VALIDATION OF LENGTH FREQUENCY ANALYSIS FOR
BOOPS BOOPS (BOGUE) GROWTH ESTIMATION

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Key words: Boops boops, Mediterranean, Scales reading, length frequency analysis, growth.

ABSTRACT

Scales reading and length frequency distribution were used for age determination and growth estimation of Boops boops (Bogue) stock of Western Mediterranean Coast of Egypt. Age determination using scale was done and the time of annulus formation was detected by the marginal increment index. Bhattacharya’s method was used for length frequency analysis. Both methods showed 6 age groups. ANOVA test revealed insignificant differences between both estimates of length at age results. Growth parameters estimated using length-at-age data from both methods confirming the age determination results. Growth performance index indicated high similarity between the two estimates. The results revealed the compatibility of length frequency distribution to scale reading for stock assessment studies of bogue stock in Western Mediterranean Coast of Egypt.

INTRODUCTION

Bogue, Boops boops (L.), family Sparidae, is an important species in the Mediterranean Sea, (Bauchot and Hureau, 1984). It is a demersal, as well as semi-pelagic species living on all types of bottom (sand, mud, rock, and seagrass beds) to 350 m, more abundant in the upper 100 m and sometimes in coastal waters. It moves in aggregations, ascending to the surface mainly at night (Bauchot, 1987). It is caught by bottom trawls, purse seines; beach seines and trammels nets. Boops boops constitutes about 2.3 % of the total Egyptian Mediterranean catch at last 5 years (GAFRD, 2003).

Growth and mortality model parameter estimates are required for analytical fisheries management. Age determination of fish is needed in order to complete the knowledge about the abundance and fluctuations of any species. Such study represents the main way by which the research can assist and develop the commercial fishery. The utility of length frequency analysis for age determination compared to other methods using hard structures is a contentious issue (Hilborn and Walters, 1992) and (Pauly, 1994). Although, Length frequency analysis method is of widespread use at the present time, some studies did not fulfill its requirements. Iversen (1996) mentioned some limitations about length-frequency methods for age determination such as;

1. Should be used for relatively short time spawning season fishes.
2. The technique requires big samples with wide size range.
3. Age at first capture should be known to detect the age of first modal group.

On the other hand, fish hard structures techniques should be validated each time when applied to a different population or stock. Ideally at the start of a study, the fish should be aged by more than one method. It is essential that whatever method of age determination is chosen, the time of ring formation must be validated by the measurements of marginal increment at the
edge of hard structure (Bagenal, 1987). According to Iversen (1996), there are five major categories which should be used when estimating age from scales or other hard parts namely; interpretation, validation, collaboration, automation and innovation. Most of recent studies on fish growth did not validate their age determination results. Moreover, due to the expense and difficulty of age determination using scales or otolithes of fishes, length frequency analysis (LFA) method has become very popular, attractive and useful in estimating the growth parameters. However, most of Egyptian studies on Bogue were used scales for age determination.

The present study is an attempt to confirm the use of length frequency analysis to derive reliable growth parameters of Boops boops (Bogue) stock of Western Mediterranean Sea coast of Egypt.

MATERIAL AND METHODS

The Western Mediterranean Coast of Egypt (from Matrouh city to Saloum Bay near Libyan border) was selected as a fishing area in the present study. Bogue that were caught by trawl and purse seine from the study area and landed at Alexandria-Eastern harbour fish landing center were sampled.

Random samples were collected weekly from September 2003 to August 2004. In each time, one box (20 Kg) was taken directly from commercial trawlers or purse seiners.

In laboratory total length in cm (from the tip of the snout to the end of caudal fin) was recorded for each fish. Scale samples were taken from the left side under the pectoral fin for about 25 fish monthly. The scales were viewed with low power microscope (16X), scale radius (R) and distance from nucleus to each annual ring (r) were measured by an ocular micrometer.

Age was determined using scales of 319 fish varying in length between 7 and 24 cm and length frequency distribution for about 6589 fish for the same length range.

To determine the time of annulus formation on the scale; the monthly average marginal growth index (GI) of scales for each age group were calculated by the relative equation (Gallucci et al., 1996):

\[ GI = \frac{R - r_{max}}{(r_{max} - r_{max-1})} \]

Where: R is the scale radius at capture and \( r_{max} \) is the outermost annulus and \( r_{max-1} \) is the previous ring to the outermost annulus.

The total length in cm (TL) and scale radius measured in micrometer division (R) relationship was determined by linear regression method where:

\[ TL = a + bR \]

Where: (a) and (b) are constants.

The intercept (a) of the previous relation was used for correction of back calculation fish length-at-each year of life by Lee’s formula (Lee, 1920):

\[ L_n = r_n \frac{(TL - a)}{R + a} \]

Where: \( L_n \) is the length (cm) at age ‘n’, TL is the total fish length at capture (cm), \( r_n \) is the scale radius at annulus ‘n’ formation, R is the scale radius at capture (in micrometer division).

Back-calculated lengths at different ages were fitted to Von Bertalanffy’s growth model:

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

Where: \( L_t \) is the length (cm) at age t (year), \( L_{\infty} \) is asymptotic length (cm), K is the growth coefficient, \( t_0 \) is theoretical time when length was 0.

Bhattacharya’s method (1967) was used to split the age groups from the length frequency data, using FiSAT II (version 1.1.3 computer program) (Gayanilo et al., 1995) the method is based on the following function:

\[ \ln(N_{i+1}) - \ln(N_i) = a_j + b_jL_i \]

Where: \( N_i \) and \( N_{i+1} \) are successive frequencies of the same component of a group of fish in a sample (i.e., representing age group j) and where \( L_i \) is the upper class limit of \( N_i \). From this, the mean of the normal distribution is:

\[ L_j = -\frac{a_j}{b_j} \]

Two methods were used to estimate Von Bertalanffy’s growth parameters.
asymptotic length (L∞) and growth coefficient (K), Ford-Walford method (Pauly, 1983) and Length-at-age data subroutine in FiSAT II program.

1. **Ford (1933)–Walford (1946) Method**:
   This is most widely used method for estimating of asymptotic length (L∞) and growth coefficient (K). The Von Bertalanffy growth equation can be written in the following form:
   \[ L_{t+1} = L_\infty (1 - e^{-K}) + e^K L_t \]
   Where: \( L_t \) and \( L_{t+1} \) are fish length at age \( t \) and \( t+1 \) respectively. From this equation, \( L_\infty \) and \( K \) were estimated by linear regression between \( L_t \) and \( L_{t+1} \), as
   \[ L_\infty = \frac{a}{1-b} \quad \text{and} \quad K = -\log_e b \]

2. **Analysis of length-at-age data**: is a subroutine in FiSAT II software (version 1.1.3, 2004) to estimate growth parameters \( K \) and \( L_\infty \). This subroutine allows non-linear estimation of growth parameters from length-at-age data. The Von Bertalanffy plot is used to estimate \( t_o \) from the known age/length data and estimated \( L_\infty \) and \( K \), the method is based on the regression analysis of the following formula:
   \[ -\ln \left( 1 - \frac{L_t}{L_\infty} \right) = -K \cdot t_o + K \cdot t \]
   Where: the age \( t \) is the independent variable \( (x) \) and \( -\ln \left( 1 - \frac{L(t)}{L_\infty} \right) \) is the dependent variable \( (y) \) of the linear regression.

   **Growth performance (\( \theta' \))** was estimated using the empirical equation of (Pauly and Munro, 1984):
   \[ \theta' = \log_{10} K + 2 \log_{10} L_\infty \]
   Where: \( K \) and \( L_\infty \) are the Von Bertalanffy’s growth parameters.

**RESULTS**

**Time of annulus formation**
To test the hypothesis that the observed annuli were formed once a year, the monthly average marginal growth index (GI) of scales for each age group were calculated. The monthly progression of marginal growth increments was similar on the scales from all age groups. Monthly mean GI showed only one trough during a year, indicating that a single annulus is formed yearly. The minimum values for different age groups were recorded in December, which is the time of annulus (ring) formation for *B. boops* in the present study area (Fig. 1).

**Scale radius and total fish length relationship**
Total length, scale radius relationship was conducted; the equation expressing this linear relationship is:
\[ TL = 2.311 + 0.441 R \quad (r^2 = 0.87) \]
Where TL is total length in cm and R is scale radius in micrometer division.

**Back calculation of length at age**
Scale reading revealed the presence of six age groups. Back calculated lengths as obtained by Lee’s equation were 9.7, 12.9, 15.5, 17.6, 19.5 and 21.4 cm for age groups I, II, III, IV, V and VI respectively (Table 1). The highest increment in linear growth occurred by the end of the first year (45%) after which the rate of increase in length declined rapidly. Age group III was the most abundant among the six age groups studied followed by age group II and age groups IV and V.

**Length frequency analysis (Bhattacharya’s method)**
Six age groups could be separated by Bhattacharya’s method from length frequency data (Fig. 2). Mean length by the end of each year of life (cm) of *B. boops* from the study area were found to be 9.5, 13.4, 16.2, 18.4, 20.5 and 22.5 cm for age groups from I to VI respectively (Table 2). Age group III had the highest abundance, in the studied sample followed by age group II and age groups IV and V.

**Length-at-age validation**
ANOVA test was used to check the differences between estimated lengths for each year of life that resulted from the previous two methods. It appears that there were no significant differences between the two estimated (\( P < 0.05 \)).
VALIDATION OF LENGTH FREQUENCY ANALYSIS FOR *BOOPS BOOPS* (BOGUE) GROWTH ESTIMATION

**Table (1):** Mean back calculated lengths at different age group of *B. boops* of Western Mediterranean Coast of Egypt during 2003-2004.

<table>
<thead>
<tr>
<th>Age group</th>
<th>No</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>30</td>
<td>9.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>78</td>
<td>9.7</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>101</td>
<td>9.6</td>
<td>13.0</td>
<td>15.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>53</td>
<td>9.6</td>
<td>12.9</td>
<td>15.5</td>
<td>17.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>48</td>
<td>9.6</td>
<td>12.9</td>
<td>15.5</td>
<td>17.5</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>9</td>
<td>9.6</td>
<td>12.9</td>
<td>15.5</td>
<td>17.5</td>
<td>19.5</td>
<td>21.4</td>
</tr>
<tr>
<td><strong>Average Length (cm)</strong></td>
<td></td>
<td>9.7</td>
<td>12.9</td>
<td>15.5</td>
<td>17.6</td>
<td>19.5</td>
<td>21.4</td>
</tr>
<tr>
<td><strong>Annual increment</strong></td>
<td></td>
<td>9.7</td>
<td>3.2</td>
<td>2.6</td>
<td>2.1</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>% of increment</strong></td>
<td></td>
<td>45.3</td>
<td>15.0</td>
<td>12.1</td>
<td>9.8</td>
<td>8.9</td>
<td>8.9</td>
</tr>
</tbody>
</table>

**Table (2):** Computed mean length-at-age (cm) separated by Bhattacharya method (FiSAT program) for *B. boops* of the Western Mediterranean Coast of Egypt during 2003-2004.

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>Computed mean length (cm)</th>
<th>s. d</th>
<th>Population</th>
<th>S.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>9.49</td>
<td>1.08</td>
<td>99</td>
<td>n.a.</td>
</tr>
<tr>
<td>II</td>
<td>13.43</td>
<td>1.27</td>
<td>1780</td>
<td>3.35</td>
</tr>
<tr>
<td>III</td>
<td>16.16</td>
<td>1.24</td>
<td>2690</td>
<td>2.18</td>
</tr>
<tr>
<td>IV</td>
<td>18.37</td>
<td>0.80</td>
<td>540</td>
<td>2.17</td>
</tr>
<tr>
<td>V</td>
<td>20.50</td>
<td>0.80</td>
<td>38</td>
<td>2.66</td>
</tr>
<tr>
<td>VI</td>
<td>22.50</td>
<td>0.98</td>
<td>7</td>
<td>2.25</td>
</tr>
</tbody>
</table>
Figure (1): Monthly marginal growth increment (MGI) for the scale of B. boops in Western Mediterranean Coast of Egypt during 2003-2004.

Figure (2): Length distribution of B. boops separated by Bhattacharya method from the Western Mediterranean Coast of Egypt during 2003-2004.
Estimates of Von Bertalanffy growth parameters $L_c$, $K$ and $t_o$

Asymptotic length ($L_c$) and growth coefficient ($K$) were estimated by Ford-Walford plot and FiSAT program from length-at-age data calculated from scales and length frequency analysis (LFA). Ford-Walford method produced higher $L_c$, $t_o$ and lowers $K$ than FiSAT program as shown in Table 3.

Theoretical growth in length

Growth parameters $L_c$, $K$ and $t_o$ determined using length at age data derived from scales, and from length frequency analysis using Ford-Walford and FiSAT II program methods could be represent in the following equations:

\[
L_t = 31.9 \left[1-e^{-0.15(t + 1.53)}\right] \text{ for back calculated lengths & Ford-Walford method}
\]

\[
L_t = 28.1 \left[1-e^{-0.18(t + 1.13)}\right] \text{ for back calculated lengths & FiSAT method}
\]

\[
L_t = 30.5 \left[1-e^{-0.19(t + 0.99)}\right] \text{ for Bhattacharya data & Ford-Walford method}
\]

\[
L_t = 29.7 \left[1-e^{-0.25(t + 0.70)}\right] \text{ for Bhattacharya data & FiSAT method}
\]

Estimates of phi-prime ($\Phi'$)

Phi-prime ($\Phi'$) of $B. boops$ was estimated as 2.18, 2.15 and 2.25, 2.34 for data derived from scales and length frequency analysis (LFA) calculated using Von Bertalanffy parameter ($L_c$, $K$) from Ford-Walford and FiSAT method respectively. Both estimates of scales had less value than LFA values. However, all estimates were so close (Table 3).

DISCUSSION

Age determination of fish is needed to study growth, abundance and fluctuations of fish species. Such studies represent the main way by which the research can assist and develop the fishery. In the present study mean length-at-age was determined by scale reading and Bhattacharya method (LFA).

$B. boops$ taken from the Western Mediterranean Coast of Egypt were aged by scale reading. Similar observations were done on the same species by Hassan, (1990), Abdel-Rahman (2003) and Allam (2003) for data collected at 1999-2000.

Validation and corroboration are required if reliable ages estimation are needed for management purpose. (Wootton, 1990). Determining the time and period of annulus formation is one of the most critical steps in using hard structures. It is a very useful and powerful way to determine when an annulus on scale is formed (Brothers, 1983). The results of time of annulus formation study showed that the ring in $B. boops$ scales occurs in winter season (December–January), which agree with the results obtained for Cyprus stock (Livadas, 1989) and Egyptian stock (Hassan, 1990) and (Abdel-Rahman, 2003). Such results indicate the reliability of age determination using scale reading technique.

Back calculated mean lengths at the end of each year of life derived from scale reading data and from length frequency separated by Bhattacharya method showed insignificant differences statistically $P<0.05$, between them. Some other authors determined similar number of age groups (6 age groups) for the same species from other Mediterranean areas (Table 4), they used variety of methods in ageing, but the present results were more close to that obtained by (Hassan, 1990) for the sample collected from west of Alexandria. However the results were slightly vary from other estimates of eastern Alexandria samples (Allam, 2003) and (Abdel-Rahman, 2003). Such differences might be due to the sampling methods (i.e. from purse seine only or trawl and purse seine) or sampling size and length groups distributions, as well as bias caused by reading techniques.

The mean length-at-age estimated by both methods in the present study have similar age groups (six age groups), similar to the number of age groups that were determined by otolith reading and length frequency analysis (LFA) of the same species from the Adriatic Sea (Algeria-Hernandez,
The present results revealed higher length at age determined by LFA than scale, opposite to the results of Adriatic Sea population used otoliths and LFA. The differences may attribute to the different environmental conditions in either areas or sample methods.

Von Bertalanffy model is one of the most commonly used methods in studying theoretical growth in fishery biology. Von Bertalanffy growth parameters ($L_\infty$, $K$ and $t_0$) of $B. boops$ for the present study area were estimated by two methods. The results revealed that using Ford-Walford method produced slightly higher values of $L_\infty$, $t_0$ and lower ones for $K$ than age at length subroutine (FiSAT program). The data resulted from Ford-Walford methods gives butter fitting of the model than those produced by FiSAT program (Table 3). Although all methods well fitted the model ($r^2 = 0.999$).

Estimated $L_\infty$ in the present study by both methods was lower than that recorded for the whole Mediterranean Sea (36 cm) by Bauchot and Hureau, (1986). In spite of the different methods used for ageing it is possible to achieve certain agreement of growth pattern of bogue from various localities of Mediterranean Sea (Table 5). The variability in growth may result from several factors including difference in mortality rates, environmental conditions or genetic variations (Dutka-Gianelli and Murie, 2001).

FiSAT program (fish stock assessment tools) has been developed to provide estimate of growth rate. This program became most commonly used. The available method for ageing provides a powerful tool for the study of growth patterns in natural populations. But the tools need to use with care and with a critical awareness of their limitation. In the present study, data were collected from Trawl and purse seine fishing methods all over the year on weekly bases covering small and large fishes in the landings to overcome the gear and size selectivity. There is an agreement in the number of determined age groups and in length at age values between the results of the two methods. Moreover, the values of growth performance ($\Omega'$) for the present study estimated from growth parameters that were calculated from length-at-age data as determined by scales and those by length frequency analysis are so close to each other, which confirms the validity and reliability of the growth parameters calculated from length-at-age data by analysis of length frequency (Pauly, 1979).

Age composition determined from scale reading or Bhattacharya methods results, revealed that age group III predominated the catch followed by age group II among the six age groups recorded (both were constituted about 56 and 87% from the total catch for data revealed by back calculated lengths at ages and FiSAT program respectively). The length at first maturity was estimated by 12.9 cm at the end of the first year of life for the same species of the present study area (unpublished data). This can lead to say that $Boops boops$ population of the present study area could spawn at least once per life and generally is moderate exploited and should keep the present level of fishing effort for stock conservation purpose. Similar recommendation reached for off Alexandria population by Allam (2003).

CONCLUSION

From the present study, even when age determination is possible from scales; using the length frequency analysis (LFA) might reduce the great effort in age determination needed by hard structure if we overcome the disadvantage of LFA method; for example, sampling bias, such as a small number of younger and older fish, gear and site selectivity that makes modal separation difficult (Gallucci et al., 1996).
Table (3): Von Bertalanffy growth formula (V.B.F.) parameters $L_\infty$, $K$, $t_0$, and growth performance index $\dot{e}$ for *Boops boops* of Western Mediterranean Coast of Egypt derived from scales and length frequency analysis length at age data. ($r^2$ is correlation coefficient and $P$ is significance level)

<table>
<thead>
<tr>
<th>VonBertalanffy growth parameters</th>
<th>Ford-Walford</th>
<th>FiSAT-II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scales</td>
<td>Bhattacharya</td>
</tr>
<tr>
<td>$L_\infty$</td>
<td>31.9</td>
<td>30.5</td>
</tr>
<tr>
<td>$K$</td>
<td>0.148</td>
<td>0.192</td>
</tr>
<tr>
<td>$t_0$</td>
<td>-1.527</td>
<td>-0.993</td>
</tr>
<tr>
<td>$\dot{e}$</td>
<td>2.177</td>
<td>2.251</td>
</tr>
<tr>
<td>$r^2$</td>
<td>0.9996</td>
<td>0.9993</td>
</tr>
<tr>
<td>$P$</td>
<td>2.6E-07</td>
<td>7E-07</td>
</tr>
</tbody>
</table>

Table (4): Length-at-age for *B. boops* estimated by different ageing methods from some localities in the Mediterranean Sea.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Age groups</th>
<th>Source &amp; localities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Otoliths</td>
<td>14.7</td>
<td>17.7</td>
</tr>
<tr>
<td>Scales</td>
<td>12.8</td>
<td>14.7</td>
</tr>
<tr>
<td>Scales</td>
<td>10.2</td>
<td>13.3</td>
</tr>
<tr>
<td>Scales</td>
<td>9.3</td>
<td>11.3</td>
</tr>
<tr>
<td>Scales</td>
<td>9.7</td>
<td>12.9</td>
</tr>
<tr>
<td>Bhattacharya</td>
<td>9.5</td>
<td>13.4</td>
</tr>
</tbody>
</table>
Table (5): Growth parameters ($L_{\infty}$, K and $t_0$), growth performance ($\bar{\Omega}$) and using aging methods of B. boops from some localities in Mediterranean Sea.

<table>
<thead>
<tr>
<th>Region</th>
<th>Growth parameters</th>
<th>$\bar{\Omega}$</th>
<th>Aging Methods</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L_{\infty}$</td>
<td>K</td>
<td>$t_0$</td>
<td></td>
</tr>
<tr>
<td>Adriatic</td>
<td>33.2</td>
<td>0.17</td>
<td>-1.48</td>
<td>2.28 Otoliths</td>
</tr>
<tr>
<td>Adriatic</td>
<td>33.9</td>
<td>0.16</td>
<td>-1.46</td>
<td>2.2 Bhattacharya</td>
</tr>
<tr>
<td>Cyprus</td>
<td>24</td>
<td>0.53</td>
<td>-0.45</td>
<td>Scales</td>
</tr>
<tr>
<td>France</td>
<td>31.1</td>
<td>0.18</td>
<td>0</td>
<td>2.2</td>
</tr>
<tr>
<td>Egypt</td>
<td>29.8</td>
<td>0.18</td>
<td>-1.33</td>
<td>2.2 Scales</td>
</tr>
<tr>
<td>Egypt</td>
<td>31.7</td>
<td>0.15</td>
<td>-1.78</td>
<td>2.19 Scales</td>
</tr>
<tr>
<td>Egypt</td>
<td>33.5</td>
<td>0.09</td>
<td>-2.64</td>
<td>2.00 Scales</td>
</tr>
<tr>
<td>Egypt</td>
<td>31.9</td>
<td>0.15</td>
<td>-1.53</td>
<td>2.18 Scales</td>
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<tr>
<td>Egypt</td>
<td>29.7</td>
<td>0.25</td>
<td>-0.70</td>
<td>2.34 Bhattacharya</td>
</tr>
</tbody>
</table>

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