Age and growth of squirrel fish, *Sargocentron rubrum*, (Forsskal, 1775) from Cuddalore waters, Southeast coast of India

Anbalagan.T 1, A.Murugan1, P. Jawahar2, P. Vijayanand1, R. Saravanan1 & N.Veerappan1

1Faculty of Marine Science, CAS in Marine Biology, Annamalai University, Parangipettai, Tamilnadu – 608 502, India.
2Fisheries College and Research Institute, Thoothukudi, Tamilnadu, India.

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Age and growth of the squirrelfish, *Sargocentron rubrum* was determined based on the length frequency data collected from Cuddalore waters, southeast coast of India. Biological information was recorded from 1128 individuals, which includes 464 males and 664 females. Length data were analyzed using the FiSAT software package that is mainly used for determining the age through indirect method (Mathematical calculation). Significant differences could be noticed between sexes in terms of length at age and estimated parameters that portrayed males growing larger than females (P<0.05). Estimated parameters of the von Bertalanffy growth function for the pooled data was $L_t=24.43\text{cm} \times [1-\exp (-1.18\text{year}^{-1} (t-0.1417))]$ for males and $L_t=23.63\text{cm} \times [1-\exp (-1.15\text{year}^{-1} (t-0.1468))]$ for females.

**Keywords:** Squirrel fish, *Sargocentron rubrum*, age and growth, von Bertalanffy growth function, southeast coast

**Introduction**

Growth in fishes is a result of the processes tending to increase the body mass. Knowledge on the age and growth of fishes is of utmost importance in understanding longevity, population structure and dynamics of the stock and role played by various year classes in the fishery. Studies on age and growth of fishes are useful in understanding the life span of fish, environmental condition and the age at first sexual maturity. 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 population. Determination of age and mathematical description of growth is perhaps the most complicated and controversial matter in biological sciences, whereas this method is most widely practiced in tropical waters.

The squirrel fish (Family: Holocentridae) supports a diverse group of economically important commercial and recreational fishes widely distributed in tropical and subtropical waters. They mainly inhabit in coral reef and rocky region, whereas they have been fished from depth range of 5 to 85 m. Commercial catch of squirrel fish in bottom trawl nets for protein source and collection of these fishes using gill nets coupled with skin diving and coral reef fish trap for live marine ornamental fish trade is being in practice from Indian waters. *Sargocentron rubrum* is a small – sized fish with a size range of 7 to 24.5 cm, which occurs all along the east coast of India. For most the squirrel fishes studies information on the fishery characteristic and biology and very much limited. Although, some aspects of the biology of this fish have been studied earlier, there is no published information on the age and growth of this species from Indian waters. Previous studies on age and growth of *S. rubrum* has been made from Israel and Syrian waters. Aim of this study was therefore, to estimate the age and growth of *S. rubrum* using size frequency analysis. However, a lack of biological data, particularly on age and growth rates, prevents definitive assessment of the status of the resource. Such knowledge is crucial for analyzing the reproductive strategy of the fish and development of resource management plans.

**Materials and Methods**

Squirrelfish, *Sargocentron rubrum* specimens were collected on monthly basis from bottom trawl fisheries in Cuddalore landing center, South east coast of India (Fig.1), from January to December 2008.
Totally 1128 specimens (Males 464; females 664) were analyzed for growth studies. The total length of the fish was measured to the nearest cm from the tip of snout to the tip of the caudal fin. Size ranges from 7.0 to 24.5 cm for males and 7.0 to 23.9 cm for females were recorded during the survey period. Size frequency data were collected on monthly basis and the yearly collected data were pooled together and classified under different subclasses with an interval of 1 cm. VBGF curve obtained was fitted to the monthly length frequency data using the ELEFAN routine in the FISAT computer package. Curve obtained through the non-parametric method passes through the most number of modes, giving estimates of $L_\infty$ and $K$. Von Bertalanffy’s equation to calculate the length at age data was expressed as $L_{t+1} = L_\infty - [1 (1-e^{-K}) + L_t - e^{-K}]^{1/2}$. Growth performance index was calculated by the equation $\phi = \log_{10}(K) + 2 \cdot \log_{10}(L_\infty)$. One-way analysis of variance (ANOVA) was used to assess the differences between the sex in terms of growth obtained on yearly basis.

**Results**

In *Sargocentron rubrum*, small sized (7.5 cm) females were dominant during the month of March where as the largest one was represented during the month of October (23.4 cm). For males the smallest size group was represented during March (7.2 cm) and the largest during October (23.7 cm). Analysis using Powell–Wetherall’s method (Fig. 2) revealed that the $L_\infty$ values for males and females of *S. rubrum* as 24.40 cm TL [$r = -0.998$ regression equation, $Y = 9.41 + (-0.386) \cdot x$] and 23.13 cm TL [$r = -1.000$ regression equation $Y = 10.26 + (-0.444) \cdot x$] and $Z/K$ obtained was 1.59 and 1.25 respectively. The computed growth curves of *S. rubrum* obtained with these parameters have been shown over the restructured length distribution of individual species (Fig. 3). Based on the VBGF calculation the obtained asymptotic length
(L∞) for male and female was 24.43 cm (TL) and 23.63 cm (TL) respectively. The ‘Rn’ value for the growth curve for male and female was 0.373 and 0.342 respectively.

The optimized growth parameters (L∞ and K) and the goodness of fit index (Rn) obtained for males and females of S. rubrum using ELEFAN I method in FiSAT II package are provided (Table 1). Growth parameters obtained for males and females of S. rubrum by Appeldoorn’s method using the growth increment data are graphically represented (Fig. 4).

Through this method the asymptotic length obtained for males and females of S. rubrum was 25 cm and 23.63 cm and the growth co-efficient K was 1.2 and 1.1 yr⁻¹ respectively. On the other hand, the estimated growth rate (K), which is generally inversely correlated to L∞, was higher in males than the females. This growth equation was fitted to calculate the growth rates in S. rubrum. Based on the values of parameters, the equation for growth of S. rubrum can be written as Male: \( L_c = 24.43 \left[ 1 - e^{-1.18(t-0.1417)} \right] \) and for females: \( L_c = 23.63 \left[ 1 - e^{-1.15(t-0.1468)} \right] \). This equation for calculating fish growth seems to be best suited because it was an expression of biological interactions.

This growth equation for calculating fish growth in the wild population seems to be best studied by many researchers. To follow the growth rate trend during the life span, the length-at-age data were calculated from the von Bertalanffy growth function.

<table>
<thead>
<tr>
<th>Sex</th>
<th>L∞(cm)</th>
<th>Z/K</th>
<th>K(yr⁻¹)</th>
<th>Rn Score</th>
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<tr>
<td>Female</td>
<td>23.63</td>
<td>1.15</td>
<td>0.1468</td>
<td></td>
</tr>
</tbody>
</table>

Table 1- Growth parameters of males and females of Sargocentron rubrum obtained from different methods from length frequency data.
Growth data obtained in the present study shows that S. rubrum male and female have a life span of about 3.5+ years (Fig. 5). Male attains a length of 18.08cm, 22.48cm, 23.83cm during first, second and third years whereas female attains a length of 17.31cm, 21.63cm and 23.0cm during the above period, suggesting that males growing at slightly faster rate than the females. Estimated growth performance index ($\Omega'$) values for males and females of S. rubrum were 2.848 and 2.808 respectively. $\Omega'$ value is an index for comparing the growth performance of organisms in terms of their growth length.

Discussion

Estimating the growth rates of fish population is often an important component of ecological or fisheries studies. Variation in growth rate of a fish stock may be due to differences in competitive ability, life history differences or variation in environmental quality. The results obtained here for S. rubrum will improve our knowledge on the biology and the life history traits of this species and contribute to a better growth modeling for biological studies. Results provide information about the growth rate of S. rubrum using VBGF which must be taken into account carefully. It has been evidenced that VBGF for growth rate in similar species varies when the stocks are studied spatially with regard to growth parameters.

The empirical length at different ages described by von Bertalanffy growth equation is almost in parity with the estimates from other methods. Theoretical growth equation adequately describes the actual growth. In the present study, growth parameters $L_\infty$ and $K$ estimated by Powell-Wetherall methods, Appeldoorn’s method and ELEFAN I are comparable.
Growth parameters obtained are reasonable since the theoretical maximum length value is higher than the size of the largest fish sampled 24.4 cm for males and 23.13 cm for females.

In the same approach, different growth rates for both sexes have been reported on coral reef fishes like Pomacanthus imperator having von Bertalanffy parameters $L_x = 411.9$ mm, $K = 0.067$ years$^{-1}$, and $t_0 = -0.91$\textsuperscript{30}. In the case of the file fish, Stephanolepis hispidus asymptotic lengths calculated was 25.7 and 27.4 cm for females and males which were collected from Canary Islands\textsuperscript{31}. The seahorse Hippocampus trimaculatus collected from Gulf of Mannar region (South east coast of India) had an life span around 3 years and the $K$ value was 0.49, $L_x$ was 162 mm and -- $t_0$ was -0.07\textsuperscript{32}. The reef fish moon wrasse, Thalassoma lunare had a life span of 4 to 4.5 years with a $K$ value of 0.1881, $L_x$ = 323.6268 mm and $t_0$ = 1.7322\textsuperscript{33}. In Siganus sutor the $L_x$ was around 35 cm with an $K$ value of 0.9 on annual basis\textsuperscript{34}, however in the Madeira scorpionfish, Scorpaena maderensis the asymptotic length $L_x$ (cm) and $K$ (year$^{-1}$) was 9.6, 0.44 for females, 14.8, and 0.23 for males respectively\textsuperscript{36}.

In general, the growth rate of $S$. rubrum was found to be high during the first year 18.08 cm, 2nd year 22.48 cm and 3rd year 23.83 cm for males; whereas in females growth rate of 17.31 cm, 21.63 cm and 23.0 cm were calculated for 1st, 2nd and 3rd year respectively, suggesting a slight decrease in growth rate. In most fishes decline in growth with increase in age has been reported\textsuperscript{(32, 33&35)}. However it seems to be natural since the younger stages (juvenile phase) of fishes are known to have more rapid growth rate since the energy is spent for somatic growth whereas in matured or older fishes the energy is utilized for reproduction.\textsuperscript{37,38} In the studied species the maturation of the fishes begins in the third year whereas the growth was slower after observed onset of maturity period.

The life span of most tropical fishes is short and seldom exceeds 2-3 years\textsuperscript{39,40}. Present study reveals that $S$. rubrum has a life span of about 3.5 years. Age and growth of $S$. rubrum based on mathematical calculation suggest that they attain a length of around 94.5 mm during the first year, whereas they reached a length of 127.7 mm during the second year; a length of 143.5 mm was calculated for the third year and 154.6 mm was calculated for the fourth year. The maximum size recorded in the previous study from the Eastern Mediterranean coast was 180 mm, however in the present study the maximum size observed for $S$. rubrum was 244 mm from Cuddalore waters (South east coast of India).

The present study reveals that the growth of females was slower than the males, whereas the occurrence of larger males was in considerable number when compared to large females recorded. Similar findings were observed for $S$. rubrum collected from Eastern Mediterranean coast\textsuperscript{12}. However the differential growth between the sexes might be due to biological parameters and further research in this aspect is needed to address this issue. Proximity of the value obtained for $L_x$ to the $L_{max}$ (maximum size observed in catches) value irrespective of sex might be due to the reliance of $L_{\infty}$ derivation based on the size group that is fully recruited by the gear.

Although the information on growth and age data for temperate and tropical marine fish species is large and expanding, little work have been done in the family Holocentrids, including $S$. rubrum. Based on von Bertalanffy estimates for the squirrel fish, S. diadema the obtained growth values are $L_{\infty} = 168$ mm; $K = 1.13$ and $t_0$.39.1\textsuperscript{41} whereas similar results were also reported in Holocentrus diadema ($L_{\infty} = 153$ mm, $K = 1.47$) and H. ascensions ($L_{\infty} = 230$ mm $K = 0.39$)\textsuperscript{42}, in Myripristis amaena the growth parameters observed was $L_{\infty} = 245$ mm and $K = 0.239$\textsuperscript{11}. The slight variation in growth parameters of the same fish family from different regions might be due to differences in environmental parameters or size structure at the specified localities caused by different gears used and methodology adopted for studying the parameters. In addition, this may result in an overfishing of many benthos-demersal species\textsuperscript{43,44}. Slight variation in growth parameters of the same fish family from different regions might be due to differences in environmental parameters or size structure at the specified localities caused by different gears used methodology adopted for studying the parameters.

Conclusion

Studies on age and growth of squirrel fishes are very much limited and hence the present study has provided the much needed biological information with regard to the life history of $S$. rubrum. At present this species falls within the important marine ornamental fish for trade, the levels of exploitation has increased in the regions like Gulf of Mannar. It is significant to have the scientific data on biology,
which will aid in responsible or sustainable fishing especially for the artisanal sectors. Lack of information about basic life-history characteristics is indicative of the need for more data for the fishes belonging to the family Holocentridae with special attention to species which have good demand in the domestic and international fish trade market. Developing countries like India needs to formulate a well structured protocol to manage targeted fishery resources in order to address core issues like food security and livelihood of artisanal fishing communities.

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