European anchovy *Engraulis encrasicolus* (Linnaeus, 1758) from the Gulf of Annaba, east Algeria: age, growth, spawning period, condition factor and mortality

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Abstract. Age, growth, spawning period, condition factor and mortality were determined in the European anchovy *Engraulis encrasicolus* populated the Gulf of Annaba, east Algeria. The age structure of the total population is composed of 59.1% females, 33.5% males and 7.4% undetermined. The size frequency distribution method shows the existence of 4 cohorts with lengths ranging from 8.87 to 16.56 cm with a predominance of age group 3 which represents 69.73% followed by groups 4, 2 and 1 with respectively 19.73, 9.66 and 0.88%. The VONBIT software package allowed us to estimate the growth parameters: asymptotic length $L\infty$ = 17.89 cm, growth rate K = 0.6 $year^{-1}$ and t0 = -0.008. The theoretical maximum age or tmax is 4.92 years. The height-weight relationship shows that growth for the total population is a major allometry. Spawning takes place in May, with a gonado-somatic index (GSI) of 4.28% and an annual mean condition factor (K) of 0.72. The total mortality (Z), natural mortality (M) and fishing mortality (F) are 2.31, 0.56 and 1.75 $year^{-1}$ respectively, with exploitation rate E = F/Z is 0.76 is higher than the optimal exploitation level of 0.5.

Key Words: biology, fisheries, Mediterranean, pelagic, anchovy.

Introduction. European anchovy, *Engraulis encrasicolus* (Linnaeus, 1758) is a widespread coastal fish in the Atlantic Ocean, the Black Sea and the Mediterranean Sea (Whitehead et al 1988). Anchovy has been the subject of numerous studies in the field of ecology (Guidetti et al 2013), reproduction (Uriarte et al 2012; Manzo et al 2013) and its fishery (La Mesa et al 2009). In Algeria, anchovy and sardines represent the most important fish in terms of biomass and commercial interest. Over the past 10 years, anchovy fishing has experienced large annual fluctuations between 1374 and 6085 tonnes (MAPRH 2004). The work done on anchovy is particularly relevant to its biology (Arrignon 1966) and its exploitation (Hemida 1987). The latter concerned the whole Algerian coastline: Beni saf (Bacha et al 2010), center of the coast of Algeria (Djabali & Hemida 1989), Béjaia (Bacha 2009; Bacha & Amara 2012), Skikda (Mezedjri et al 2013), and El Kala (Ladaimia et al 2016). It is in this context and within the framework of a national research programme on the exploitation and management of stocks of small pelagics of the Algerian coastline (Bedairia & Djebar 2009; Bacha et al 2010; Bacha & Amara 2012; Bouhali et al 2015; Ladaimia et al 2016; Dahel et al 2016) that we situate our work.

So we evaluated from landings of anchovies in 2016 in the Gulf of Annaba, East Algeria, sex ratio, age, growth, spawning period, condition index and mortality in a population of 4152 individuals.

Material and Method

Study area*.* Annaba city is located in the South of the Mediterranean coast to the extreme east of Algeria, between Cape Guard West at 36°58'05"N - 7°47'11''E and the Cape Rosa at 36°56'09"N - 8°14'14"E (Figure 1).

Figure 1. Geographical position of the Gulf of Annaba, east Algeria (red rectangle delimits the sampling locations).

Data collection*.* Random samples of fish were obtained monthly in 2016 from commercial landings of sardines and trawlers operating in the Gulf of Annaba (Figure 1).

Sex-ratio*.* The evisceration of the fish allowed us to identify the males (M), females (F) and undetermined (NI). Two estimates of the sex ratio were established: M/F to calculate the deviation from 1 which was statistically tested by the Chi2 test, χ-test according to Dagnelie (1975), and the rates of femininity F/M + F and masculinity M/M + F.

Length-weight relationships*.* The length-weight relationship was estimated for the entire population of *E. encrasicolus* composed of 1390 males and 2453 females and 309 individuals not identified by the exponential equation (Ricker 1975):

$$W_T = a\ L_T^{\ b}$$

where: W_T - total weight of fish in g; b - allometry coefficient; a - constant; L_T - total length in cm. The constant (a) and the allometric coefficient (b) were calculated by the least squares method based on the logarithmic form of the equation as recommended by Froese (2006).

The allometric coefficient (b) reflects the type of mass growth relative to length. To determine the nature of the allometry, the b-value is compared with the theoretical value (3) using the Student test (t) (Dagnelie 1975). When b = 3, the L_T-W_T relationship reflects isometric growth where the relative growth of the 2 variables is perfectly identical (Mayrat 1970; Ricker 1975). If b < 3 the growth is of negative allometric type and if it is > 3 it is positive (Sokal & Rohlf 1987).

Estimation of age and growth parameters*.* The Bhattacharya (1967) method available in the fish stock assessment tool (Gayanilo et al 2005) was used to estimate the age of fish that were grouped into L_T classes and divided into cohorts at 0.5 cm intervals. To model the growth and to determine the growth parameters of *E. encrasicolus* population (asymptotic length L∞ in cm and growth coefficient K), we used the von Bertalanffy (1938) equation (FCVB), the FISAT II 1.2.0 software and the VONBIT (Stamatopoulos 2005) software package for Excel.

$$L_T = L_\infty (1-e^{-K(t-t0)})$$

These parameters allowed us to calculate the growth performance index Ø' and the theoretical maximum age tmax:

$$Ø' = \log_{10} K + 2 \log_{10} L\infty \text{ (Pauly \& Munro 1984)},$$

$$tmax = (3/k) + t_0 \text{ (Gayanilo \& Pauly 1997; Scalici et al 2015)}.$$

Spawning period and condition factor. The spawning period was established by a monthly calculation of the gonado-somatic index (GSI) considered by Lahaye (1980) as a true maturity coefficient. The GSI consists of evaluating the increase in gonad weight and volume and determining their level of maturation during the sexual cycle according to the equation:

$$GSI = W_G \times 100/W_E$$

where: W_G - gonad weight in g; W_E - gutted fish weight in g.

The Fulton K condition factor was used to monitor changes in fish weight characteristics and reflects their eco-physiological conditions, it is defined by the equation of (Ricker 1975):

$$K = W_E \times 100/L_T^b$$

where: b is the allometric coefficient of the length-weight relationship, W_E is the eviscerated weight as suggested by Cherif et al (2007) or Nunes et al (2011).

The comparison of the monthly values of GSI and K was established by the analysis of variance ANOVA (Zar 1984).

Mortality. The total mortality coefficient (Z) was evaluated by the linearized capture curve method incorporated in the FISAT II 2.1.0 (2005) software according to Pauly (1984, 1990), and Pauly & Gayanilo (1997).

The natural mortality coefficient (M), was calculated by the empirical equation of Djabali et al (1994) specific to the Mediterranean, based on growth and mortality parameters obtained from Mediterranean fish stocks:

$$\text{Log}_{10} M = -0.0278 - 0.1172 \text{ Log}_{10} L\infty + 0.5092 \text{ Log}_{10} K$$

where: K and L∞ - parameters of the Von Bertalanffy equation.

Fishing mortality (F) was estimated using the relationship:

$$F = Z - M \text{ (Gulland 1969)},$$

The exploitation rate (E) is obtained by the ratio F/Z (Gulland 1969).

Results

Sex-ratio. The total population of *E. encrasicolus* anchovy sampled monthly in 2016 was 4152 fish divided to 2453 females or 59.1%, 1390 males or 33.5% and 309 specimens or 7.4% undetermined (Figure 2).

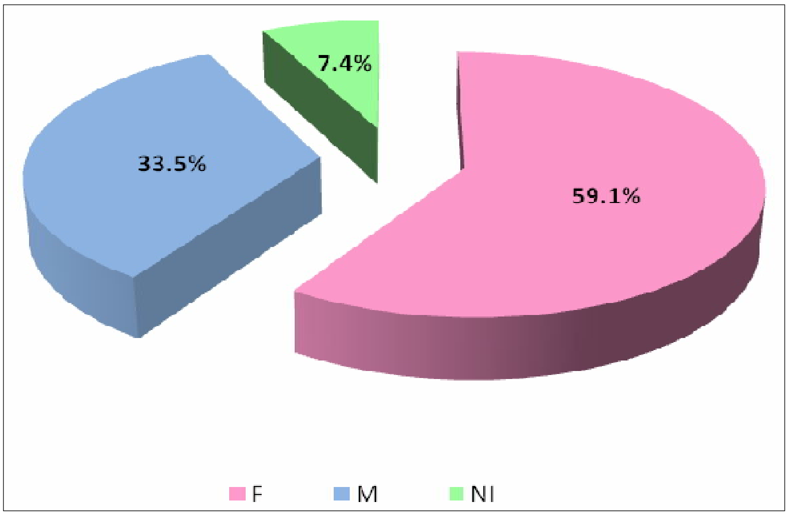

Figure 2. Distribution of sex ratio in *E. encrasicolus* in 2016 in the Gulf of Annaba (F: female; M: male; NI: undetermined).

Relationship size sex ratio. With an average of 13.72±1.76 cm the L_T fluctuate between 6.9 and 17.7 cm. Of the 10 size classes retained between 8 and 18 cm with a pitch of 1 cm, that between [8-16] cm is characterized by a dominance of females with rates between 61.83 and 86.84%, males representing 13.15 to 38.69%.

In class [16-17] cm, one notes an inversion of the rates with an advantage of the males which reach 66.66%. The rate of femininity resumes its supremacy between [17-18] cm with 93.33% (Figure 3).

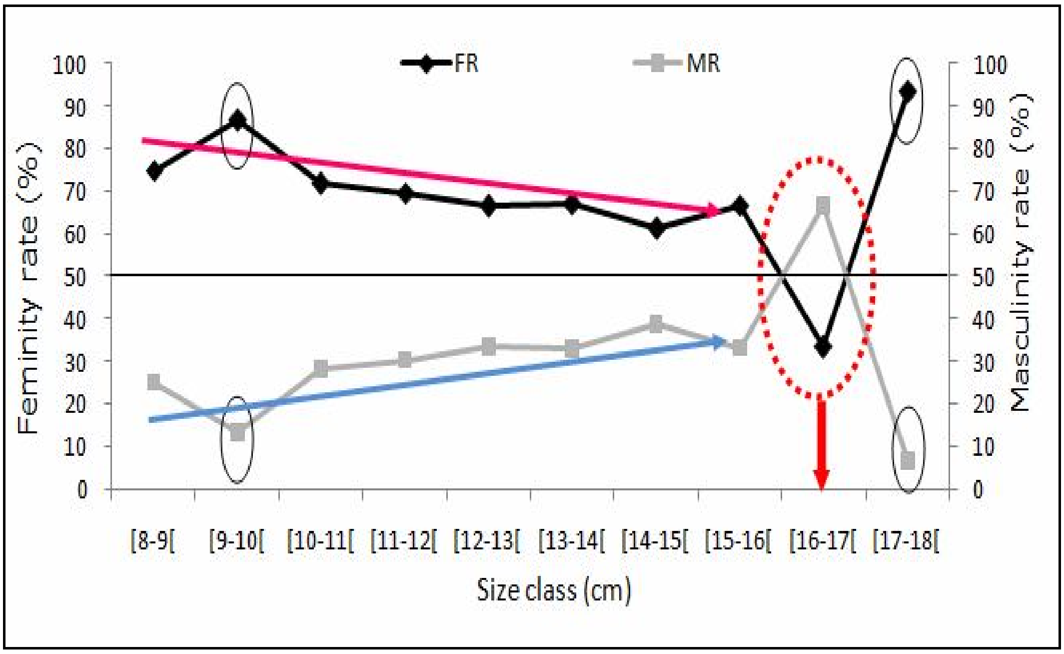

Figure 3. Feminity rate (FR) and masculinity rate (MR) by size class of *E. encrasicolus* from January to December 2016. Red circle: rate inversion [16-17] cm.

Relation spawning period - sex ratio. We studied the relationships between the sex ratio (SR) and 3 life phases. The sex ratio is in favour of females along the annual cycle (AC) it reaches 0.56:1 and in spawning period (SP) with 0.32:1 it is in favour of males with 1.91:1 outside the spawning period (OSP). For these three life phases we obtained very highly significant differences between the two sexes (Table 1).

Table 1

Population structure and sex ratio of *E. encrasicolus* between January and December 2016

Period	*SR*	*χ^2 obs*	*P*
AC	0.56:1	294.03	S*** (F > M)
SP	0.32:1	713.96	S*** (F > M)
OSP	1.91:1	106.97	S*** (F < M)

AC: annual cycle; SP: spawning period; OSP: off spawning season; SR: sex ratio; χ^2obs: observed value of χ^2-test; $\chi^2(1-0.05) = 3.84$.

Estimation of age and growth parameters. The population of *E. encrasicolus* in the Gulf of Annaba is composed of 4 cohorts with mean lengths of 8.87, 11.66, 14.97 and 16.56 cm respectively (Figure 4 and Table 2). Linear growth shows that this fish can reach 4 years. At 69.73%, 3-year-old anchovies are the most abundant while 1-year-old anchovies represent only 0.88% of catches (Table 2).

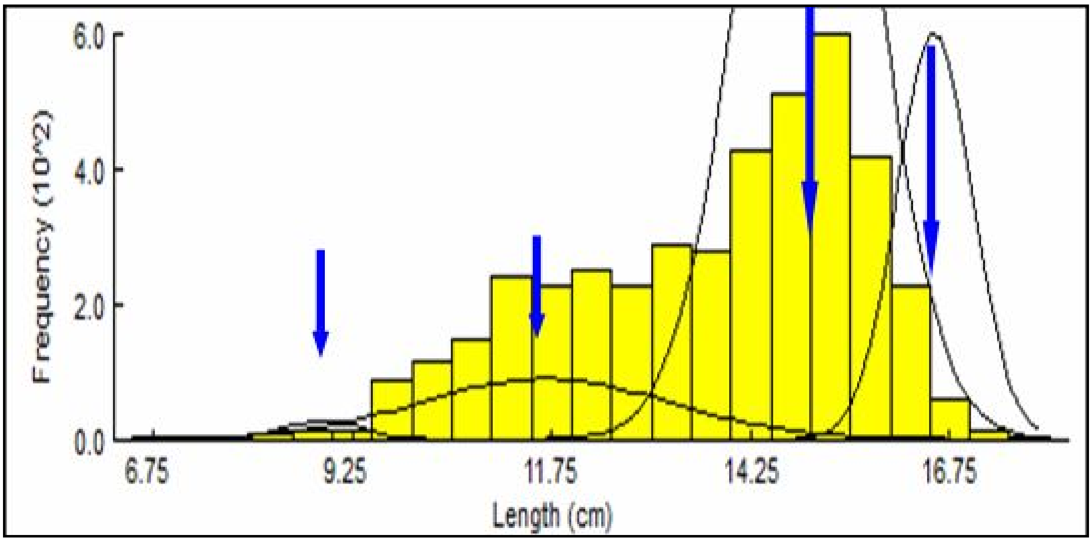

Figure 4. Decomposition of size frequencies for the population of *E. encrasicolus.* Blue arrows: 4 cohorts (FISAT II 1.2.0, 2005).

Linear growth is faster in 2-year-old anchovies. It reaches 3.31 cm $year^{-1}$ in specimens measuring on average 11.66±1.57 cm. This growth gradually decreases to reach 3 years, 1.59 cm $year^{-1}$ (Table 2).

Table 2

Average length by age for *E. encrasicolus* in the Gulf of Annaba

Age (y)	*CM (cm)*	*n*	*%*	*Growth rate (cm $year^{-1}$)*
1	08.87±0.48	32	0.88	2.79
2	11.66±1.57	351	9.66	3.31
3	14.97±0.82	2534	69.73	1.59
4	16.56±0.4	717	19.73	-

CM = computed mean±standard deviation; n = number of fish; growth rate = (L_T + 1) - L_T. % = (n/N)x100.

The growth parameters obtained from the calculation of the age-length key of *E. encrasicolus* allowed us to estimate: asymptotic length L∞ at 17.89 cm (Figure 5a), growth rate K at 0.6 year-1 (Figure 5b) and t_0 = -0.008 year. These results allowed us to determine the equation:

LT = 17.89 (1-e-0.6(t+0.008)), growth performance index Ø' = 2.283 and calculated theoretical maximum age tmax = 4.92 years.

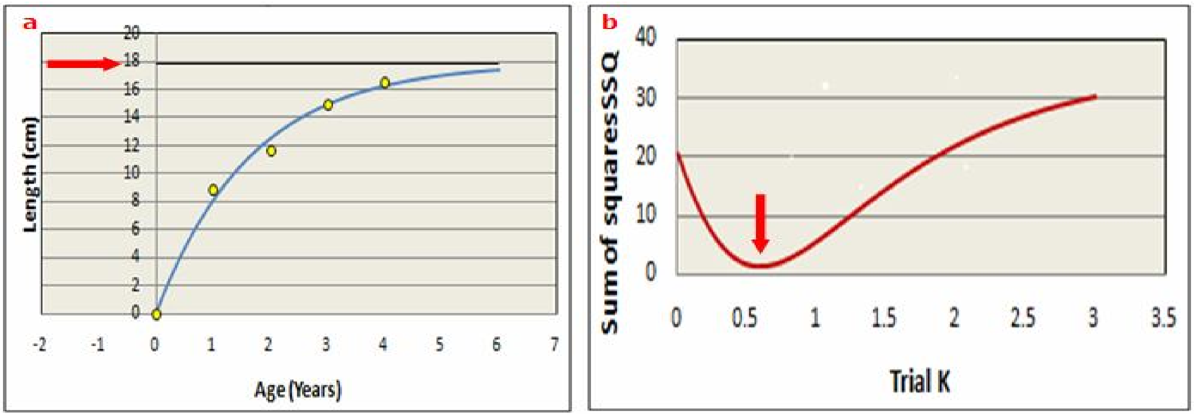

Figure 5. Asymptotic lengths L_∞ (a) and growth rate K (b) in *E. encrasicolus* in the Gulf of Annaba (FISAT II 1.2.0, 2005).

Length-weight relationships. The mean total lengths L_T for females and males are 13.95±1.54 cm and 13.58±1.93 cm, respectively, with mean weights of 17.04±5.8 g and 16.64±7 g (Table 3). The regression coefficient b is slightly higher in females than for males. In the total population b = 3.221 with R^2 = 0.957, in females b = 3.216 with R^2 = 0.964 and in males b = 3.206 with R^2 = 0.946. For the total population, both the slope and the regression coefficients indicate positive allometric growth (Table 3).

Table 3

Length-weight relationship for landed anchovies in the ports of Annaba in 2016

	a	*b*	*R²*	*n*	*Allometry type*
PT	0.0033	3.221	0.957	4152	positive
M	0.0027	3.206	0.946	2453	positive
F	0.0032	3.216	0.964	1390	positive

PT: total population, M: males, F: females; b: allometry coefficient; a: constant; R^2: determination coefficient; n = number of fish; p < 0.001 for all regressions.

Spawning period and condition factor. Gonado-somatic index (GSI) fluctuate between 0.31 and 4.28%. Statistical analysis by ANOVA shows significant heterogeneity between its monthly mean values with p < 0.001. The GSI increases between March and May, from 1.84% to a peak of 4.28% respectively. It then gradually decreases to 2.13% in October and 0.31% in November (Figure 6).

The annual average condition factor K is 0.72%. The ANOVA shows a significant difference between the monthly mean values of K with p < 0.001. This coefficient goes through 2 phases: a decline between February and October with small amplitude fluctuations ranging from 0.026 to 0.692% followed by an increase which reaches 3.844% in November (Figure 6).

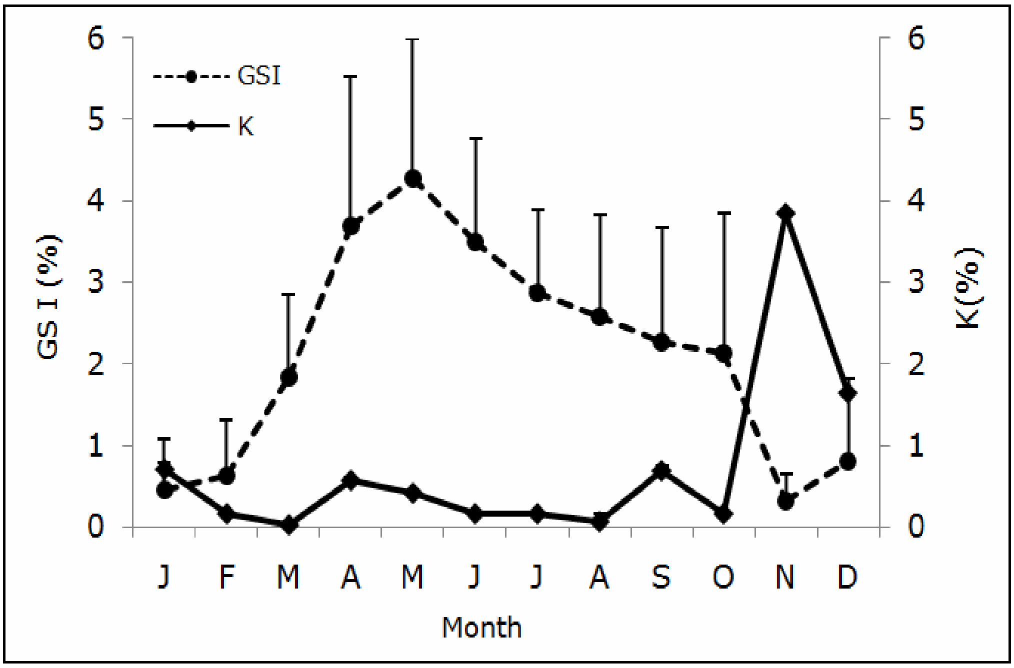

Figure 6. Monthly changes of GSI and K for *E. encrasicolus.*

Mortality. Total mortality (Z) was estimated at 2.31 $year^{-1}$ (Figure 7), natural mortality (M) at 0.56 $year^{-1}$ and fishing mortality (F) = 1.75 $year^{-1}$.

In the Gulf of Annaba, the exploitation rate (E) of *E. encrasicolus* E = 0.76, indicating a state of overfishing because > 0.5: balanced fishing rate.

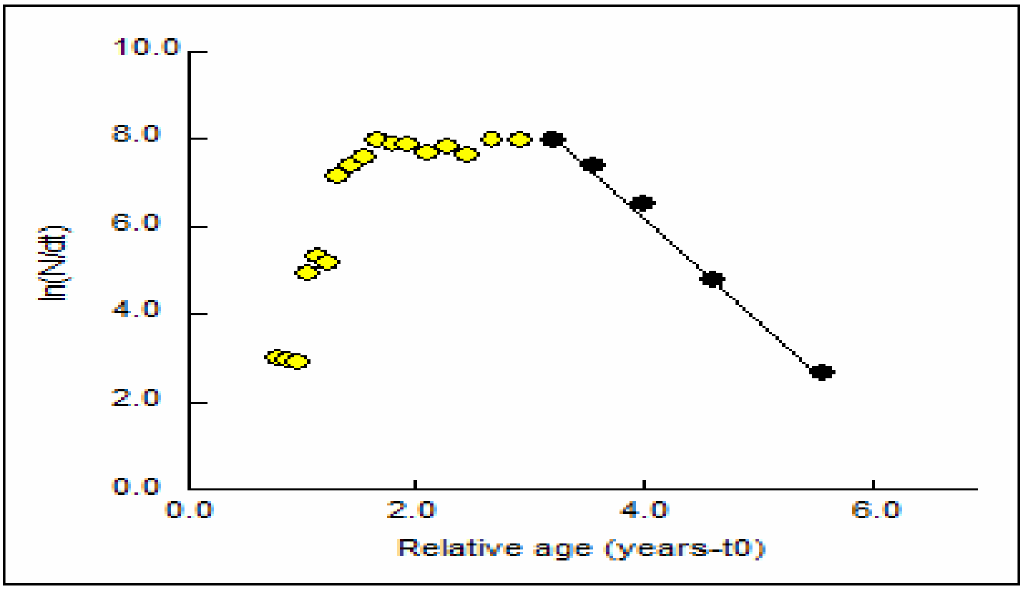

Figure 7. Calculation of total mortality Z by the catch curve converted to length (FISAT II 1.2.0, 2005).

Discussion. Estimates of ages, growth, spawning period, condition index and mortality were addressed in 2016 among European anchovy *Engraulis encrasicolus* (Linné, 1758) fished in the Gulf of Annaba, eastern Algeria. The sex ratio presents a very highly significant difference with a dominance of females. This result is comparable to that reported by Mezedjri et al (2013) in the Gulf of Skikda of the Algerian east coast and by Ba (1988) on the Mauritanian coast or Manzo et al (2013) in the southwest Adriatic in Italy. However, in the Mediterranean, (Sinovčić 2000; Gaamour et al 2004; Khemiri & Gaamour 2009; Morello & Arneri 2009) and in the Atlantic (Millán 1999), populations of *E. encrasicolus* correspond to the null hypothesis of a ratio of 1:1 for the 2 sexes. The rate of feminity varies in function of fish size; this dependence seems to be a general rule from Clupeiformes since it has been reported in several Engraulidae species such as *E. encrasicolus* (Millán 1999; Gaamour et al 2004) and in other Clupeids species such as *Sardina pilchardus* (Amenzoui et al 2006). This rate remains high in small classes because, given its size, the ovary is identified early. The numerical superiority of females in large classes may be the result of several factors such as longer life, faster growth, greater vulnerability to fishing gear and different natural mortality by sex as shown by Motos & Uriarte (1991) and Garcia & Albaret (1977).

The age structure of *E. encrasicolus* is characterized by a lifespan of 4 years and rapid linear growth until the 2nd year before slowing gradually. This is what is found in the majority of studies carried out in the Mediterranean which indicate the same age 4 years, for the different *E. encrasicolus* stocks, populating the Algerian east coast (Benchikh et al 2012), the Algerian west coast (Bacha et al 2010), the Tunisian coasts (Khemiri et al 2007) and the northwest Mediterranean (Morales-Nin & Pertierra 1990). The same in the Adriatic (Sinovčić 2000). It should be known that the extremes of the longevity of *E. encrasicolus* vary between 2 years (Fage 1911) at 5 years (Hemida 1987; Bellido et al 2000). The maximum longevity (Tmax) obtained is 4.92 years. This result is close to that reported in the Bay of Biscay estimated at 5 years (Berné et al 2004). This difference is probably due to the use of other methods of age determination or identical but not standardized methods.

The growth parameters obtained with the age-length key allowed us to determine the asymptotic length L_∞ which is 17.89 cm obtained after only 4 years with a growth rate k of 0.6 year-1. These are rapid growing species, as reported by several authors in different regions of the Mediterranean (Campillo 1992; Machias et al 2000; Erkoyuncu & Ozdamar 1989; Volovik & Kozlitina 1983; Cendrero et al 1981; Samsun et al 2004; Kada et al 2009; CGPM 2000; Basilone et al 2004; Djabali & Hemida 1992; Bacha et al 2010) and Atlantic (Guérault & Avrilla 1974; Ramos & Santos 1999; Amponsah et al 2016)

(Table 5). The growth performance index Ø' was calculated for *E. encrasicolus* at 2.283, showing that it has rapid linear growth, these results being identical to those found in the same species by many authors in different regions of the Mediterranean (Volovik & Kozlitina 1983; Hemida 1987; Morales-Nin & Pertierra 1990; Sinovčić 2000; Khemiri et al 2007; Bacha et al 2010) and Atlantic (Bellido et al 2000) (Table 5).

Table 5
Representation of the parameters of the von Bertalanffy equation (1938) and the growth index of *E. encrasicolus* in different regions of the world

Area	L_∞ *(cm)*	*K* *(year^{1})*	T_0 *(year)*	*Ø'*	*Sources*
Catalonian littoral (SE, Spain)	19.10	0.35	-	2.106	Morales-Nin & Pertierra (1990)
Gulf of Lion (SE, France)	19.10	0.35	-	2.106	Campillo (1992)
Strait of Sicily	18.60	0.29	-	2.016	Basilone et al (2004)
Middle Ionian Sea (Greece)	17.50	0.51	-	2.194	Machias et al (2000)
Middle-North Adriatic (Croatia)	19.40	0.57	-	2.331	Sinovcic (2000)
North Portugal	15.80	0.53	-	2.120	Ramos & Santos (1999)
Black Sea	16.76	0.32	-	1.960	Erkoyuncu & Ozdamar (1989)
Azov Sea	13.30	0.61	-	2.030	Volovik & Kozlitina (1983)
Bay of Biscay	22.10	0.57	-	2.446	Guérault & Avrilla (1974)
Cantabrian Sea, N Spain	21.30	0.48	-	2.343	Cendrero et al (1981)
Turkish(Black Sea)	16.36	0.42	-1.35	2.050	Samsun et al (2004)
Spain (Gulf of Cádiz)	18.69	0.9	-	2.497	Bellido et al (2000)
Spain (Gulf of Cádiz)	18.95	0.9	-	2.509	Bellido et al (2000)
Lagune de Nador (Moroccan Mediterranean)	10.68	0.87	-0.21	1.996	Kada et al (2009)
Alboran Sea (Moroccan Mediterranean)	18.80	0.34	-	2.079	CGPM (2000)
Algeria	16.57	0.59	-	2.205	Hémida (1987)
Ghana	11.03	0.58	-	1.849	Amponsah et al (2016)
South Tunisian coast	17.19	0.36	-	2.069	Khemiri et al (2007)
North Tunisian coast	19.16	0.32	-	2.028	Khemiri et al (2007)
Center coast of Algeria	16.57	0.584	-1.184	2.205	Djabali et al (1992)
Benisaf (west Algeria)	15.61	0.75	-1.320	2.261	Bacha et al (2010)
Benisaf (west Algeria)	15.61	0.75	-1.320	2.261	Bacha et al (2010)
Gulf of Annaba (east Algeria)	17.89	0.6	-0.008	2.283	This study

The length-weight relationship indicates positive allometric growth for the total population indicating good weight growth of anchovy fished in the Gulf of Annaba as reported by Benchikh et al (2013) and Ladaimia et al (2016) in eastern Algeria.

This relationship is important for fish biology because it gives, as Gonzalez Acosta et al (2004) show, information on the state of stocks and allows the assessment of the relative condition of fish. The same results have been obtained by several authors in different regions: Millán (1999) in the Atlantic, Funamoto et al (2004) in the Pacific, and Gaamour et al (2004) and Manzo et al (2013) in the Mediterranean.

Reproduction period is between March and October, coinciding with the warming of surface waters. Spawning takes place in summer, when oocytes and spermatozoa are released in May and continues until September-October. The gonads return to sexual rest between November and December. The sprawl of the reproductive period observed in *E. encrasicolus* from east Algeria is comparable to that found in the same species in different regions of the Mediterranean (Fage 1920; Palomera & Sabatés 1990; Palomera 1992; Motos 1996; Regner 1996; Sinovčić 2000; Gaamour et al 2004). Shorter reproductive periods have been observed by various authors: Chavance (1980), Casavola et al (1996), Lisovenko & Andrianov (1996) and Sinovčić & Zorica (2006), whereas in the

Atlantic, Ba (1988) and Berraho et al (2005) show that reproduction of *E. encrasicolus* occurs all year.

The weight indexes, GSI and K evolve inversely, when the first increases the second decreases. It is probable that the increase in the K condition is related to the accumulation of reserves associated with the high productivity of the environment as observed by Thiriot (1976), Somoue (2004) and Ladaimia et al (2016), particularly in summer when planktonic production is optimal.

Total mortality (Z) is estimated at 2.31 year^{-1} and natural mortality at 0.56 year^{-1}. These mortality coefficients are similar to those found by Fedja & Bouaziz (2015) for the same species captured along the Algerian coast where Z = 2.63 year^{-1}, or by Sağlam & Sağlam (2013) in the Black Sea in Turkey where Z = 2.84 year^{-1}. This value differs from that of Samsun et al (2004) in the same region of Turkey where they estimate Z at 1.6 year^{-1}, while in the Ghana, between July 2014 and January 2015, Amponsah et al (2016) find total mortality coefficients of about 3.4 year^{-1} (Table 6).

Table 6

The variations of mortality M, Z and F from *E. encrasicolus* in different regions

Location	*Z (year^{-1})*	*M (year^{-1})*	*F (year^{-1})*	*Sources*
Turkish (Black Sea) 1999-2000	1.6	0.46	1.44	Samsun et al (2004)
Turkish (Black Sea) 1998 -1999	1.44	0.49	0.95	Samsun et al (2004)
Turkish (Black Sea) 2010-2011	2.84	0.66	2.18	Sağlam & Sağlam (2013)
Algeria (Center)	2.63	0.61	2.02	Fedja & Bouaziz (2015)
Ghana	3.4	1.59	1.81	Amponsah et al (2016)
Gulf of Annaba (east Algeria)	2.31	0.56	1.75	This study

The total, natural and fishing mortality estimates obtained are higher than estimates reported by other authors such as Samsun et al (2004). This difference would be as suggested by Pauly (1984) in relation to the density of predators and competitors, the intensity of pressure and mesh size of fishing gear.

Conclusions. Age, growth (K and L ∞) directly influence the total mortality (Z), by fishing mortality (F) and natural mortality (M) of *E. encrasicolus*. Their values allow us to consider that in 2016 *E. encrasicolus* populating the waters of the Gulf of Annaba was overfished. These growth parameters must be taken into account and evaluated periodically in any stock management strategy. It is essential to increase the mesh size to target larger specimens and to respect fishing areas and periods. The same is the case for environmental factors that need to be taken into account, as they affect in particular the growth and reproduction of *E. encrasicolus*.

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