6. AGE AND GROWTH

6.1. INTRODUCTION

For understanding the biology of any animal, information on age and growth is an inevitable aspect. A study in this line provides an insight into age class structure of the stock, changes in the abundance of population, longevity and growth. It is also very important to have information on age and growth of an organism so as to plan the exploitation strategies. The growth rate of many species has been studied using various techniques like labeling, annual growth rings in hard parts like scales, otoliths, opercular bones, fin rays and the distribution of size cohorts (Wilbur and Owen, 1964). Fluctuations in abundance were often accompanied by changes in the size of the fish, and it was obviously useful to try to find ways of tracing fish of a particular age through the fishery year by year. Peterson (1891) noticed that length distribution of samples from fish catches often showed several modes and he deduced that these modes represented various year classes. The weakness of this method is that growth in length slows with increasing age and spread of the size within in the year class increases so that the overlap is successively greater with age.

The growth of fishes has often been specified by a mathematical curve or equation fitted to observation points and they reveal stability and small range of pattern among individuals and populations (Winsor, 1932; Hjort et al., 1933; Brody, 1945; Smith, 1963). Determination of age and mathematical description of growth is perhaps the most complicated and controversial matter in biological sciences. With proper statistical analysis of data on growth the present status, past history and future course of any population can be traced.
The methods of determining the age of fish such as length frequency
distribution and growth markings on hard parts like otoliths, scales, opercular bones,
fin rays etc., has been well developed for temperate species. The methodologies used
for temperate species cannot be used for tropical fishes which more are less live in a
stable environment and have continuous breeding behaviour.

In tropical waters the determination of age of a fish is often difficult
(Seshappa, 1958; Fagade, 1974; Bagenal and Tesch, 1978). One of the reason being
the rings which are formed in hard parts are not necessarily annual and they may be
associated with external factors (Qasim, 1973). The rings in hard plates may be
observed in relation with spawning (Seshappa, 1958; Luther, 1973; Brothers, 1983).
Seasonal variations are also known to induce the growth in fishes (Pannella, 1971).
Qasim (1973) reviewed the earlier works on age and growth of fishes in Indian waters
and outlined the difficulties encountered in the determination of the age of tropical
fishes.

In temperate waters, where shellfishes form a fishery and are used as food
more commonly than India considerable works on the age and growth of gastropods
are available. Studies by Feder and Paul (1974), Wendell et al. (1976), Kato and
Hamai (1975) and Isla and Gordillo, (1996) are the few worth mentioning works on
age and growth of gastropods.

Among molluscs, growth is estimated in terms of shell dimensions like length,
width, height etc., because the shell is determined as one of the prominent
characteristic features of the phylum. Researches on age and growth would help to
explain the impact of environmental parameters on growth and would facilities
comparison of growth rates in different water bodies.
The appraisal of age and growth helps in fishery management as it expounds the year class composition, growth rate and optimum growth in fishery. Evaluation of different age classes and the rate of growth and variations in the abundance of population inhabiting a particular environment are more important. The growth rate of various animals has been studied in molluscs using different techniques such as labeling (Branch, 1981), annual growth rings and distribution of size cohorts (Balaparameswara rao, 1976; Emam, 1994). As regard to Indian marine molluscs, the age and growth studies have been done on few species of Trochidae and Turbinidae.

6.2. MATERIALS AND METHODS

The monthly sample of *T. radiatus* was collected from the study area for a period of one year (May 2011 to April 2012). The distance between the anterior and posterior extremities of the shell in a direction parallel to the ventral margin was measured to the nearest 0.1mm using vernier calipers and used in the studies.

6.2.1. Length frequency method

Estimation of age and growth by use of modal values in length frequency distribution has been widely employed. The basic principle of this method is as:

- Lengths of animals, of each group, of each brood, are approximately normally distributed in a population with restricted spawning season.

- Growth is such that the modes of length distribution in successive age group or broods are separated along length axis and may be readily distinguished

- When the length frequency distribution of a sample containing a number of age group or brood is drawn, a polymodal curve is obtained: the separate mode represents the approximate mean size of the constituent age groups. This method is suitable for the younger groups. But with advance in age, growth
slows down, which results in overlapping of modes and makes it difficult to separate them.

In the case of animals with continuous spawning (without short or restricted), extreme care is necessary to apply this method and interpret the results there from, because of frequent overlapping of various groups entering the populations under such circumstances; the only possible way in that case is to trace average monthly growth rate in different stages and then to compute. From this appropriate average size at different ages can be calculated. The lengths of the gastropods were classified into 17 groups with a length class interval of 1.9 mm.

6.2.2. Probability plot method

Probability plot method of estimation of growth is advantageous for species, which have prolonged breeding seasons. Certain year classes may not be represented in the sample collected and overlapping of distribution of older size groups is likely to yield erroneous results when Peterson’s method is used. The Probability plot method (Harding, 1949; Cassie, 1954) of separating the polymodal length frequency distribution has been used at present to find out the modal lengths of different year classes.

6.2.3. von Bertalanffy’s equation

The mathematical model derived by von Bertalanffy (1938) was used to calculate the length of the trochid at a given time. The von Bertalanffy’s growth curve is an exponential that has been used to detail the growth in a various form (von Bertalanffy, 1938; Beverton and Holt, 1957; Fabens, 1965; Wolfe, 1968).
The mathematical expression is useful in interpolation and extrapolation and also in production computation (Pantulu, 1963; Kamal, 1969). Since growth is the net result of anabolism and catabolism, a growth curve in length fits well with the growth rate of many species (Beverton, 1954; Beverton and Holt, 1957). This equation gives a linear relationship between length, at time \( t \) and \( t + x \) and is expressed as:

\[
L_t = L \times (1 - e^{-k(t-t_0)})
\]

where,

\( L_t \) = Length at age \( t \)

\( L \) = asymptote of the growth curve in length

\( e \) = base of the natural logarithms

\( k \) = coefficient of catabolism

\( t \) = age of the animal

\( t_0 \) = arbitrary origin of the growth curve

6.2.4. Ford-Walford graph

Ford (1933) and Walford (1946) have independently developed a geometric interpretation of the pattern of growth in length similar to that of von Bertalanffy. This method is based on the assumption that successive increment added to the length at definite time intervals decrease in magnitude in a geometric progression till a limiting value of total length, ultimate length or infinity (\( \infty \)) is approached. Ford-Walford graph was constructed for *Trochus radiatus* by plotting \( L_t + 1 \) against \( L_t \), where \( L_t \) is the length of animal at a specific age. From the straight line obtained
from the Lt against Lt + 1 graph, when intersected by a 45° diagonal from the origin, the L ∞ value was obtained.

6.2.5. ELEFAN-1

Growth parameters were estimated using FISAT-1 software (Gayanilo et al., 1996). Growth was modeled following von Bertalanffy's growth function (VBGF). An initial estimate of L ∞ was obtained using Powell Wetherall plot. Then this length frequency data was run on ELEFAN-1 sub package available in FISAT using the automatic search routine, response surface analysis and scan of K values, the best fitting curve was estimated.

6.3. RESULTS

6.3.1. Length frequency method

Length frequency histogram for the study period (May 2011 to April 2012) is shown in Figures 6.1 - 6.2. Monthly length measurement was classified into 14 groups with class interval of 1.5 mm. The percentage frequencies were calculated which were multimodal in most of the months and bimodal and trimodal in some months. Fresh recruitments to the population appeared in May 2011. The earlier mode during July 2011 in 15.5 –19.3 mm was traced to 26.7 – 30.5 mm group during January 2012 recording 14.2 mm growth in 6 months time which showed 26.06 mm growth in the first year. This growth in 21.2 - 24.0 mm group during May 2011 was traced to 29.7 - 32.5 mm group in February 2012 recording a growth 7.64 mm for 10 month. The growth in 22.8 - 24.6 mm group during December 2011 was traced to 28.7 - 32.5 mm during April 2012 recording 1.5 mm in 5 months.
Figure 6.1. Length frequency histogram for males of *T. radiatus*
Figure 6.2. Length frequency histogram for females of *T. radiatus*
Figure 6.3. Theoretical growth curve fitted using von Bertalanffy’s equation of male and female *T. radiatus*

6.3.2. Ford-Walford graph

The straight line obtained from the Lt against Lt + 1 graph, when intercepted by a 45° diagonal from the origin, indicated the L infinite value of 45.0 mm for males and 40.5 mm for females of *T. radiatus*. (Figures 6.4 - 6.5)

Figure 6.4. Ford-Walford graph showing maximum attainable length by male *T. radiatus*
6.3.3. The probability plot method

The cumulative percentage occurrence of different size groups for one year was plotted separately in arithmetic probability paper to note the points of inflection. Based on the data, the males of *T. radiatus* showed a growth of 24.6 mm in the first year, 32.1 mm in the second and 36.7 mm in the third year and for females it was 24.8 mm in the first year, 32.8 mm in the second and 38.2 mm in the third year.

6.3.4. Von Bertalanffy’s equation

Von-Bertalanffy’s equation for growth in *T. radiatus* may be given as:

For males

\[ L_t = 44.61 \left[ L - e^{0.2877 (t +1.0324)} \right] \]

For females

\[ L_t = 40.555 \left[ L - e^{0.3313 (t +0.8542)} \right] \]
By using this equation, asymptotic length or maximum length attainable was found to be 44.61 for males and 40.56 for females, age at the origin of the growth curve was 1.0324 for males and 0.8542 for females and coefficient of catabolism 0.2877 for males and 0.3313 for females. Currently, age and corresponding length of the trochid was obtained from probability method have been used to construct von Bertalanffy’s growth curve. From the theoretical growth (Figure 6.3) it could be observed that the trochids attained 24.6 mm in the first year, 32.4 and 37.8 mm in the second and 31.9 and 37.4 mm in the third years respectively for males and females.

6.3.5. ELEFAN - 1

Using the ELEFAN -1 package, the growth parameters were worked out for male and female *Trochus radiatus* and presented (Figures 6.6 - 6.11). The $L_\infty$ for male and female was arrived at as 42.6 and 40.0 mm; ‘K’ value was 0.359 and 0.320 respectively from the best fit curve.

**Table 6.1. Growth obtained by different methods employed for male *T. radiatus***

<table>
<thead>
<tr>
<th>Methods employed</th>
<th>First year</th>
<th>Second year</th>
<th>Third year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic probability</td>
<td>24.15</td>
<td>32.1</td>
<td>36.68</td>
</tr>
<tr>
<td>von Bertalanffy’s equation</td>
<td>24.387</td>
<td>31.986</td>
<td>37.69</td>
</tr>
<tr>
<td>Petersons method</td>
<td>26.06</td>
<td>34.20</td>
<td>38.76</td>
</tr>
<tr>
<td>Months mode curve</td>
<td>24.20</td>
<td>31.80</td>
<td>37.88</td>
</tr>
</tbody>
</table>

$L_\infty = 44.61 \quad k = 0.2877 \quad -t_0 = 1.0324$
Table 6.2. Growth obtained by different methods employed for female *T. radiatus*

<table>
<thead>
<tr>
<th>Methods employed</th>
<th>First year</th>
<th>Second year</th>
<th>Third year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic probability</td>
<td>24.78</td>
<td>32.79</td>
<td>38.15</td>
</tr>
<tr>
<td>von Bertalanffy’s equation</td>
<td>24.391</td>
<td>31.798</td>
<td>37.118</td>
</tr>
<tr>
<td>Petersons method</td>
<td>24.87</td>
<td>34.37</td>
<td>38.93</td>
</tr>
<tr>
<td>Months mode curve</td>
<td>24.20</td>
<td>31.80</td>
<td>37.50</td>
</tr>
</tbody>
</table>

$L_{\infty} = 40.555 \quad k = 0.03313 \quad -t_0 = 0.8542$

Figure 6.6. Powel - Wetherall Plot for males of *T. radiatus*
Figure 6.7. Scan of ‘K’ values for males of *T. radiatus*

Figure 6.8. Growth curve for males of *T. radiatus*
Figure 6.9. Powell - Wetheral Plot for females of *T. radiatus*

![POWELL - WETHERALL PLOT](image)

**Regression Equation:**

\[ Y = 7.17 + (-0.142)X \text{ } , \text{ } r = 0.860 \]

Estimate of \( L_{oo} \) = 40.621 mm  
Estimate of \( Z/K \) = 6.056

Figure 6.10. Scan of ‘K’ values females of *T. radiatus*

![Scan of ‘K’ values](image)
Figure 6.11. Growth curve of females of *T. radiatus*

6.4. DISCUSSION

Determination of age and growth of *T. radiatus* using various methods showed more or less similar growth for the males and females during the study period.

The determination of age and growth based on a single method has its own limitations especially when the determination of age and growth is through indirect methods or through statistical analysis. The age and growth estimation of *T. radiatus* has been done through several methods so that the outcome of one method will act as a check and control over the other.

Comfort (1957) estimated the longevity for a number of gastropods and found it to range polymodal frequency distributions, from 1 to 20 years. Generally temperate polar species live for more years than tropical animals. In tropics few studies have
been done on the age and growth of gastropods. Sadasivan (1947) based on his studies suggested that the longevity of *Cerithidea cingulata* a species closely related to *T. telescopia* as around 5 years. Balaprameswara Rao (1976) found longevity of *Cellana radiata* to be around 5 years. Sreenivasan (1985) studied the age and growth of *Cerithidea cingulata*, and found it to live for 4 years.

The present observations on *T. radiatus* revealed faster growth rate in the first year of age when compared to the subsequent years. The observations of Rao (1952), Mane (1976) and Kalyanasundaram and Kasinathan (1983) in *Katelysia opima* (26.6, 36.6 and 43.2mm), and Jayabal and Kalyani (1986) in *Meretrix meretrix* (47.0 and 61.5mm) also supports and are in conformity with the present results. Ansell (1968) related the growth mainly to the availability of food.

George John (1980) has also found that food availability is the prime factor affecting growth in *Anadara rhomboe* in Indian waters. Wilbur and Olsen (1964) reported that the decrease in the relative growth with an increase in age is known in molluscs. Brown (1957) stated that specific growth rate declines more and more slowly as the organisms increase in age. Seshappa (1971) and Harkantra (1975) showed that the young ones exhibit greater growth rate. Various environmental factors are known to influence molluscan growth (Wilbur and Owen, 1964). Several investigations have found that both in tropical and temperate waters growth rate of the molluscs are not uniform throughout the year. The growth rate is faster in their early part of life than during the later (Brown, 1957; Kamala, 1983).

The growth rate of *T. cornutus* and found that the shell length increment from the first to fifth year was, and 7.0, 10.3, 15.1, 22.0 and 32.3mm respectively (Chung *et al.*, 1983). The growth observed by (Srinivasan, 1999) *Trochus tentorium* by probability plot method was 19.14mm (I$^{st}$ year), 24.36mm (II$^{nd}$ year), and 27.6 mm
(IIIrd year). In several species of molluscs, slow growth for several months after settlement was found (Thompson et al., 1980), thus, there is the possibility of underestimating age. The settlement of *U. costatum* occurred from July to September and registered a peak in August. The period during which the sand snails are smaller than 1 mm after settlement is about a month. This is considered relatively short because the age group was first collected a month after the appearance of animals smaller than 1 mm in 1987 and 1988 (Takashi, 1991). In various species of gastropods, seasonal growth has been observed (Paul et al., 1977; Shepherd and Hearn, 1983; Tutschulte and Connel, 1988) and the major factors affecting this are thought to be seasonality of sea water temperature (Ekaratne and Crisp, 1984), season of gonadal development and release (Fretter and Graham, 1976; Ekaratne and Crisp, 1984; Tutschulte and Connel, 1988), and seasonal changes in availability of food (MacQuaid, 1981; Burgett et al., 1987).

Effects of population density and availability of food resources seem to be more common causes for growth rate variations, as earlierly exposed for many intertidal gastropods (Black, 1977; Hylleberg and Christensen, 1978; Underwood, 1979; Haven 1983). Research by Seed (1979) and (Brousseau, 1979) showed that other factors, almost certainly nutritional could similarly result in crossing over of growth curves from different populations. Hence, size related changes in diet, food availability or other aspects of interspecific competition might have important consequences for wide scale as well as local growth investigation. The age of *Trochus radiatus* appears to be 3 years estimated by various methods. Longevity data of molluscs were assembled by (Fischer, 1950) and the observed longevity of *T. niloticus* is 12 years (Rao, 1937), 2½ years for *Umbonium vestiarium* (Rajagopal, 1982), and 3 years for *T. tentorium* (Srinivasan, 1999).