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Estimation of the exploitable biomass and the reference biological point, $F_{0.1}$, of bogue *Boops boops* L., in the bay of Bou-Ismail, centre Algerian

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Abstract

A study of age and growth of Mediterranean bogue ; *Boops boops (Linneaus, 1758)* from Algerian Mediterranean bay of Bou-Ismail was carried out during the period from Februaries 2013 to January 2014. Five age groups could be separated by Bhattacharya's method from length frequency data. Mean length by the end of each year of life (cm) of *B. boops* from the study area were found to be 13.87, 17.13, 21.49, 24.78, and 27.44 cm for age groups from I to V respectively. The estimated von Bertalanffy growth parameters were $L\infty$= 29.66 cm, K= 0.33 year^{-1} and t_0= 0, $W\infty$=209.79 g .The length-weight relationship was W = 0.016 $L^{2.798}$. Total mortality (Z), natural mortality (M) and fishing mortality (F) were 1.02, 0.36 and 0.66 year^{-1} respectively the. VIT software (Lleonart and Salat, 2000) was used to determine biomass, virtual population analysis (VPA), and yield or productivity per recruit. The exploitable biomass of the bogue was estimated at 278.87 tons by the V.P.A. The yield per actual recruit (Y/R = 24.864 g) is very close to the MSY or Y_{max} /R (25.092 g). This result indicates that the bogue stock is in a state of full exploitation. The biomass per actual recruit (B/R = 55.863 g), which refers to the mean annual biomass of survivors as a function of fishing mortality, is higher than the maximum sustainable biomass (B_{max} /R = 48.606 g). Given the state of full exploitation of the bogue stock, an adjustment of the ratio Y_{actual} /R is recommended. To do this, fishing effort is set at $F_{0.1}$, and the values obtained for $Y_{0.1}$/R and $B_{0.1}$/R then correspond to 22.799 g and 80.18 g, respectively.

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Introduction

Bogue, *Boops boops (L),* family Sparidae, is an important species in the Mediterranean Sea, (Bauchot and Hureau,1984). is a commercial species inhabiting coastal waters in different habitats and is intensively fished throughout the Mediterranean (Monteiro *et al.,* 2006; Katsanevakis *et al*., 2010). 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). bogue is captured on line gear, with bottom trawls, purse seines, beach seines, trammel nets, and gillnets In the Mediterranean Sea.

The bogue has been the subject of many studies in the Mediterranean, such as those of Anato and Ktari(1986) along the Tunisian coast, Hernandez(1989) in the Central Adriatic Sea and Hassan(1990) along the Egyptian coast, from Rashid to Salloum, Botros *et al*.(1985) in western Libyan and Stergioand Moutopoulos(2001) in Greece. Gon, Calves *et al*. (1997) along the south coast of Portugal.

In Algeria, the biology and the exploitation of the bogue have the subject of several papers. Thes include the works of Chali-Chabane (1988) in centre Algeria, Kherraz (2011) in west Algeria.

In the bay of Bou-Ismail, situated between Cape of Chenoua in the West 2° 20'' E and Cape Caxine in the East 2° 55'' E, production of bogue continues to decrease. To better understand the decline in bogue production in the centre region of Algeria, we have found useful to undertake the study of the state of exploitation, by adjusting its production to $F_{0.1}$. This level value of fishing, still known as F cible, is one of the Points of biological reference, TRP (Target Reference Points). It allows the largest catches by weight, while safeguarding the conservation of the stock (Caddy, 2009).

The purpose of the present work was will allow access to and control over resources and to maximize the catches in weight, while ensuring their availability and the renewal of their stock.

Material and methods

Collection of data

A total of 1372 individuals of both sexes were collected biweekly from the commercial landings of the purse-seine fleet at the fishing port of the bay of Bou-Ismail from February 2013 to January 2014. The individuals measured between 9 and 29 cm, and were divided into 21 length classes with a step of 1 cm. Total length (TL) was measured to the nearest mm. Total body weight (BW) and eviscerated body weight (BW_{ev}) were measured to the nearest 0.01g. Sex was macroscopically identified.

Analysis of data

Data were consequently used to estimate the following biological parameters: (1) length–weight relationship; and (2) growth parameters. Length-weight relationships

To analyse length frequency we used $L\infty$, K, t0 of von Bertalanffy growth equation, where K is the curvature parameter, $L\infty$ is the asymptotic length, t_0 is theoretical age. Length–weight relationship was calculated using the equation:

$$BW = a\ (TL)b$$

The parameters a (intercept) and b (slope) were estimated by linear regression analyses based on the natural logarithms transformed equations

$$\text{Ln } BW = b \text{ Ln}TL + \text{Ln } a$$

The regression coefficient is generally between 2.5 and 3.5 and the relation is said to be isometric when it is equal to 3 (Ecoutin *et al*., 2005). A t–test was used to determine whether the ***b*** of relationships was significantly different from 3 using the equation described by (Schwartz, 1992).

T_{L50} was defined as the smallest length interval at which 50% of the specimens were mature.Growth parameters and virtual population analysis.

To study the dynamics of the bogue stock in the study area we used two software packages published by the FAO. The first of these was FISAT (Gayanilo *et al.*, 2005). This software was used to assess essential parameters for population dynamics (age–length key, growth parameters and mortality rates). The second was VIT (Lleonart and Salat, 2000), a tool for the stock assessment based on the application of Length Cohort Analysis (LCA) together with a Yield per Recruit Analyses (Y/R) based on short series of data. This software uses pseudo–cohorts that may limit the reliability of results as the methodology assumes a steady state in the stock structure, and requires knowledge of the catches over one year only (Lleonart and Salat, 2000).Growth parameters were determined by length frequency analysis. Age–class distributions were separated using the method of Bhattacharya (1967) whose protocol of application was slightly modified by Gayanilo *et al.* (2005) (table 1). We chose this approach, firstly, because of the difficulties of age reading, due to the convex and thick aspect of the otolith, and secondly, on the basis of the recommendations of Campana (2001) and the working group DYNPOP of the CIESM (Abella *et al.* 1995; Aldebert and Recasens 1995; Alemany and Oliver 1995).

Table 1. Results of the age–length key of *B. boops* obtained by Bhattacharya method (1967) using FISAT II software (Gayanilo *et al.*, 2005).

Age (yr)	1	÷	3	4	5
Size (cm)	13.87	17.13	21.49	24.78	27.44

Total and natural mortality

For total mortality (Z), we retained only the method of Pauly 1984 – based on the curves of catches according to lengths – as it adapted best to the sample. The curve is defined according to Gayanilo *et al.* (2005) by the following equation: ln (Ni / Δti) = a+ b (ti) where Ni is the number of fish in length class **i**, **Δti** is the time needed for the fish to grow through length class **i**, **ti** is the age (or the relative age, computed with t0 = 0) corresponding to the mid–length of class **i**, and the arithmetic value of the slope bis an estimate of Z. Consequently, natural mortality (M) was estimated using Djabali *et al.* (1993) empirical equation based on the growth parameters, as follows:

Log M= -0.0278 - 0.1172 Log $L\infty$+ 0.5092 Log K, while the fishing mortality coefficient (F) was computed as F= Z – M.

Results

Age composition of sampling

The method of Bhattacharya (1967) enabled us to separate the sample of bogue into five cohorts in relation to lengths in (cm). All included both males and females (Table 1).

The FISAT II software used to calculate growth parameters enabled us to establish von Bertalanffy expression (1938).Using the t–test LWR indicated isometric growth in both sexes based on the comparison of two slopes < 1.96 for α = 5%. Estimated parameters of the LWR and growth are presented in Table 2.

The parameters of the length–converted catch curve were ln (Ni / Δti) = 10.319 – 1.019 (ti) (r^2 =0.992) and mortality estimates were Z = 1.02 yr^{-1} (Fig. 2), M = 0.36 yr^{-1} and F = 1.66yr^{-}

Table 2. Growth parameters (FISAT II, 2005) and estimated parameters of the length–weight relationships for *B.boops*, both sexes combined, in the bay of Bou-Ismail from February 2013 to January 2007: L∞. Asymptotic length; a. Equation intercept; b. Regression coefficient, slope; K. Curvature parameter; t_0.Theoretical age where $T_L = 0$; |t| cal. Statistical t–test based on the comparison of two slopes.

vB Growth parameters			Length–weight relationship			
L_∞(cm)	K (yr^{-1})	t_0 (yr)	*a*	*B*	*r*	|t| cal.(α = 5%)
29.66	0.33	0	0.016	2.798	0.996	0,098

Catches in number and weight

The results of the catches in number and weight of individuals according to class sizes (Table 3) show that the exploitation of bogue primarily involved individuals from the size class of 18 cm, corresponding to age 2 (Table 1).The annual average product was 15.07 tons, corresponding to catches of approximately $3 \cdot 10^5$ individuals. These results also show that size and age of catches averaged 17.988 cm and 2.989 years, respectively.

Table 3. Representation of catches in number and in weight of individuals according to size, obtained by the VIT (Lleonart & Salat, 2000), of *B. boops* from the bay of Bou-Ismail.

Size (cm)	Catches (number)	Catches (weight in tons)
9	1607,40	12031,72
10	4822,19	48441,27
11	14466,57	189642,92
12	45007,10	752256,34
13	90014,20	1881221,73
14	106088,16	2727125,01
15	218605,92	6810582,20
16	305405,32	11388717,62
17	292546,15	12921266,53
18	290938,75	15070683,87
19	170384,02	10272928,23
20	188065,38	13078986,99
21	136628,7	10891735,85
22	114125,15	10358390,95
23	90014,20	9247872,94
24	49829,29	5769085,45
25	38577,51	5003776,40
26	19288,76	2793057,68
27	14466,57	2325278,64
28	12859,40	2268817,03
29	1607,4	310100,64
Total	**2205347,91**	**124122000**
Mean age (yr^{-1})	**2,989**	
Mean size (cm)	**17,988**	

Analysis of fishing mortalities

Analysis of the fishing mortalities by length showed that the bogue ranging between 9 and 12 cm had a low F. Mortality then increased with size, reaching 0.16 yr^{-1}, for the 14 cm size. This peak also corresponded to the size at sexual maturity which was 13.6 cm. The two main peaks corresponded to 0.7 yr^{-1} and 0.78 yr^{-1}, class sizes 18 and 28 cm respectively (Table 3),(Fig. 1).

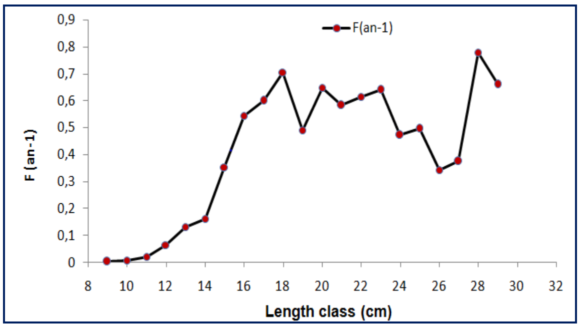

Fig. 1. Fishing mortalities according to the size, obtained by the LCA, of bogue stock,in the bay of Bou-Ismail.

VIT software makes it possible to calculate mortality by fishing (F*). This total value is essential to estimate the capture. F* binds the total annual capture to the average number of individuals the population, corresponding to an average mortality by fishing balanced by many individuals (Lleonart and Salat, 2000). The average fishing mortality (F) of 0.567 $yr^{-1}$was above the total fishing mortality (F*) that is 0.285 yr^{-1}. We can define the total fishing mortality F* as:

$$F^* = \frac{\sum_{i=1}^{n} C_i}{\sum_{i=1}^{n} \bar{N}_i} = \frac{\sum_{i=1}^{n} \bar{F}_i \ N_i}{\sum_{i=1}^{n} \bar{N}_i}$$

This can be explained by the fact that F* connects the total annual catch to the average number of individuals in the population. This trend in mortality tells us about the class sizes reached for fishing.

Analysis of biomass

The results of Lk8ength Cohort Analysis (LCA) based on pseudo–cohorts using length frequency data, and assuming a steady state showed that the exploitable average biomass of the bogue stock was 278,874.24 tons, of which 219.08 tons (~78%) were Spawning Stock. The size and the average age of catches were 17.988 cm and 2.989 years, respectively.

The total Biomass balance (D) was estimated at 226,817.96 tons. This corresponded to growth in weight of 194,824.05 tons (85.89 %), as compared to recruitment of only 31,993.9 tons (14.11%). The natural mortality (M) corresponded to 102,076.32 tons (45 %), while fishing mortality (F) was only 124,741.6 tons (55 %) (Table 4).

Table 4. Results of the LCA, obtained by VIT (Lleonart & Salat, 2000) according to the length of *B.boops* from the bay of Bou-Ismail.

Age critical current stock (year)	2.245
Mean age of current stock (year)	2.241
Age critical virgin stock (year)	3.56
Mean length of current stock (cm)	14.702
Length critical current stock (cm)	15.5
Length critical virgin stock (cm)	20.5
Number of recruits (R)	4992102.9
Mean biomass (tons)	278.874
Spawning stock biomass (tons)	219.0803
Total balanced biomass (D) (tons)	224.516
Turnover D/B mean (%)	80.51

Virgin stock (B_o) or carrying capacity was characterized by a respective size and critical age of 20.5 cm and 3.65 years, (Table 4). According to Caddy (1994), the virgin stock is regarded as a biological reference point (PRB). This stock corresponds to the average value in the long run of the biomass discounted in the absence of fishing mortality.

Yield and biomass per recruit

The current yield per recruit (Y/R = 24.864 g) was lower than the maximum yield per recruit (Y_{max} /R = 25.092 g). On the other hand, the biomass per recruit (B/R = 48.606 g),which expresses the annual average biomass of the survivors according to fishing mortality, was largely higher than the maximum sustainable biomass (B_{max}/R = 43.382 g). The values of $Y_{0.1}$/R and $B_{0.1}$/R, corresponding to $F_{0.1}$estimated at 0.6 yr^{-1}, were 22.799 and 80.18 g, respectively (Table 5, Fig. 2).

Table 5. Yield and biomass per recruit of *B. boops* from the gulf of Annaba, according to F, obtained by VIT (Lleonart & Salat, 2000): B/R. Biomass per recruit; Y/R. Yield per recruit;F. Fishing mortality.

Type of F	F (yr^{-1})	Y/R (g)	B/R(g)
F_0	0	0	197,347
$F_{0.1}$	0,6	22,799	80,18
F actuel	1	24,864	55,863
F_{MSY}	1,÷	25,092	48,606

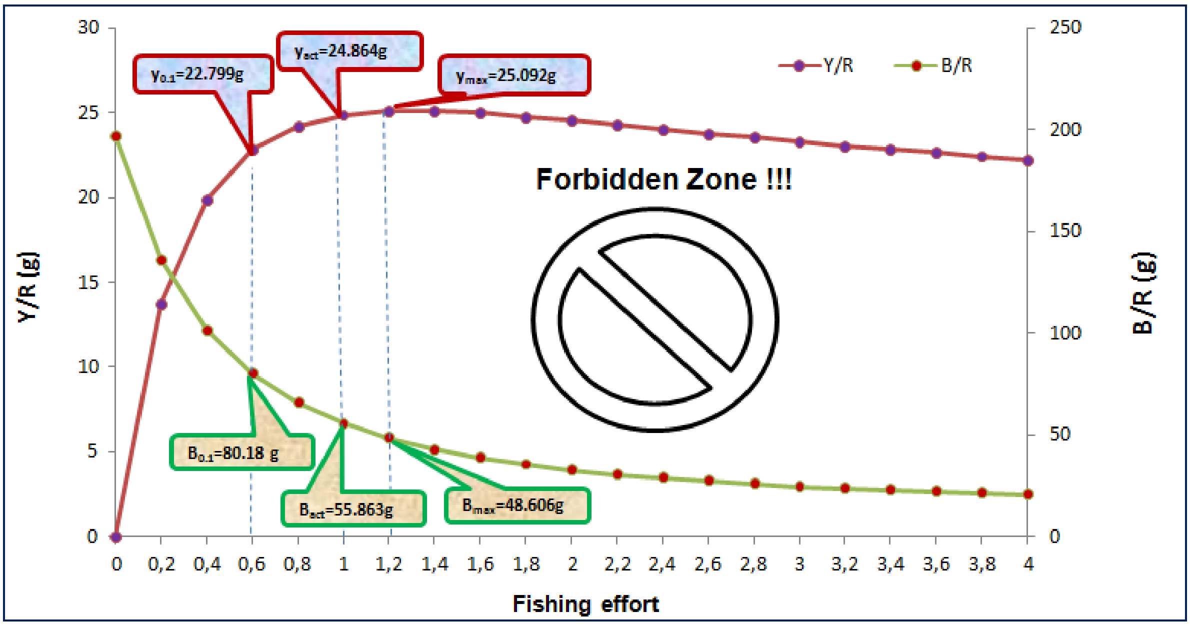

Fig. 2. Generalized evolution of the yield and biomass per recruit of bogue from the bay of Bou-Ismail area in case of increasing the fishing effort: LRP. Limit Reference Points; Y_{curent}.Yield per recruit corresponding to current fishing mortality (F_{curent}); $Y_{0.1}$.Yield per recruit corresponding to fishing mortality ($F_{0.1}$); MSY. Maximum sustainable production corresponding to maximum fishing mortality (F_{max}).

Discussion

Direct methods have not been used previously to evaluate bogue stock in the bay of Bou–Ismail, Centre Algeria. This study thus presents the first attempt to assess the state of exploitation of bogue using indirect methods based on analytical models. Considering the lack of reliable data bases, the Length Cohort Analysis (LCA) proved to be the best and perhaps the only method available that is adapted to the current characteristics of the region.

The average length and age of catches

The average length of catches, estimated at 17.988 cm for an age of 2.989 years, was greater than the average length at first sexual maturity (L_{50}), 13.6 cm for both sexes combined.

Spawning stock biomass

It is reassuring that the bogue has a high capacity to reproduce and regenerate (turnover of 79.99%). Protecting bogue stock until sexual maturity has contributed considerably to the conservation of the Spawning Stock Biomass (SSB), which is sufficient to maintain the recruitment of stock on a high level. The SSB was last estimated at 219.08 tons, that is to say 78.56% of the mean biomass is around 278,874.24 tons.

Relative Biomass per recruit

The Biomass per current recruit (B/R = 55.863 g), which refers to the mean annual biomass of survivors as a function of fishing mortality, is higher than the maximum sustainable biomass (B_{max} /R = 48.606 g.). From the study of the yield and the biomass per recruit it result a State of full exploitation of the sardine stock of the eastern region of the Algerian coast.

Relative Yield per recruit

Given the state of full exploitation of the sardine stock in the eastern part of the Algerian coast, an adjustment of the ratio Y_{actual} /R is recommended. To do this, fishing effort is set at $F_{0.1}$(0.6), and the values obtained for $Y_{0.1}$/R and $B_{0.1}$/R then correspond to 22.799 g and 80.18 g respectively.

Fishermen are more interested in the total yield of the exploitable stock than the imaginary yield per recruit

(Bouaziz, 2006). To compute this value, we simply multiply the number of recruits (R= 4992102.9) by $Y_{0.1}/R$ (Fig. 2).

Conclusion

In conclusion, based on the principles of the precautionary approach, we recommend adjusting the current production to 124.12 tons, or a decrease of 8.3% of current production 113.81 tons. The implementation of this recommendation would increase the exploitable biomass of 278.87 to 400.27 tons guaranteeing the preservation of bogue in the bay of Bou-Ismail and will ensure a sustainable production in the long term.

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