Mediterranean Marine Science

Vol 4, No 1 (2003)

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doi: 10.12681/mms.244

Mediterranean Marine Science
Vol. 4/1, 2003, 87-96

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S. M. ALLAM

National Institute of Oceanography and Fisheries,
Kayet Bay, Al-Anfoushy, Alexandria, Egypt
e-mail: allamsm@hotmail.com

Abstract

Age and growth of Boops boops (L.) from the Mediterranean Sea off Alexandria were estimated from scales. No significant difference in growth was found between male and female. Back-calculated lengths at annulus formation for combined sex were 10.97, 14.03, 16.39, 18.56 and 20.51cm TL. The estimated von Bertalanffy growth parameters were $L_\infty = 31.68$ cm, $K = 0.1531$ year^{-1} and $t_\circ = -1.7838$.The length-weight relationship was $W = -2.1548L^{3.1031}$. Total mortality (Z), natural mortality (M) and fishing mortality (F) were 1.283, 0.458 and 0.824 year^{-1} respectively. The exploitation rate (E) was 0.464. A Beverton-Holt yield-per-recruit model indicated that the maximum yield-per-recruit was 21.06 g when fishing mortality was 2.4 and the current fishery harvests approximately 95% of the potential yield.

Keywords: *Boops boops*, Mediterranean, growth, mortality and yield-per-recruit.

Introduction

Boops boops is a demersal or semipelagic species inhabiting inshore waters above various bottoms (sand, mud, rocks or posidonia beds) in the whole Mediterranean, eastern and western Atlantic (BAUCHOT & HUREAU, 1986). In the eastern Atlantic (from British Isles to Angola) *Boops boops* forms schools far from the coast at the surface (at night) or down to 200 m, normally above 100 m (BRAVO DE-LAGUNA, 1982).

Off Alexandria coast, *Boops boops* is one of the most abundant species caught mainly in purse seine net ("shanshoulla") (HASSAN, 1990). It constitutes 9.92 % of the total commercial catch landed at Alexandria (ALLAM *et al.*, 1998).

In the Mediterranean Sea, age and growth of bogue, *Boops boops*, have been studied by ANATO & KTARI (1986) along the Tunisian coast, HERNANDEZ (1989) in the Central Adriatic Sea and HASSAN (1990) along the Egyptian coast, from Rashid to Salloum, while length-weight relationship was studied by BOTROS *et al.* (1985) in western Libyan and STERGIO & MOUTOPOULOS (2001) in Greece. GONÇALVES *et al.* (1997) studied the length-weight relationship of *B. boops* and other demersal fish along the south coast of Portugal.

The present study aimed to model age and growth of *Boops boops* off Alexandria and to estimate growth performance, mortality parameters, exploitation rate and yield-per-recruit in order to evaluate the state of this fish stock.

Materials and Methods

Individuals of *Boops boops* were collected from the commercial catch of purse seine net ("Shanshoulla") landed at Alexandria during the period from March to December 1999. For each fish, sex, maturity stages, total length (cm), total and gutted body weight (g) were recorded. Scales were removed from under the pectoral fin of the left side of the fish, cleaned and viewed with low-power microscope (16 X). Scale radius and distance from focus to each ring were measured with an ocular micrometer. Mean values of scale radius were calculated for each 1-cm length group. The scale radius-total length relationship was determined by least square method. Correction for back-calculated fish length-at-each year of life were calculated by Lee formula:

$$L_n = S_n\,(TL - a) / S + a$$

where L_n is the length (cm) at age 'n', TL is the total fish length (cm), Sn is the radius of annulus 'n', S is the scale radius and a is the intercept of the regression line. Mean observed length-at-age and back-calculated lengths were computed. Length-weight relationships were determined using the formula

$$W = a\,L^b$$

where W is weight (g), L is total length (cm), b is the length-weight factor and a is a constant. The von Bertalanffy growth model was fitted to back-calculated length–at-age. The model was of the form:

$$L_t = L_\infty\,(1 - e^{-k\,(t - t_o)})$$

where L_t = length at time t (years), L_∞ = theoretical maximum length (cm), K = growth coefficient and $t_\circ$ = theoretical time at which L = 0. The values of all growth parameters (L_∞, K and $t_\circ$) were estimated according to GULLAND (1964).

In order to compare different estimations of growth parameters, the empirical equation of growth performance,

$$\varnothing = \log_{10} k - 2 \log_{10} (L_\infty),$$

of PAULY & MUNRO (1984) was used. Maximum age (tmax) was estimated after PAULY (1983) as:

$$t_{max} = 3 / k + t_o.$$

Mortality rate (Z) was calculated from the catch curve as described in Ricker (1975). Natural mortality coefficient (M) was estimated from the equation of PAULY (1980) as follows:

$$\text{Log } M = -0.0066 - 0.279 \log10 L_\infty + \\ + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where L_∞ and K are the parameters of the von Bertalanffy growth model and T is the mean water temperature, here set at T = 21.65°C (MAIYZ & SAID, 1988). The difference between total mortality coefficient (Z) and the natural mortality coefficient (M) gave an estimate of fishing mortality (F):

$$F = Z - M.$$

Survival rate (S) was estimated from the equation $S = e^{-z}$ (RICKER, 1975). According to CUSHING (1968), the rate of exploitation E = F*A / Z where F and Z are fishing and total mortality and A = 1 – S.

Length at first capture (L_c) was determined using BEVERTON & HOLT (1957) equation of $L_c = L^- - K\,(L_\infty - L^-) / Z$, where L_c is the length at first capture, L^- was the mean length of fish in the catch sample, K and L_∞ are parameters of the von Bertalanffy growth equation and Z is the instantaneous mortality rate. The corresponding age at first capture (t_c) was calculated as

$$t_c = -1/K \log10 (L_\infty - Lc / L_\infty) + t_o.$$

The BEVERTON & HOLT (1957) model of yield-per-recruit was estimated according to GULLAND (1969) as follows:

$$Y / R = F (e^{-M(tc-tr)})$$
$$W_\infty \{1/Z - 3S / (Z + K) +$$
$$+ 3 S^2 / (Z+2K) - S^3/ (Z+3K)\},$$

where Y/Z is yield-per-recruit, F is the fishing mortality coefficient, M is the natural mortality coefficient, t_c is the mean age at first capture, t_r is the mean age at recruitment, W_∞ is the asymptotic weight, Z is the total mortality, K is the growth coefficient and

$$S = e^{-K(tc-to)}.$$

Results

Age and growth

The frequency distribution of age reading for all *Boops boops* is given in table 1. Boops boops population ranged in age from 1 to 5 years. The majority of fishes were found to belong to 2 and 3 years old (33.25 % and 37.06 %). Fishes of 5 years old contributed only 2.85 %.

The relationship between scale radius and total fish length was found to be linear (Fig. 1). No significant difference was found in this relationship between male and female ($F = 0.55$ at $df_{1,20}$, $P > 0.200$). Therefore this

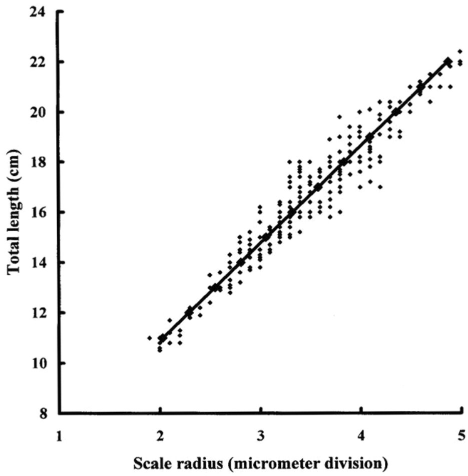

Fig. 1: Scale radius – total length relationship of *Boops boops*.

Table 1
Frequency distribution of age readings of *Boops boops*.

Fish length group (cm)	Number of fish at age (years) 1	2	3	4	5	Total number
11	16					16
12	18					18
13	9	6				15
14	2	43				45
15		61	6			67
16		21	57			78
17		9	45	8		62
18			40	14		54
19			6	39	1	46
20			2	7	3	12
21					6	6
22					2	2
Total number	45	140			156	68
12	421					
Percent	10.69	33.25	37.06	16.15	2.85	-
Mean length	12.02	14.79	16.82	18.57	20.58	16.02
S.D.	±0.87	±0.96	±0.99	±0.89	±0.90	±2.23

relationship was computed for combined sex as L = 3.163 + 3.863S (r^2 = 0.986, n =292). The intercept of this equation (3.163) was used as a correction factor in back-calculated length-at-end of each year of life (Table 2). Since the back calculated length-at-age for males and females were nearly equal (Table 2), the sexes were pooled. *Boops boops* grew to 10.97 cm TL in the first year of growth, reaching a maximum length of 20.51 cm in the fifth year (Table 2). The maximum growth rate was in the first year (53.49 %) and then decline with age.

Length-weight relationship was highly correlated with coefficients ranging from 0.996 for females to 0.982 for males (Fig. 2). In spite of the rate of putting in weight for females was slightly higher than that of males for the same length group, the analysis of co-variance revealed a highly insignificant difference between them (F = 0.2 at $df_{1,20}$ P>0.200). Sexes were therefore pooled and the regression representing this relationship was described by W = -2.1548 $TL^{3.1031}$ (r^2 = 0.996, n =421). The weight of fish at different ages was determined by using length-weight equation.

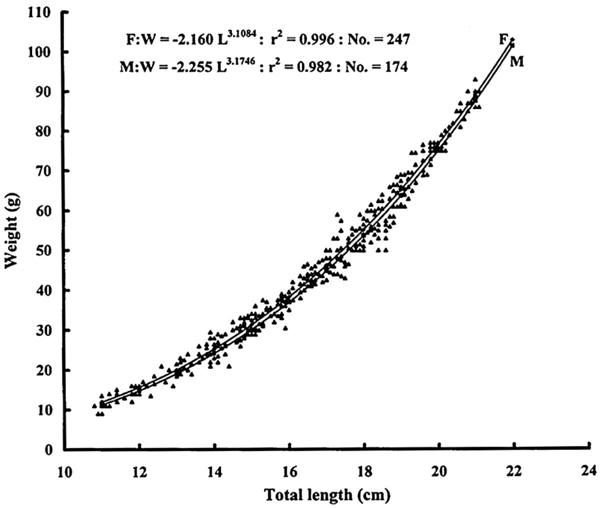

Fig. 2: Length (L) – weight (W) relationship of males and females of *Boops boops*.

Table 2
Back-calculated and theoretical length and weight of *Boops boops* at different years.

	Age (years) 1	2	3	4	5
Males					
Number	4	13	21	12	2
Mean back-calculated length(cm)	10.74	14.03	16.45	18.41	20.90
Females					
Number	11	29	33	18	5
Mean back-calculated length(cm)	11.06	14.03	16.35	18.66	20.35
Combined sex					
Number	15	42	54	30	7
Mean back-calculated length(cm)	10.97	14.03	16.39	18.56	20.51
Theoretical Length (cm)	10.99	13.93	16.45	18.61	20.46
Back-calculated weight (g)	12.28	25.79	41.39	60.48	81.90
Theoretical weight (g)	12.27	25.2	41.85	60.94	81.38

The rate of putting on weight was minimal in the first year (14.99 %) and then increased as the fish got older reaching maximum increment at fifth year (26.15 %; Table 2).

The von Bertalanffy growth equation describing *Boops boops* growth in length was:

$$TL\,t = 31.68\,(1- e^{-0.1531\,(t + 1.7838)})$$

The length-at-age calculated form this equation was close to the back-calculated length (Table 2). The length-weight relationship was used to convert the asymptotic length (L_∞ = 31.68 cm TL) to the corresponding asymptotic weight (315.3 g). The von Bertalanffy equation for growth in weight was described by the following equation:

$$Wt = 315.3\,(1 - e^{-0.1531\,(t + 1.7838)})^{3.1031}$$

The theoretical weight-at-age and back-calculated weight agrees closely (Table 2).

The maximum theoretical age attained by this fish species was 17.81 years. The growth performance was estimated as $\varnothing$ = 2.19.

Mortality and exploitation rate

The instantaneous total mortality coefficient (Z) was estimated from the catch curve as 1.283 (Fig. 3). The natural mortality (M), fishing mortality (F) and annual mortality (A) were estimated to be M = 0.458, F = 0.824 and A= 0.722 year^{-1}. The exploitation rate was estimated as E = 0.464.

Length and age at recruit and first capture

The length at recruitment (L_r) was graphically determined from the cumulative curve of recruit proportion at different length (Fig. 4). The length obtained was L_r = 11.7 cm. The corresponding age was t_r = 1.23 year. The mean length of the commercial catch was estimated as 16.02 cm TL for fishes ranging from 11 to 22 cm TL (Table 1). Consequently, the length at first capture was estimated as L_c = 14.15 cm TL and the corresponding age (T_c) was 2.08 years.

Yield-per-recruit

The yield-per-recruit of *Boops boops* (Fig. 5) increases rapidly as the fishing mortality

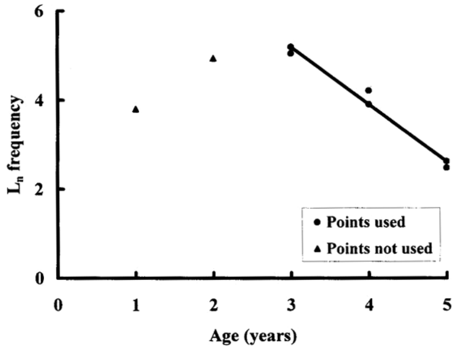

Fig. 3: Catch curve of *Boops boops.*

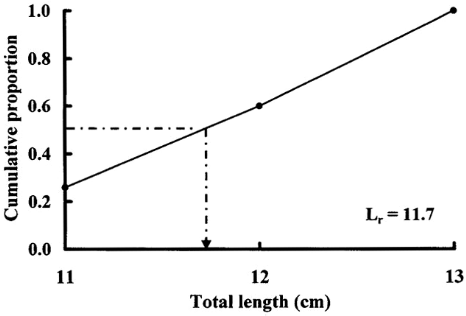

Fig. 4: Cumulative curve of recruit proportion at different lengths of *Boops boops.*

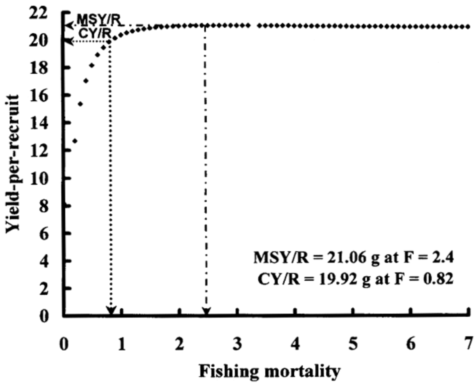

Fig. 5: Yield-per-recruit of *Boops boops*.

increases reaching a maximum value (MSY/R = 21.06 g) at a fishing mortality F = 2.4, after which the yield-per-recruit was more or less stable with further increase in fishing mortality. At the present level of fishing mortality (F = 0.824), age of first capture (T_c = 2.08 year), and natural mortality (M = 0.458), the current yield-per-recruit (CY/R) was estimated to be 19.92 g.

Discussion

Boops boops attain their maximum size slowly (K= 0.1531) and have a long life span (17.8 years). These estimates agree with that of HERNANDEZ (1989) who gives a maximum age of 16.6 years for *B. boops* in the Central Adriatic Sea.

Five years were separated in the present study. The mean length-at-age values estimated by different authors are represented in Table 3. The length-at-age for 1 to 5 years obtained in the present study are very similar to that obtained in 1977-1978 for *B.boops* caught from Rashid to Salloum (HASSAN, 1990). The absence of fishes of six-years old in the present study was mainly due to disappearance of larger fishes from the catch (from 22 to 25 cm TL) and also to sampling locality. The length-at-age, however varied from various localities (Table 3). The variability in growth of *B. boops* may result from several factors including differences in mortality rates, environmental conditions or genetic variations (DUTKA-GIANELLI & MURIE, 2001).

Boops boops grew quickly in length during the first year of life reaching 53.49 % of its final growth; this was followed by a reduced growth rate that coincided with sexual maturity (one year for both males and females). EZZAT *et al.* (1992) stated that during the first year of life most of food consumed is used for growth in length while at sexual maturity food is used for maintenance of gonad formation and growth in weight. Therefore, the increment in weight of *B. boops* was slower in the first year of life then increased to reach its maximum value at 4 and 5 years old (23.31 and 26.15 %).

The length-weight relationship of *Boops boops* shows a positive allometric growth. The same growth was observed for *B. boops* in western Libya (BOTROS *et al.*, 1985) and in central Adriatic Sea (HERNANDEZ, 1989). The parameters of length-weight relationship estimated in the present study fall within the result of the previously reported values in other localities (Table 4). The length-weight relationship given by HASSAN (1990) was based on gutted body weight. For comparison, length-gutted body weight relationship was computed in the present study. The factor (b) of this equation (3.2249) was greater than the value of 2.8306 recorded in 1977-1978 (HASSAN, 1990). On the other hand, the

Table 3
Mean length-at-age of *Boops boops* given by various authors.

Age (Years)	Anato &Ktari, 1986. Tunisian coast Scales & Otoliths	Hernandez, 1989. Central Adriatic Otoliths	Hassan, 1990. Egyptian coast Scales	Present study Off Alexandria Scales
	SL (TL)*	TL	TL	TL
1	7.67 (10.24)	-	10.16	10.97
2	9.79 (12.78)	14.73	13.29	14.03
3	13.02 (16.63)	17.53	15.93	16.39
4	15.62 (19.73)	20.04	18.27	18.56
5	16.74 (21.07)	22.03	20.24	20.51
6	18.99 (23.76)	23.80	21.65	-
7	20.19 (25.19)	-	-	-
8	21.10 (26.27)	-	-	-

* SL = 0.838 TL – 0.9172, given by these authors

Table 4
Comparison of length -weight parameters for combined sex of *Boops boops* from different localities.

Locality	A	B	No	Length range	Source
Egyptian coast from Rashid to Salloum	-1.844	2.8306*	2609	8 – 25 cm TL	Hassan,1990
Western Libya	-2.1554	3.1125	-	-	Botros *et al.*,1985
Tunisian coast	0.02423	2.8874	785	8 – 22 cm TL (=10.6 – 27.4 cm TL)	Anato &ktari, 1986
Greece	0.0149	3.093	256	9.6 24.3 cm TL	Stergiou & Moutopoulos, 2001
Central Adriatic Sea	6.44×10^{-5}	3.113	165	12.8 – 23.0 cm TL	Hernandez, 1989
Spanish coast of Western Mediterranean	0.0082	3.0	228	12.4 -26.6 cm TL	Merella *et al.*,1997
South coast of Portugal	0.0083	3.037	603	15.8 – 35.3 cm TL	Gonçalves *et al.*, 1997
Egyptian coast off Alexandria	-2.1548 -2.3373	3.1031 3.2249*	435 435	10.5 – 22.4 cm TL 10.5 – 22.4 cm TL	Present study

* Calculations based on gutted weight

gutted body weight-at-length in the present study was lower than the corresponding value given in 1977-1978, but the difference was not significant.

The asymptotic length of 31.68 cm estimated for *Boops boops* was considerably greater than the maximum observed length of 22.4cm and 26cm TL reported before in 1977-1978 (HASSAN, 1990). The maximum length of B. boops recorded was less than that value recorded in other localities (Table 5). BAUCHOT & HUREAU (1986) assigned a maximum length of 36 cm to *B. boops* from the whole Mediterranean Sea.

The von Bertalanffy growth parameters of *Boops boops* reported by various authors are shown in Table 5. The growth coefficient (K) was generally low, ranging from 0.1107 to 0.1779 per year and the asymptotic length ranged from 29.97 to 39.6 cm TL. It can be concluded that the growth pattern of *B.boops* from the Egyptian Mediterranean coast off Alexandria appears to be smaller than that of *B. boops* population inhabiting western Mediterranean Sea.

The estimate of growth performance (∅ = 2.19) showed best agreement with the value obtained in 1977-1978 (∅ = 2.20; HASSAN, 1990). Also, this value lies within the corresponding values in other localities (Table 4).

Table 5
Comparison of von-Bertalenffy growth parameters, maximum length, Growth performance (∅) and aging method for combined sex of *Boops boops* from different localities.

Locality	L_∞	K	To	Max. length	∅	Aging method	Source
Egyptian coast, from Rashid to Salloum	29.79 cm TL	0.1779	-1.3323	26 cm TL	2.2	Scales	Hassan, 1990
Tunisian coast	32.27 cm TL (= 39.6 cm TL)	0.1107	-1.6882	22 cm TL	2.07	Scales & otoliths	Anato & Ktari,1986
Central Adriatic Sea	33.89 cm TL	0.167	-1.296	25 cm TL	2.28	Otoliths	Hernandez, 1989
Egyptian coast off Alexandria	31.68 cm TL	0.1531	-1.7838	22.4 cm TL	2.19	Scales	Present study

The mean observed length of the commercial catch of *Boops boops* (16.02cm) was lower than that value obtained in 1977-1978 (17.26 cm; HASSAN, 1990). The decreasing in the mean length may be due to disappearing of larger fish from the catch (from 22 to 25 cm) and different fishing areas.

At the present level of fishing mortality (F = 0.824), age at fish capture (T_c = 2.08 year) and natural mortality (M = 0.458), the current yield-per-recruit (CY/R) was estimated to be 19.92 g. This means that the level of fishing mortality (F = 0.824) was greatly lower than that which gives the maximum yield-per-recruit (MSY/R = 21.06 at F = 2.4) by about 65.83 %. If the current fishing mortality (0.824) increases to maximum fishing mortality (2.4) the yield-per-recruit will be increased only from 19.92 to 21.69 by about 5.41 %. Also, the estimates of exploitation rate (E = 0.464) showed that *Boops boops* stock was optimally exploited (GULLAND, 1971). Therefore, keeping the fishing of bogue at the present level of effort will permit harvest of the most of the potential yield (94.59 %) and avoid stock-recruitment problems.

Conclusion

Boops boops is one of many species (mainly sardine and mackerel) targeted by purse seine net, therefore an increase in effort to harvest other species will also affect the bogue, B. boops, stock.

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