploitation rate (E) obtained by the relationship:

$$E = F/Z = F/(F+M) \quad (4)$$

**Recruitment Pattern**

Seasonal changes in recruitment were displayed in the graphical form of a recruitment pattern suggestive of the recruitment season. Growth parameter estimates $L_\infty$, K, C and $L_t$ were used as inputs in this analysis in application of the relevant program in FISAT.

Note that FISAT has a routine which has been used to get a preliminary estimate of $L_\infty$ and of the ratio (Z/K) using the method of WETHERALL (1986) as modified by PAULY (1986).

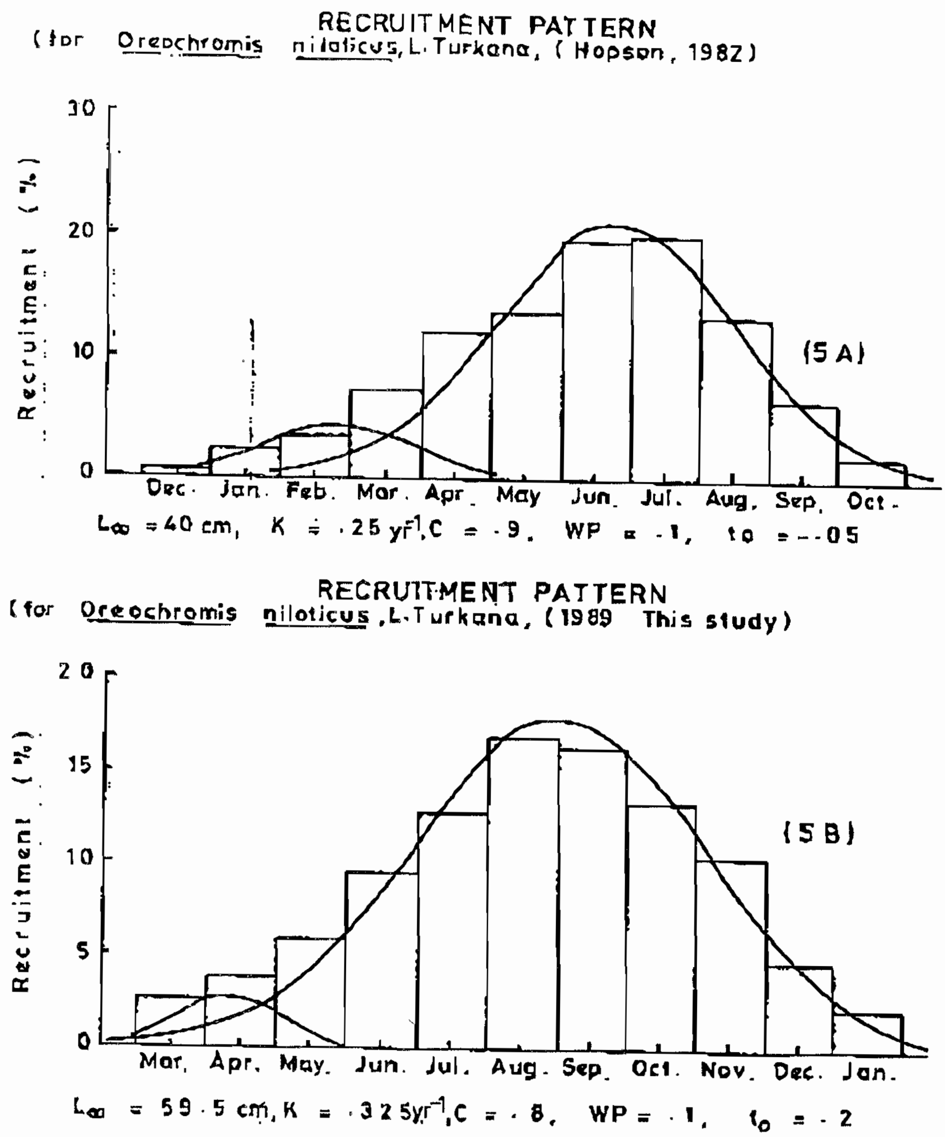



Fig. 5A, 5B: Recruitment pattern for Oreochromis niloticus in Lake Turkana (Inputs are growth parameters estimated in this study)

### The Growth Performance Index (Ø)

To allow comparisons with other populations of the same species, the growth performance index (o) for Nile tilapia was computed using the expression suggested by PAULY and MUNRO (1986):

$Ø = \log_{10}K + 2^* \log_{10} L\infty$ ........................................(5)

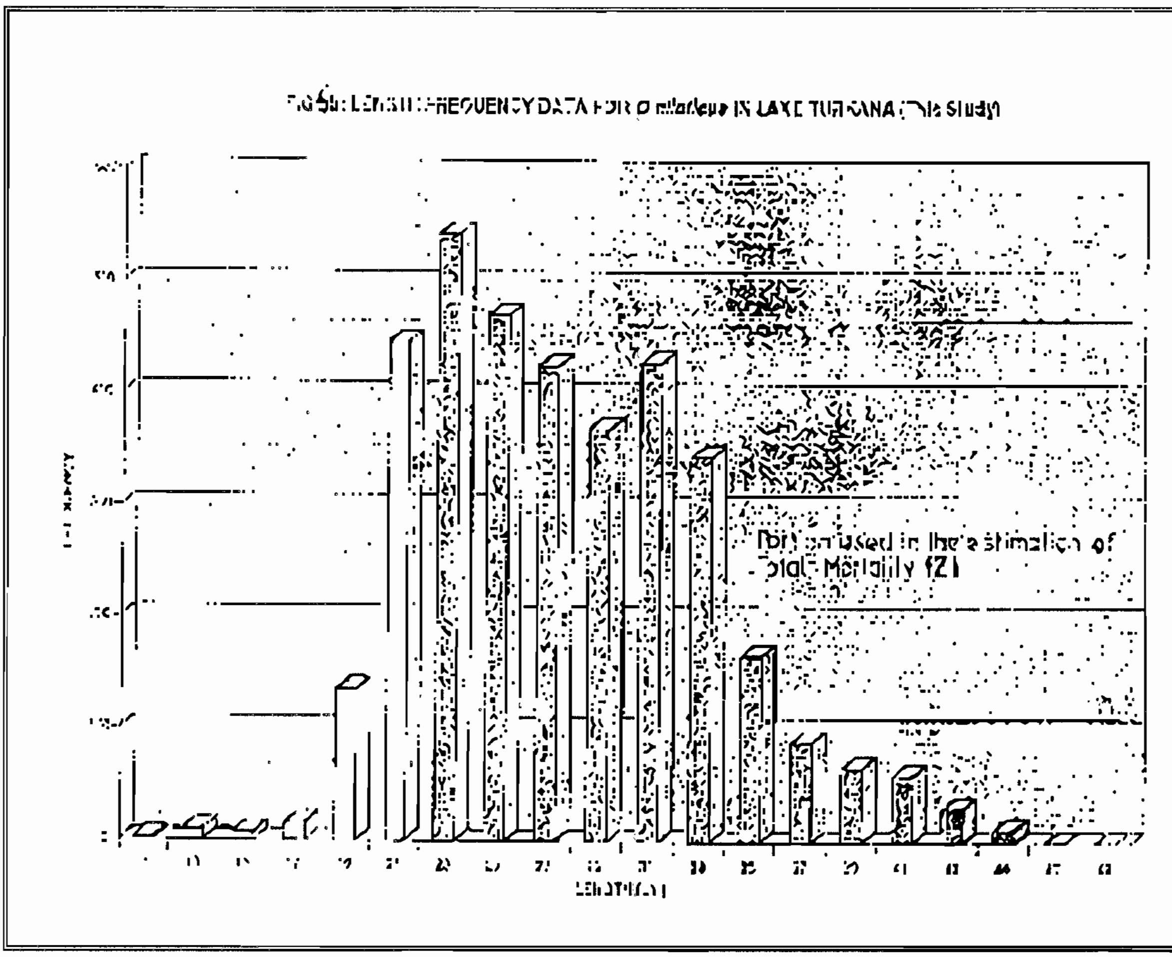
Where K is expressed on an annual basis and L∞ is in cm.

## RESULTS

### Growth Parameters, Mortality estimates and recruitment Pattern

Preliminary estimates of L∞ using the method of WETHERALL (1986) quoted above did give the following values: 31cm in 1974 and 59 cm in 1989, respectively (Fig. 2A, 2B). With FISAT, the growth parameter estimates were L∞ = 40.5 and 59.5 cm and K = 0.25 and 0.325 $yr^{-1}$, respectively (Fig. 3A and 3B). The "length-converted catch curve" analysis produced total mortality estimates of Z = 0.96 and 1.59 $yr^{-1}$ respectively in the same ranges of ages: 1 to 5 years (Fig. 4A, B). The natural mortality (M) estimated are 0.65 and 0.69 $yr^{-1}$, leading to fishing mortality (F) values of 0.31 and 0.9 $yr^{-1}$ respectively.

In both cases, the recruitment pattem (Fig. 5A, 5B) suggests a major peak recruitment from June to September, supporting what is known on the reproductive biology of Lake Turkana fish that they reproduce during the warm rainy season; from May to September.



**Growth performance Index (Ø)**

Two values of the growth performance index (PAULY and MUNRO 1984) were obtained using the relevant input parameters. A comparison was made with results obtained on the same species in the Table 1.

Table 1: Growth parameters estimates for Nile tilapia in several lakes of Africa.

| *Source* | *L∞(cm)* | *K yr$^{-1}$* | *Ø'(a)* | *Range of ages (yrs)* |
|---|---|---|---|---|
| Lake Chad<br>Merona *et al.*, (1988) | 45.5 | 0.31 | 2.81 | 1 to 7 |
| Lake George<br>Palomares (1991) | 40 | 0.24 | 2.58 | 1 to 5 |
| Lake Albert<br>Merona *et al.*, (1988) | 48 | 0.50 | 2.98 | 1 to 6 |
| Lake Victoria<br>Moreau *et al.*, (1994) | 70 | 0.27 | 2.92 | 1 to 7 |
| Lake Kainji<br>Kapetsky and Petr (1984) | 70.4 | 0.45 | 3.11 | 1 to 7 |
| Lake Victoria<br>Getabu (1992) | 64.6 | 0.254 | 3.025 | 1 to 11 |
| Lake Nasser<br>Kapetsky and Petr (1984) | 58 | 0.55 | 3.07 | 1 to 8 |
| Lake Victoria<br>Dache, (1995) | 61.3 | 0.35 | 3.120 | 1 to 8 |
| This study<br>(seines) (1974) | 40 | 0.25 | 2.57 | 1 to 6 |
| This study (gillnets)<br>(1989-91) | 59.5 | 0.325 | 2.87 | 1 to 6 |

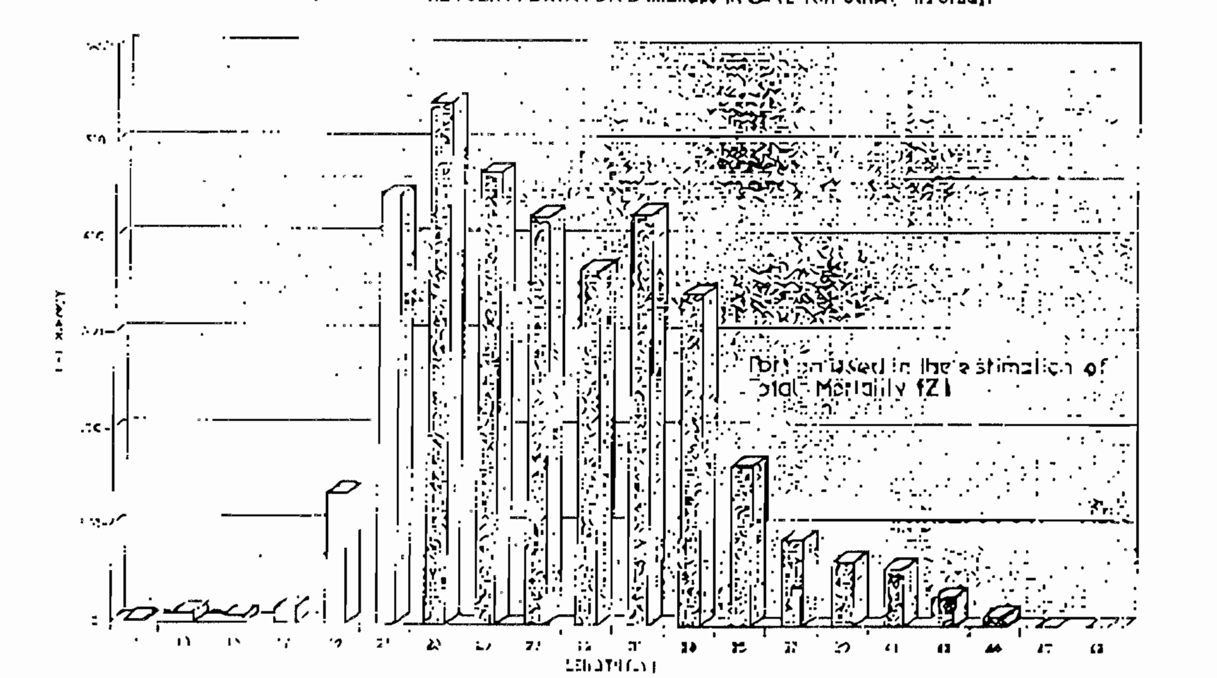
a:$Ø' = Log_{10} K + 2 Log_{10} L\infty$ computed using SL (SL = 0.8 TL) Trewavas (1983).

**DISCUSSION**

FISAT was conveniently used on two sets of length-frequency data for *Oreochromis niloticus* in Lake Turkana in order to estimate the growth parameters L∞, K and which are in the range of already available values from the literature. The seasonal growth pattem is clear for the two sets of samples; however, both L∞ and K values obtained on beach seining samples are lower than on gillnet samples. In first step, it could be considered that this comes mainly from the differences of sampling techniques leading to different ranges of sizes. Another possible hypothesis might be that the two sets of length frequency data come from slightly different stocks: one living in the littoral areas and exploited by beach seines and one living in more open and deep waters which was exploited with multimesh gillnets with some large meshes. The exploitation rate (E) (1974) is quite low in littoral areas: 0.32 compared with 0.57 in open waters in 1989. These values are quite high because in both cases Tilapias contributed slightly to the actual catch of the lake (HOPSON 1982, KOLDING 1989).

The application of the WETHERALL-POWELL PLOT modified version PUALY, (1986) appears to be less effective in the estimation of Loo and Z/K for gillnets compared with the application of FISAT. The growth parameters estimated for *Oreochromis niloticus* in Lake Turkana are compared with the parameters obtained for *Oreochromis niloticus* populations in other African lakes (Table 1). It attains greater L∞ val-

FIG 5b: LENGTH FREQUENCY DATA FOR O. niloticus IN LAKE TURKANA (This study)



ues in Lakes Victoria (70 cm), Kainji (70.4 cm) and Nasser (58 cm) GETABU (1992). The growth performance index (ø) is highest in Lakes Kainji (3.11) Victoria (3.02, 3.120) and Nasser (3.07). The magnitude of K, and the asymptotic length, L∞ determine the growth performance index. An increase in K results in high growth performance index. The growth constant K is highest in Lakes Albert (0.50 $yr^{-1}$), Nasser (0.53 $yr^{-1}$) and Kainji (0.45 $yr^{-1}$). Concerning the recruitment, a minor pulse takes place in February or March but it seems to be an artifact due to the structure of the samples. However, the main recruitment pulse lasts from June to September. This is supportive of the findings of HOPSON (1982) who suggested that Lake Turkana fishes have one breeding season per year during the rainy season.

## CONCLUSION

For the first time, length frequency analysis **was performed on** *Oreochromis niloticus* of Lake Turkana, considering two sets of data from two different periods and areas. This exercise showed different demographical situations of the two concerned stocks. However, high values of Z show that further investigations are needed to monitor its demographical evolution and possible over fishing as it occurred for some other species in some areas of this lake.

## ACKNOWLEDGEMENTS

Thanks are due to Dr. E. Okemwa, the Director of KMFRI and Mr. J. Ogari, Deputy Director (Inland Waters) for their helpful support and to the field staff of Lake Turkana for collecting the data.

## REFERENCES

Dache, S.O. (1995); Observations on the Fisheries, Growth and Mortality Rate of *Oreochromis niloticus* (Tilapia) in the Nyanza Gulf of Lake Victoria. In Proceeding of EEC Workshop 25-27 September 1991. [Gayanilo F. Jr. F. Sparre and D. Pauly 1994. The FISAT user's Guide, F.A. O/I.C.L.A.R.M./D.I.F.M.A.R.] *Getabu A.M. (1992). Growth parameters and total mortality in *Oreochromis niloticus* (Linnaeus) from Nyanza Gulf, Lake Victoria. *Hydrobiologia* 232: 91-97.* "Hopson A.J. (1982): Lake Turkana: A report on the findings of the Lake Turkana Project (1972-1975). Pubi overseas development agency London: 1873 p."

Kapetsky J. and T. Petr (1984); Status of African reservoir fisheries FAO/CIFA Occas Doc. 10: 326p.

Kolding J. (1989); The fish resources of Lake Turkana and their environment, KEN 043 Trial Fishery 1986-1987, Final report to NORAD, Oslo. The University of Bergen, Norway: 262 p.

Kolding J. (1993); Population dynamics and life-history styles of Nile tilapia, *Oreochromis niloticus,* in Ferguson's Gulf, Lake Turkana, Kenya. *Environmental Biology of Fishes* 37:25-46.

Lowe-McConnell R.H. (1958); Observations on the Biology of *Tilapia niloticus* (L) in East Africa waters. *Revue Zool. Bot.* Aii. 57: 130-172.

Merona B., de J. Moreau and T. Hecht (1988): Croissance de' eau douce africains p 191-219 in Leveue c., LA. Eruton and G.W. Ssentongo (Eds): Biologie et ecologie des poissons d; eau dounce d'afrique. Trav. Doc ORSTOM 213; 538 p Publ O.R.S.T.O.M Paris.

Moreau J.M., L. Palomares, F. Jr Toras and D. Pauly (1994). Atlas demographic des populations de poissons deau douce dafrique ICLARM studies and reviews. In press.

Odero N., (1979); Fish species, distribution and abundance in Lake Victoria. In C.O. Okidi (ed) Natural resources and development of Lake Victoria Basin of Kenya IDS, University of Nairobi, Occasional paper No. 34: 390-406.

Palomares, M.L. (1991); La Consummation de nourriture chez les poisons, etude comparative, mise au point d'un model predictif et application a l'etude des researxtrophiques. Ph.D. thesis Institute National Polytechnique, Toulouse, France 221 p.

Pauly, D. (1980); A selection of simple methods for the assessment of tropical fishstocks. FAO Fish. Circ., No. 729.

Pauly, D. (1981); On the interrelationship between natural mortality, growth parameters and the mean environmental temperature in 175 fish stocks. *J.Conc. Explor. Mer.* 39 (3)175-192.

Pauly, D. (1984); Length-converted catch curve. A powerful tool for fisheries research in the tropics (parts 3). *Fishbyte* 2 (3):9-10.

Pauly, D. (1986); On improving operation and use of the ELEFAN programs. Part II. Improving the estimation of L∞. *Fishbyte* 4 (1): 18-20.

Pauly, D & G. Gaschutz (1979); A simple method for fitting oscillating length growth data, with a program for pocket calculator. ICES CM 1 979eG:24 Demersal Fish Ctee, 26p.

Pauly, D. and J.L. Munro (1984); Once more on the comparison of growth in fish and invertebrates. *Fishbyte* 2 (1): 21.

Somers I.F. (1988); On a Seasonally Oscillating growth Function. *Fishbyte* 6(1) 8-11.

Sterwart, K.M. (1988); Changes in condition and maturation of the *Oreochromis niloticus* L. population of ferguson's Gulf, Lake Turkana, Kenya.

Welcomme R.L. (1972); The inland waters of Africa, F.A.O. C.I.F.A. Tech. Pap. 1 :11 7p.

Wetherall J.A. (1986); A new method for estimating growth and mortality parameters from length frequency data. *Fishbyte* 4(1): 12-14.

Worthington, E.B. and C.K. Ricardo, (1936); Scientific Results of the Cambridge Expedition to the East African lakes 1 930-3 1, No. 15. The Fish of Lake Rudolf and Lake Baringo. *J. linn. Soc. Zool.* 39 (267): 353-89.