CHAPTER VIII
AGE AND GROWTH
8.1. Introduction

Age and growth of fish are closely interrelated. As age increases, there will be a change in size. Studies on age and growth are important in fisheries research. Besides being of biological interest, the determination of age has significant practical utility. It helps in the study of dynamics of fish populations. Most of the methods employed for assessing the state of exploited fish stocks rely on the availability of age composition data (Ricker, 1975a). Information on growth rate, natural and fishing mortality, age at maturity and spawning, age composition of the exploited population, etc., can be evolved from the age data of fish populations. Such information are essential tools for the scientific interpretation of the fluctuations in the fish populations over space and time and to formulate scientific and economic management policies for the fisheries in question (Seshappa, 1999).

The growth process is specific for each species of fish. However, it can differ in the same fish inhabiting different geographical locations and is easily influenced by several biotic and abiotic factors. Growth is an adaptive property, ensured by the unity of the species and its environment (Nikolsky, 1963). A comparison of rate of growth from different localities may help in identifying suitable environmental conditions for the sustenance of the stock. The purpose of growth studies in any fish species is to determine the amount of fish that can be produced with respect to time (Qasim, 1973b).
The age and growth rate of fishes are determined by a series of direct and indirect methods. The direct methods include rearing the fishes in captivity under controlled conditions and observing their growth and also using mark recapture method (tagging programmes). Dissection of annual rings laid down on scales, otoliths or other hard parts of the body and length frequency analysis are the indirect methods mostly relied upon. As the direct methods have limited scope due to practical difficulties, biologists prefer the indirect method for age and growth studies. The annular rings on scales and other hard parts of the body are effectively used in temperate regions where, during winter seasons, slow growth leaves clear rings of closely placed circuli. On the other hand, in tropics, the age determination based on direct reading of check marks is difficult because the growth rings do not necessarily represent year marks. Qasim (1973 b), while critically reviewing the age and growth studies by Indian authors, has drawn attention to the fact that though tropical fishes do show clear zonations on hard parts, it is difficult to conclude that they are formed annually only.

The length frequency analysis method of Peterson (1895, 1903) is well known. In this method, the peaks of the length distribution are assumed to represent the different age groups. The method is very good for younger fish (2-4 years of life) but in older fishes, as the growth rate slows down, there are possibilities of overlapping of length frequencies in individuals of different age groups. Length-frequency distribution does not apply well also to the fishes with prolonged breeding season. Length-frequency method is widely used by fishery
biologists in fishes inhabiting tropical waters. A computer based method for the analysis of length frequency data, ELEFAN (Electronic Length Frequency Analysis) (Gayanilo et al., 1988), is effectively used to separate the composite length frequency into peaks and troughs and the best growth curve passing through maximum number of peaks is selected using a goodness of fit ratio of ESP (Explained sum of peaks)/ASP (Accumulated sum of peaks) (Rn) (Pauly and David, 1981; Gayalino et al., 1988). The peaks are believed to represent individual cohorts. This module is incorporated into the FiSAT (FAO-ICLARM Fish Stock Assessment Tools) Software (Gayanilo and Pauly, 1997).

hard parts. Information on the age and growth of *O.bakeri*, an endemic vulnerable carp of Kerala, is totally unknown and hence a pioneer study is attempted in this direction.

**8.2. Materials and Methods**

850 individuals of *O.bakeri* comprising of 557 males and 293 females were collected from Periyar river during August 2001 to May 2003. All specimens were measured to the nearest mm in total length (TL). Length frequency data were grouped into 10 mm class interval. Growth was estimated separately for males and females. The von Bertalanffy growth formula (VBGF) (Bertalanffy, 1938) was used to describe the growth. The equation in growth in length is given by:

\[ L_t = L_\alpha \left[ 1 - \exp^{-K(t-t_0)} \right] \]

where

- \( L_t \) = length at age \( t \).
- \( L_\alpha \) = asymptotic length or the maximum attainable length if the organism is allowed to grow.
- \( K \) = growth coefficient
- \( t_0 \) = age at which length equals 0, i.e. the theoretical age at zero length.

The growth parameters for both the sexes were estimated separately using the ELEFAN 1 programme in the FiSAT software (Gayanilo and Pauly, 1997). Age length key at 3 months interval was prepared from ELEFAN 1. Estimate of \( t_0 \) was made using von Bertalanffy(1934) plot in which the results of the regression of \( - \ln \left(1 - \frac{L_t}{L_\alpha}\right) \) against \( t \) was used to calculate \( t_0 \):

\[ t_0 = -a / b \]
The growth-parameters arrived at were further revalidated following Integrated method of Pauly (1983a). Estimate of $L_\alpha$ and $K$ were done using Ford-Walford Plot (Ford, 1933; Walford, 1946) which in linear form is given by:

$$L_{t+1} = L_\alpha (1 - e^{-K}) + e^K L_t$$

OR

$$L_{t+1} = a + b L_t$$

The lengths at age derived were subjected to linear regression and the results obtained were employed to calculate $L_\alpha$ and $K$ following:

$$L_\alpha = a/(1-b)$$

$$K = - \log e^b$$

The time interval used was 3 months and hence, annual growth coefficient was arrived at by multiplying the $K$ value obtained by 4.

Since ELEFAN curves showed the existence of two broods in *O. bakeri*, the growth parameters were estimated separately for the two cohorts. Growth performance of the two cohorts in terms of length was compared by Munro’s PHI prime index, $\phi'$ (Munro and Pauly, 1983) which was computed from the equation:

$$\phi' = \log_{10} K + 2 \log_{10} L_\alpha$$

where $K$ and $L_\alpha$ are von Bertalanffy’s growth parameters.

According to Pauly (1982 b), the structure of a set of length frequency data is dependant on the recruitment pattern into a population and hence it is possible to derive some information on the seasonality of recruitment from the length frequency data. FiSAT applies this inverse
approach, thereby identifying the number of recruitment pulses per year and evaluating the relative importance of these pulses when compared to each other. The recruitment patterns of male and female *O. bakeri* were obtained from FiSAT.

An attempt was also made to determine the age from the study of scales. For this purpose, scales were collected from the region just below the dorsal fin above the lateral line (Jhingran, 1959). They were cleaned, dried and mounted between 2 glass slides and were examined with a slide projector at a magnification of 15 times of its actual size.

### 8.3. Results

#### 8.3.1. Distribution of length

The length composition of males ranged from 95 to 150 mm TL and the modal length was 110-120 mm TL. The length of females ranged from 104 to 163 mm TL with a mode at 120-130 mm. The smallest fish observed was 89 mm TL and belonged to immature undifferentiated sex.

#### 8.3.2. Estimation of growth parameters

ELEFAN 1 growth curves (Figs. 8.1 and 8.2) showed that the male and female populations of *O. bakeri* were composed of 2 cohorts annually generated by two annual recruits. The first cohort represented individuals recruited during May-June in males and March-June in females while the second cohort was composed of individuals...
originated during November-December in both the sexes. The growth parameters estimated separately for the two cohorts by ELEFAN 1 and Integrated method of Pauly along with the growth performance index, $\phi'$, are given in Tables 8.1 and 8.2 respectively. The growth performance index values obtained by ELEFAN 1 were identical for the males (2.4) and females (2.3) for the two cohorts. The response surface ($R_n$) values used for the estimates of growth parameters through ELEFAN 1 are given in Table 8.1. The $\phi'$ values derived using Integrated method of Pauly for male were the same for both the cohorts (2.5) while in females, the values were slightly different (2.3 and 2.5).

Based on the values obtained through ELEFAN 1, the von Bertalanffy growth equation (VBGE) of *O. bakeri* can be express as:

\[
\text{Males: } L_t = 168 \left[1 - e^{-0.365 (t + 0.365)}\right]
\]

\[
\text{Females: } L_t = 177 \left[1 - e^{-0.645 (t + 1.0604)}\right]
\]

The von Bertalanffy growth equation, when expressed by taking the growth parameters estimated by the Integrated method of Pauly, is as follows.

\[
\text{Males: } L_t = 169.09 \left[1 - e^{-1.0962 (t + 1.0604)}\right]
\]

\[
\text{Females: } L_t = 171.75 \left[1 - e^{-0.9962 (t + 1.0604)}\right]
\]

On applying the average growth coefficients estimated by ELEFAN 1, the males were found to attain average length of 87,132 and 152 mm at the end of I, II and III years respectively. On the contrary, females attained a higher length of 130 mm at the end of first
year, 152 mm at the end of second year and 164 mm at the end of third year of life. From the growth equation arrived at from Pauly (1983a), it was found that the males were 107, 148 and 162 mm TL and females 129, 154 and 166 mm TL at the end of first, second and third years respectively (Table. 8.3).

The recruitment pattern obtained for the two cohorts of males and females through FiSAT is given in Figs. 8.3, 8.4 and 8.5, 8.6 respectively. It manifested the occurrence of two recruitment pulses every year. In male *O. bakeri*, for the stock originated in May-June, the major recruit was identified from March to September with a peak in June (17.24%) whereas the minor mode of recruit appeared in April and showed its peak in October (13.5%). Thereafter it gradually declined and continued till March. For the stock originated in November – December, the major recruit could be traced from April to December with highest occurrence in August (16.71%) while the minor one was registered from December to August with peak in April (9.24%). In females, for March-June cohort, the major recruit first showed its entry in September and continued till August with a peak in March (18.08%). On the other hand, the minor mode of recruit was found during March-September with peak in June (14.83%). For the stock generated in November – December, the major recruit was identified from October to September, attaining a peak in February (15.67%) while the minor one corresponded to September - February with a peak in December (11.8%).
The study of the scales of *O.bakeri* revealed the absence of any definite pattern of the growth rings. Hence a meaningful conclusion on the age of the species based on the rings which appeared on the scale could not be made.

8.4. Discussion

Age and growth determination in fishes is possible only by indirect methods such as length frequency analysis and rings appearing on the scales. In the present study, $L_\alpha$ estimated by ELEFAN 1 and Integrated method of Pauly are comparable in males; in contrast, in females, $L_\alpha$ obtained by ELEFAN 1 was slightly higher than that obtained by Integrated method of Pauly. Higher values of $K$ were also derived by Integrated method of Pauly in both the sexes compared to ELEFAN 1. The higher values of $K$ in males indicated that males attained asymptotic length at a faster rate than the females. The values of growth performance index $\phi'$ were identical for both the cohorts of males and females except for a slight variation found in the values of females obtained by integrated method of Pauly. Therefore, the average values of $L_\alpha$ and $K$ for the two cohorts were used to describe the growth.

In the present study, the maximum size of male *O.bakeri* was found as 150 mm and that of female 163 mm. The length of males at the end of first, second and third years of life were estimated to be 87, 132 and 152 mm and that of females 130, 152 and 164 mm (ELEFAN 1) respectively while the corresponding values from integrated method of Pauly were
107, 148 and 162 mm for males and 129, 154 and 166 mm for females. The length at age values obtained by the above two methods were almost similar in females, on the contrary, variation was observed in the values of males. Based on the results of the present study, it can reasonably be inferred that the longevity of *O. bakeri* is around three years. Since majority of the male fishes fall in the length class 110-120 mm and females in 120-130 mm, it can be postulated that the exploited population of males belonged to two year age group and conversely, the same with respect to female is less than one year age group. Both in males and females, individuals belonging to age group three and above were very sparsely represented in the catches.

*O. bakeri* is listed under vulnerable category of fishes based on its biodiversity status following IUCN (Walker and Molur, 1997). The basic principle of fishery resource conservation and sustenance of the stock is by allowing a fish to breed at least once in its lifetime for ensuring the natural recruitment. In *O. bakeri*, the length at first maturity has been estimated to be 115 mm in males and 118 mm in females (Chapter VI). This implies that the female fishes can mature and spawn before they complete one year of their life cycle and conversely, males spawn only during its second year of life cycle. Johal and Tandon (1987 a) recommended to harvest carps in the second and third years of life when the fish definitely attained size above 30 cm in TL fulfilling their size at maturity. Harvestable size of *L. rohita* has been calculated as 46 cm, which is attained after third year (Sing *et al.*, 1998). Based on the results of the present study, it can be recommended that females of
*O.bakeri* can be exploited during the second year of their life while males shall be allowed to grow up to two years before they are exploited ensuring their recruitment and regeneration in the open waters.

*O.bakeri* was found to exhibit fastest increment in length during the first year of its life history and it was relatively higher in females compared to its male counterpart. A drastic reduction in the growth rate was observed in the second and third years of life during when males performed better than females. Similar results of faster growth rate during the first year and subsequent decline in the following years have been reported in many cyprinids such as *Cirrhinus mrigala* (Kamal, 1969; Desai and Shrivastava, 1990), *Labeo calbasu* (Gupta and Jhingran, 1973; Kamal et al., 2002), major carps (Mathew and Zacharia, 1982), *Labeo dussumieri* (Kurup, 1997), *Labeo rohita* (Singh et al., 1998) and *Tor putitora* (Nautiyal, 2002).

The K values reported for other cyprinids like *L.rohita* (0.41), *Catla catla* (0.53), *C. mrigala* (0.55) and *L. calbasu* (0.63) in Sylhet basin by Haroon et al. (2002) and Indian major carps (*C. catla*-0.1044, *C. mrigala*-0.2750, *L.rohita*-0.2551) by Mathew and Zacharia (1982) are less than that of *O. bakeri*. However, Haroon et al. (2002) recorded higher values of 0.8 in *L.rohita*, 0.73 in *C. catla*, 0.7 in *C. mrigala* and 0.76 in *L. calbasu* collected from beels. The growth coefficient of *L. dussumieri* was estimated to be 0.64 for males and 0.81 for females by Kurup (1997) revealing better growth rate in females. Pauly (1984 a) reported that species having shorter life have higher 'K' value and reach
their $L_\alpha$ within one or two years. On the other hand, those having flat growth rates have lower 'K' values and take many years to reach their $L_\alpha$. *O. bakeri* has moderately high 'K' values and moderate life span, which is in general agreement with the relationship between 'K' values and $L_\alpha$ as reported by Pauly (1984 a).

Recruitment to the fishery was found to occur throughout the year and two recruitment pulses were identified for both the sexes. This is very much in agreement with the results of maturation and spawning studies (Chapter VI) which could identify two spawning seasons in *O. bakeri* viz., April-June and October-November. The growth curves obtained using ELEFAN 1 also strongly corroborate the possible existence of two broods in one year. The products of spawning of a particular season appeared to grow to commercial size and enter the fishery of the next year.

Difficulties were encountered in the age determination using scales. It appeared that the rings found in the scales did not show any definite pattern and hence it was reasonably assumed that age determination based on the rings present in the scales may not be dependable method in *O. bakeri* for the age determination. However, a more detailed and systematic study of the regular and annual nature of the true rings can be taken up for further validation on the use of scales for the age determination in the species.
*O. bakeri*, an endemic species to Kerala, is having the status of a vulnerable fish. Non-availability of enough specimens belonging to all size groups at regular intervals had been one of the major limiting factors in pursuing the studies on length frequency using more refined methods. Since there is total lack of knowledge on the age and growth of *O. bakeri*, the results of this pioneer work on these parameters would definitely advance our knowledge on the biology of fish species and immensely help in formulating relevant conservation and management programmes for the protection and preservation of the germplasm of the endemic fishes of Kerala.
Table 8.1 Growth parameters estimated by ELEFAN 1 for male and female *O.bakeri*

<table>
<thead>
<tr>
<th>Sex</th>
<th>Cohort</th>
<th>(L_m) (mm)</th>
<th>(K)</th>
<th>(R_n)</th>
<th>(\phi')</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>May-June</td>
<td>161</td>
<td>0.98</td>
<td>0.215</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>November-December</td>
<td>175</td>
<td>0.63</td>
<td>0.228</td>
<td>2.4</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>168</td>
<td>0.805</td>
<td></td>
<td>2.4</td>
</tr>
<tr>
<td>Females</td>
<td>March-June</td>
<td>172</td>
<td>0.63</td>
<td>0.406</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>November-December</td>
<td>182</td>
<td>0.66</td>
<td>0.454</td>
<td>2.3</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>177</td>
<td>0.645</td>
<td></td>
<td>2.3</td>
</tr>
</tbody>
</table>

Table 8.2 Growth parameters of male and female *O.bakeri* estimated by Integrated method of Pauly (1983)

<table>
<thead>
<tr>
<th>Sex</th>
<th>Cohort</th>
<th>(L_m) (mm)</th>
<th>(K)</th>
<th>(t_0)</th>
<th>(\phi')</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>May-June</td>
<td>165.71</td>
<td>1.0919</td>
<td>-0.0836</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>November-December</td>
<td>172.48</td>
<td>1.0889</td>
<td>0.2566</td>
<td>2.5</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>169.0972</td>
<td>1.0904</td>
<td>0.0865</td>
<td>2.5</td>
</tr>
<tr>
<td>Females</td>
<td>March-June</td>
<td>178.5124</td>
<td>0.6985</td>
<td>-0.8549</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>November-December</td>
<td>164.9775</td>
<td>1.2939</td>
<td>-1.2658</td>
<td>2.5</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>171.7450</td>
<td>0.9962</td>
<td>-1.0604</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Table 8.3 Length arrived at various ages in males and females of *O.bakeri*

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>ELEFAN 1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>87</td>
</tr>
<tr>
<td>11</td>
<td>132</td>
</tr>
<tr>
<td>111</td>
<td>152</td>
</tr>
<tr>
<td>Integrated method of Pauly</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>107</td>
</tr>
<tr>
<td>11</td>
<td>148</td>
</tr>
<tr>
<td>111</td>
<td>162</td>
</tr>
</tbody>
</table>
Fig. 8.1 Growth Curve of male _O. bakeri_ as estimated using the ELEFAN 1 programme

<table>
<thead>
<tr>
<th>Cohort 1</th>
<th>Cohort 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_i$</td>
<td>161.000</td>
</tr>
<tr>
<td>$L_e$</td>
<td>175.000</td>
</tr>
<tr>
<td>$K$</td>
<td>0.980</td>
</tr>
<tr>
<td>$C$</td>
<td>0.000</td>
</tr>
<tr>
<td>$WP$</td>
<td>0.000</td>
</tr>
<tr>
<td>$SS$</td>
<td>2.000</td>
</tr>
<tr>
<td>$SL$</td>
<td>110.000</td>
</tr>
<tr>
<td>$Rn$</td>
<td>0.212</td>
</tr>
<tr>
<td>$Rn$</td>
<td>0.224</td>
</tr>
</tbody>
</table>
Fig. 8.2 Growth Curve of female *O. bakeri* as estimated using the ELEFAN 1 programme

<table>
<thead>
<tr>
<th>Cohort 1</th>
<th>Cohort 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_a$ = 172.000</td>
<td>$L_a$ = 182.000</td>
</tr>
<tr>
<td>$K$ = 0.630</td>
<td>$K$ = 0.660</td>
</tr>
<tr>
<td>$C$ = 0.000</td>
<td>$C$ = 0.000</td>
</tr>
<tr>
<td>WP = 0.000</td>
<td>WP = 0.000</td>
</tr>
<tr>
<td>SS = 2.000</td>
<td>SS = 8.000</td>
</tr>
<tr>
<td>SL = 120.000</td>
<td>SL = 135.000</td>
</tr>
<tr>
<td>$R_n$ = 0.406</td>
<td>$R_n$ = 0.454</td>
</tr>
</tbody>
</table>
Fig. 8.3. Recruitment Pattern of males (May - June Cohort) of O.bakeri

![Graph showing recruitment pattern for May-June cohort]

Absolute Percent
Time Recruitment
1 Apr 3.38
2 May 10.56
3 Jun 17.24
4 Jul 16.54
5 Aug 9.25
6 Sep 11.49
7 Oct 13.50
8 Nov 8.18
9 Dec 3.40
10 Jan 3.22
11 Feb 3.24
12 Mar 0.00

Fig. 8.4. Recruitment Pattern of males (November - December Cohort) of O.bakeri

![Graph showing recruitment pattern for November-December cohort]

Absolute Percent
Time Recruitment
1 Jan 2.71
2 Feb 6.02
3 Mar 5.71
4 Apr 9.24
5 May 7.94
6 Jun 9.02
7 Jul 15.52
8 Aug 16.71
9 Sep 16.36
10 Oct 9.22
11 Nov 1.55
12 Dec 0.00
Fig. 8.5. Recruitment Pattern of females (March - June Cohort) of O. bakeri

![Graph showing recruitment pattern for March-June Cohort]

Absolute Percent Recruitment
- Jan: 1.62
- Feb: 10.74
- Mar: 19.08
- Apr: 12.78
- May: 12.07
- Jun: 14.83
- Jul: 4.43
- Aug: 4.20
- Sep: 0.00

$L_0 = 172, K = 0.63, C = 0, WP = 0, \lambda = -1.266$

Fig. 8.6. Recruitment Pattern of females (November - December Cohort) of O. bakeri

![Graph showing recruitment pattern for November-December Cohort]

Absolute Percent Recruitment
- Jan: 11.10
- Feb: 15.67
- Mar: 14.68
- Apr: 13.44
- May: 11.03
- Jun: 4.01
- Jul: 3.01
- Aug: 0.89
- Sep: 0.00

$L_0 = 182, K = 0.66, C = 0, WP = 0, \lambda = -0.855$