Population dynamics of Nile Tilapia (*Oreochromis niloticus*) at Chashma Barrage, Pakistan

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Growth and mortality parameters of *Oreochromis niloticus*, 480 samples collected through four research trawls during the months of April, May, June and July of 2014, were evaluated by using FiSAT-II computer package. Length-weight parameters were found to be as $W = 0.001 * L^{2.144}$ ($R^2 = 0.939$), where $W$, $L$ and $R^2$ represents weight, length and coefficient of determination. Computed von Bertalanffy growth functions, ELEFAN method, were $L_\infty$ (asymptotic length) = 227.85 mm (FL) and $K$ (growth coefficient) = 0.070 year$^{-1}$ respectively. Estimated value of $t_0$ (hypothetical length at which age is zero) remained -0.158 year$^{-1}$ whereas $R_s$ (goodness of fit) was 0.182. $Z$ (annual mortality rate) was evaluated as 1.11 with its 95% confidence interval at (0.74 – 1.49) and $M$ (natural mortality) was 0.16. The value of fishing mortality ($F$) and exploitation ratio ($E$) was 0.95 year$^{-1}$ and 0.85 year$^{-1}$ correspondingly. $F_{max}$, $F_{0.1}$ and $F_{current}$ were evaluated as 0.2 year$^{-1}$, 0.15 year$^{-1}$ and 0.15 year$^{-1}$ correspondingly. $\Phi$ (growth performance index) was computed as 3.560. Current study suggests that the capture of this fishery resource should not exceed from current catch level.

Keywords: Growth, Mortality, Population dynamics, *Oreochromis niloticus*, Pakistan

Introduction

*Oreochromis niloticus* is a bony fish that belongs to the group Actinopterygii. This is found in both freshwater as well as in brackish water. It lives and grows in various naturally occurring freshwater bodies such as lakes, rivers and sewage canals. *O. niloticus* lives and feeds throughout the water column i.e. bottom, mid water and surface and shows short migratory behavior for spawning purposes therefore it is also known as potamodromous. This is mainly oviparous fish which consumes phytoplankton or benthic algae as a food. This tropical bony fish exists in waters with temperature ranging from 14°C to 33°C. The size of this fish at first maturity varies usually from 6 to 28 cm. However, this aquatic creature has a capacity to gain much more size and weight. Maximum reported size and weight of this fish is 60 cm and 4.3 kg. *O. niloticus* has long life span and can live up to 9 years.

Within 3 to 6 months when the fish becomes about 30 g in weight it reaches its maturity. The maturity time depends upon the water temperature. *O. niloticus* reproduces only when the water temperature is higher than 20°C. Shedding of eggs and sperms takes place every thirty days. The size of the egg is about 1.5 mm while larval length when it hatches is about 4 mm. Early development takes place in the mouth of the females where the larvae retreat and grow. Eggs are released in clusters and are subsequently fertilized by the males. Eggs are picked up by the females to brood them in their mouth. However, mostly females does not involve in the brood care. On average each female carries about 200 eggs for mouth brooding where hatching takes place and larvae emerge.

Age structured data of the fish stock is the commonly used for fish stock assessment however when this data is not available the length frequency data is frequently used. The collection of age structured data is complicated as it is more difficult to interpret bands on the otoliths. In order to detect rings on the otoliths high powered microscopes are used.
even then sometimes it is hard to count them exactly\(^{11}\). Sometimes the rings become invisible due to the changing weather and this phenomenon mostly happen in tropical fishes\(^{10}\). Thus the use of length frequency data has an advantage over the age structured data and we have used this type of data in this study. *O. niloticus* is listed among the most distributed fishes of the world. Various researchers have evaluated its growth and mortality rates in different regions\(^{12-15}\).

However, the population dynamics of *O. niloticus* have not been previously studied in Pakistan. Only one study has been conducted which describes only growth parameters \(a\) and \(b\) and is devoid of detailed analysis\(^{16}\). This project is the first attempt to evaluate growth and mortality parameters comprehensively. The findings of this research shall help fishery managers for better fishery management of this resource.

### Materials and Methods

Length-weight and length frequency data of *O. niloticus*, four monthly research trawl surveys conducted with the help of local fishermen community, was collected from Chashma Barrage located on Indus River in Pakistan. The surveys were conducted during the months of April, May, June and July of 2014. In total, 480 samples, both sexes combined, were analyzed for data procurement as 97 in April, 143 in May, 133 in June and 107 in July. The individuals were measured by using fork length method by considering length nearest to 1.0 mm and weight nearest to 1.0 g. The gathered data was statistically analyzed by using FAO’s specialized fishery software viz. FiSAT-II\(^{17}\). Various growth and mortality parameters estimated by using this computer package are as follow:

In order to calculate length-weight relationship in *O. niloticus* power function of \(W = aL^b\) was used. In this equation \(a\) represents condition factor whereas \(b\) stands for allometric growth slope.

To estimated growth parameters, the von Bertalanffy growth function (VBGF) was employed which is as follow:

\[
L_t = L_\infty (1 - \exp (-K (t - t_0)))
\]

\(L_t, L_\infty, K\) and \(t_0\) represents predicted length in mm at age \(t\), asymptotic length, growth coefficient and hypothetical length at which age is zero (usually its value is negative)\(^{18}\). \(t_0\) was calculated by using Pauly’s equation as follow:

\[
\log_{10} (-t_0) = -0.3922 - 0.275 \log_{10} L_\infty - 1.038 \log_{10} K
\]

Growth performance index (\(\Phi\)) was computed by using following equation which is available in the FiSAT-II software:

\[
\Phi = \log_{10} K + 2 \log_{10} L_\infty
\]

Following Pauly’s formula\(^{19}\) was used to calculate natural mortality (\(M\)):

\[
\log_{10} M = 0.0066 - 0.279 \log_{10} L_\infty + 0.654 \log_{10} K + 0.4634 \log_{10} (T)
\]

Where \(T\) is the VBGF parameter and represents average annual water surface temperature which is 23\(^\circ\)C at Chashma Barrage. To estimate total mortality (\(Z\)) Pauly’s length-converted catch curve was used. \(E\) (exploitation ratio) was estimated by using this equation: \(E = F / Z\). \(F\) stands for fishing mortality which can be calculated as \(F = Z - M\).

Gulland method\(^{20}\) was employed to calculate biological reference points. The formula used for this is as follow: \(F_{opt} = M\).

To calculate yield per recruit, Beverton-Holt model\(^{21}\) was used which is as follow:

\[
Y_n / R = FW e^{-M(t - t_c)} \sum_{n=0}^{\infty} \frac{Q_n e^{-nK(t-t_0)}}{F + M + nK} (1 - e^{-(F+M+nK)(t-t_c)})
\]

In this equality \(Y_n / R, t_c, t_c\) and \(t_c\) stand for yield per recruit, mean age of fish at first capture, recruitment age and asymptotic age correspondingly. \(Q\) represents a constant value which equals to 1, -3, 3 and -1 when \(n\) is 0, 1, 2 and 3 in that order\(^{21}\).

### Results

Overall 480 samples, both sexes, of *O. niloticus* collected during April to July 2014 were analyzed in this study. Four monthly research trawls were conducted during these months to collect length-weight and length frequency data. The fork length ranged from 52 – 217 mm while total weight from 5 – 105 g. The average length remained 151 mm (± 27.70) respectively. The dominant length range, fork length, of *O. niloticus* were from 150 mm to 205 mm excluding length range of 169 mm to 174 mm (Fig. 1).

![Fig. 1 — Length frequency distribution of *O. niloticus* at Chashma Barrage during 2014](image-url)
The computed length-weight relationship for *O. niloticus* was $W = 0.001 \times L^{2.144}$ ($R^2 = 0.939$) and $n = 480$ (Fig. 2). To get estimate of growth parameters collected data was analyzed by using ELEFAN method which is available in FiSAT-II computer package. The computed growth parameters of *O. niloticus* were $L_{\infty} = 227.85$ mm (FL) and $K = 0.070$ year$^{-1}$ (Fig. 3). The value of $t_0$ obtained by using Pauly’s mathematical expression was -0.158 year$^{-1}$. The goodness of fit was $R_n = 0.182$. For *O. niloticus* the growth performance index ($\Phi$) was computed at 3.560 based on the data used in this study collected from four monthly research trawls during 2014.

Fig. 2— Length-weight relationship of *O. niloticus* (both sexes combined) at Chashma Barrage during 2014

The estimated value of annual mortality rate ($Z$) was obtained by using length-converted catch curve method by inputting values of $L_{\infty}$ and $K$ as 227.85 mm (FL) and 0.070 year$^{-1}$ in that order. Calculated value of $Z$ was 1.11 with its 95% confidence interval at (0.74 – 1.49) (Fig. 4). The value of natural mortality ($M$) was 0.16 which was computed by using average annual surface temperature of 23°C at Chashma Barrage. The value of fishing mortality and exploitation ratio was 0.95 year$^{-1}$ and 0.85 year$^{-1}$ correspondingly.

Fig. 3— Graphical representation of length-frequency distribution data and growth curves estimated for *O. niloticus* using ELEFAN method

Fig. 4— Length converted catch curve of *O. niloticus* at Chashma Barrage during 2014

The growth of fish depends upon many factors. In common, it is assumed that fish grows faster when either the population density is low or the habitat is improved. Work on the growth parameters of *O. niloticus* has been done by various researchers.
Ahmed et al. from Bangladesh computed the VBGF growth coefficient for *O. niloticus* as 0.39. In Egypt, Yamaguchi et al. reported \( K \) (growth coefficient) = 0.55. Other reported values include 0.41, 0.44, and 5.41.

In this present study, the estimated value of VBGF growth coefficient is 0.07 which is very low as compared to already reported literature. The reason may be unsuitable biotic or abiotic factors retarding the growth of this fish in Chashma Barrage which must be further investigated.

ELEFAN is a very popular method which is used frequently in length frequency analysis of fish. It is a non-parametric method, *ad hoc* method, and does not depend on cohort distributions directly. Thus, assumptions are made by this method regarding the distribution of sizes with in classes. The lengths of each cohorts are fixed such as in the von Bertalanffy growth model which makes a strong assumption about growth. The Chashma Barrage is located in temperate region where mostly the fish species spawn in the May or June every year. Thus, the used data satisfies the requirements of the ELEFAN method. The data used also include all the classes in the fish stock which is another requirement of the ELEFAN method.

Mortality rates were computed by employing two methods i.e. length-converted catches curve and Beverton-Holt method. In order to evaluate mortality rates, values obtained from VBGF growth parameters were used. We could not find literature documenting mortality rates of *O. niloticus*. The estimated values of \( Z \) and \( M \) were as 1.11 and 0.16 respectively. It is a proven fact that fishing mortality is result of several factors such as fishing, pollution, diseases, predation and old age etc. The growth parameters may be different in different regions having direct effect on the mortality rates such as fishing, feeding and sampling methods. The most common reason of fish mortality is predation.

Biological reference points are the tools used for better fishery management. \( F_{0.1} \) and \( F_{\text{max}} \) are very important biological reference points which are computed by using length frequency data. \( F_{0.1} \) represents fishing mortality at which there is an increase of 10% in YPR while \( F_{\text{max}} \) stand for that fishing mortality at which YPR is maximum. These mortality reference points are very important for fishery management. Since, fishery resources contribute significantly in Pakistan’s economy thus it is of utmost importance to manage them. Graphical representation of YPR analysis is shown in Fig. 5.

\[
\text{Graphical representation of YPR analysis is shown in Fig. 5.}
\]

**Conclusion**

Obtained statistical results indicate that this fishery resource is not overfished. The Gulland biological reference point, where \( F_{\text{opt}} = M \), which is 0.16 suggests the capture of this fish resource should be kept at current level.

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**References**


