

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

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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 otoliths 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_n) 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):

$$GI = (R - r_{max}) / (r_{max} - r_{max-1})$$

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:

$$TL = a + b R$$

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):

$$L_n = r_n (TL - a) / R + a$$

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_∞ 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:

$$\ln(N_{i+1}) - \ln(N_i) = a_j + b_j \cdot L_i$$

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:

$$\bar{L}_j = -a_j / b_j$$

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_{∞} and K were estimated by linear regression between L_t and L_{t+1} , as

$$L_{\infty} = a / 1 - b \quad \text{and} \quad K = -\log_e b$$

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_{∞} . This subroutine allows non-linear estimation of growth parameters from length-at-age data.

The Von Bertalanffy plot is used to estimate t_0 from the known age/length data and estimated L_{∞} and K , the method is based on the regression analysis of the following formula:

$$-\ln (1 - L_t / L_{\infty}) = -K * t_0 + K * t$$

Where: the age t is the independent variable (x) and $(-\ln (1 - L (t) / L_{\infty}))$ is the dependent variable (y) of the linear regression.

Growth performance (\emptyset') was estimated using the empirical equation of (Pauly and Munro, 1984):

$$\emptyset' = \log_{10} k + 2 \log_{10} (L_{\infty})$$

Where: K and L_{∞} 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 indices (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 group IV.

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 ($P < 0.05$).

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

Age group	No	Length at the end of each year of life (cm)					
		L1	L2	L3	L4	L5	L6
I	30	<u>9.8</u>					
II	78	9.7	<u>13</u>				
III	101	9.6	13.0	<u>15.6</u>			
IV	53	9.6	12.9	15.5	<u>17.6</u>		
V	48	9.6	12.9	15.5	17.5	<u>19.5</u>	
VI	9	9.6	12.9	15.5	17.6	19.5	<u>21.4</u>
Average Length (cm)		9.7	12.9	15.5	17.6	19.5	21.4
Annual increment		9.7	3.2	2.6	2.1	1.9	1.9
% of increment		45.3	15.0	12.1	9.8	8.9	8.9

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.

Age Groups	Computed mean length (cm)	s. d	Population	S.I.
I	9.49	1.08	99	n.a.
II	13.43	1.27	1780	3.35
III	16.16	1.24	2690	2.18
IV	18.37	0.80	540	2.17
V	20.50	0.80	38	2.66
VI	22.50	0.98	7	2.25

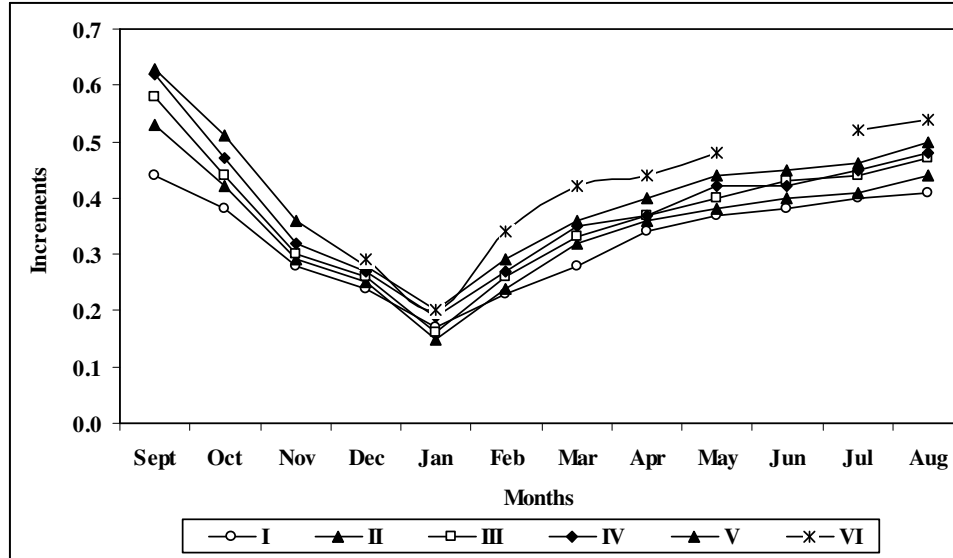


Figure (1): Monthly marginal growth increment (MGI) for the scale of *B. boops* in Western Mediterranean Coast of Egypt during 2003-2004.

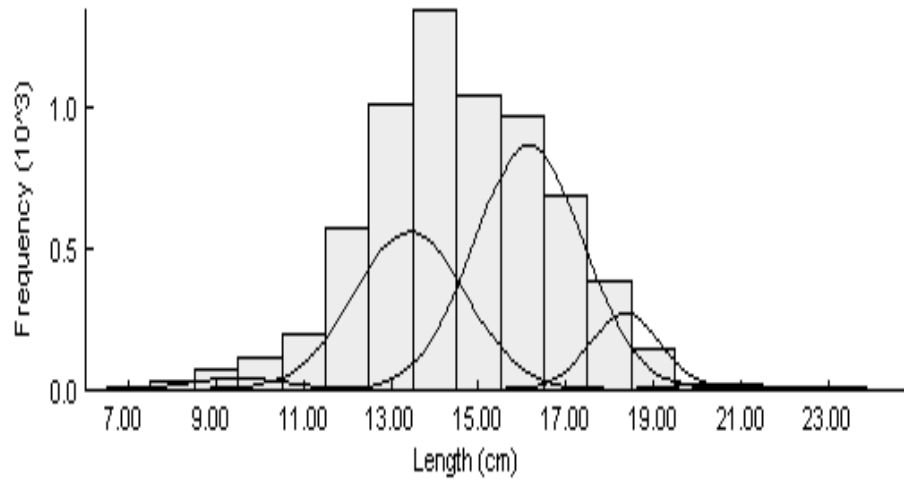


Figure (2): Length distribution of *B. boops* separated by Bhattacharya method from the Western Mediterranean Coast of Egypt during 2003-2004.

Estimates of Von Bertalanffy growth parameters L_{∞} , K and t_0

Asymptotic length (L_{∞}) 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_{∞} , t_0 and lowers K than FiSAT program as shown in table 3.

Theoretical growth in length

Growth parameters L_{∞} , K and t_0 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:

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

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

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

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

Estimates of phi-prime (ϕ')

Phi-prime (ϕ') 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_{∞} , 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).

Boops 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,

1989). 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_{∞} , 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_{∞} , t_0 and lower ones for K than age at length subroutine (FiSAT program). The data resulted from Ford-Walford methods gives better 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_{∞} 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 (Φ') 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 12.9cm 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 K , L_{∞} , t_0 and growth performance index ϕ 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)

VonBertalanffy growth paramters	Ford-Walford		FiSAT-II	
	Scales	Bhattacharya	Scales	Bhattacharya
L_{∞}	31.9	30.5	28.13	29.7
K	0.148	0.192	0.18	0.25
t_0	-1.527	-0.993	-1.131	-0.701
ϕ	2.177	2.251	2.153	2.343
r^2	0.9996	0.9993	0.9994	0.9983
P	2.6E-07	7E-07	5.4E-07	43E-07

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

Methods	Age groups						Source & localities
	I	II	III	IV	V	VI	
Otoliths		14.7	17.7	20	22	23.8	Alegria-Hernandez, (1989)(Adriatic)
Bhattacharya		14.1	17	19.4	21.5	23.2	Alegria-Hernandez, (1989)(Adriatic)
Scales	12.8	14.7	17.2	20			Livadas (1989) (Cyprus)
otoliths & scales	11.2	14.9	17.8	20.1			Soliman, et al (1982) (Egypt)
Scales	10.2	13.3	15.93	18.3	20.2	21.7	Hassan (1990)(Egypt)
Scales	11	14	16.35	18.6	20.5		Allam, (2003) (Alexandria-Egypt)
Scales	9.3	11.3	13.3	14.9	16.4	17.9	Abdel-Rahman (2003) (Alexandria- Egypt)
Scales	9.7	12.9	15.5	17.6	19.5	21.4	present study (Western-Egypt)
Bhattacharya	9.5	13.4	16.2	18.4	20.5	22.5	present study (Western-Egypt)

Table (5): Growth parameters (L_{∞} , K and t_0), growth performance (\emptyset') and using aging methods of *B. boops* from some localities in Mediterranean Sea.

Region	Growth parameters			\emptyset'	Aging Methods	Source
	L_{∞}	K	t_0			
Adriatic	33.2	0.17	-1.48	2.28	Otoliths	Alegria-Hernandez (1989)
Adriatic	33.9	0.16	-1.46	2.2	Bhattacharya	Alegria-Hernandez (1989)
Cyprus	24	0.53	-0.45		Scales	Livadas (1989)
France	31.1	0.18	0	2.2		Campillo, (1992)
Egypt	29.8	0.18	-1.33	2.2	Scales	Hassan (1990)
Egypt	31.7	0.15	-1.78	2.19	Scales	Allam, 2003
Egypt	33.5	0.09	-2.64	2.00	Scales	Abdel-Rahman (2003)
Egypt	31.9	0.15	-1.53	2.18	Scales	present study
Egypt	29.7	0.25	-0.70	2.34	Bhattacharya	present study

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