A preliminary analysis of the state of exploitation of the sardine, *Sardina pilchardus* (Walbaum, 1792), in the gulf of Annaba, East Algerian

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Bedairia, A. & Djebar, A. B., 2009. A preliminary analysis of the state of exploitation of the sardine, *Sardina pilchardus* (Walbaum, 1792), in the gulf of Annaba, East Algerian. *Animal Biodiversity and Conservation*, 32.2: 89–99.

Abstract

A preliminary analysis of the state of exploitation of sardine, Sardina pilchardus *(Walbaum, 1792), in the gulf of Annaba, East Algerian.*— This study was performed on 2,859 specimens of sardine, *Sardina pilchardus,* collected biweekly from November 2006 to October 2007. Samplings were carried out at the fishing port of Annaba where purse–seine methods are used for small–scale fishing at depths from 15 to 30 m. Data concerning the exploitation of catches were analysed by means of two software packages: i) FISAT (2004), which we used to determine the essential parameters for the study of dynamics; and ii) VIT (2000), the most suitable tool for stock assessment based on the application of Length Cohort Analysis (LCA) together with a Yield per Recruit Analyses (Y/R) based on a short series of data. VIT (2000) assumes steady state and functions with pseudo–cohorts, requiring knowledge of the catches over one year only instead of a historical series of several years. The results of this application revealed that the exploitable average biomass of the sardine stock, composed of 28 length sizes from 6.5 to 20 cm with a step of 0.5 cm, was around 4,778.93 tons, of which 2,513 tons (53%) were spawning stock. The size and the average age of the sardine stock were 12.5 cm and 2.7 years. Total biomass balance (D) was estimated at 5,508.64 tons. This corresponded to growth in weight of 4,453.77 tons, (80.85%), as compared to recruitment of only 1,054.86 tons (19.15%). Losses were caused mainly by natural mortality (M), estimated at 3,823.14 tons, and accounting for 69.40%. This was higher than fishing mortality (F) which was 1,685.5 tons (30.60%). We estimated the yield per recruit (Y/R) of sardine at 2.682 g. This value was lower than the threshold of maximum yield per recruit at 3.413 g. Though preliminary, these results indicate that the sardine population can be considered to be in a situation of under–exploitation in this area. The stock is moderately exploited for $F_{0.1}$ a reference considered more appropriate for management. Applying the precautionary principle, fishing efforts should not increase and we recommend limiting fishing to current levels. However, we recommend monitoring the fishing strategy and the annual evolution of catches.

Key words: Sardine, LCA, Mediterranean Sea, Biomass, Gulf of Annaba, Algeria.

Resumen

Análisis preliminar del estado de explotación de la sardina, Sardina pilchardus *(Walbaum, 1792), en el golfo de Annaba, en Argelia oriental.*— Este estudio se llevó a cabo utilizando 2.859 especímenes de sardina, *Sardina pilchardus*, recogidos cada dos semanas desde el mes de noviembre de 2006 a octubre del 2007. El muestreo se llevó a cabo en el puerto pesquero de Annaba, donde se utiliza la pesca al cerco a pequeña escala, a profundidades de 15 a 30 m. Los datos concernientes a las capturas se analizaron mediante dos programas informáticos: i) FISAT (2004), para determinar los parámetros esenciales del estudio de la dinámica; y ii) VIT (2000), la herramienta más útil para la evaluación de los estocs basándose en la aplicación del Análisis de Cohortes de Longitud (LCA) junto con un Análisis de Rendimiento por Recluta (Y/R) basados en una serie de datos corta. El software VIT (2000) asume la existencia de un estado estacionario, y trabaja con pseudocohortes, requiriendo únicamente el conocimiento de las capturas de un solo año, en lugar de una serie histórica de varios años. Los resultados de su aplicación revelaron que el promedio de la biomasa explotable del estoc de sardinas, compuesta de 28 cohortes de longitudes, de 6,5 a 20 cm con intervalos

ISSN: 1578–665X

de 0,5 cm, se situaba alrededor de las 4.778,93 toneladas, de las cuales 2.513 toneladas (el 53%) eran de estoc en fase de freza. La edad y el tamaño medio del estoc de sardinas era de 12,5 cm y 2,7 años. El equilibrio de biomasa total (D) se estimó en 5.508,64 toneladas. Ello se corresponde a un aumento de peso de 4.453,77 toneladas (un 80,85%), en comparación con el reclutamiento de sólo 1.054,86 toneladas (19,15%). Las pérdidas eran causadas principalmente por la mortalidad natural (M), estimada en 3.823,14 toneladas, responsable del 69,40%. Ésta era mayor que la mortalidad por pesca (F), que era de 1.685,5 toneladas, es decir, de un 30,60%. Se estimó el rendimiento por recluta (Y/R) de la sardina en 2,682 g. Este valor es inferior al umbral del rendimiento máximo por recluta, que está en 3,413 g. Aunque de forma preliminar, estos resultados indican que se puede considerar que, en esta zona, la población de sardinas se encuentra subexplotada. El estoc se halla moderadamente explotado en cuanto a $F_{0.1}$, un parámetro de referencia que se considera más apropiado para la gestión. Aplicando los principios preventivos, no deberían aumentarse los esfuerzos pesqueros, y recomendamos que se limiten las capturas a los niveles actuales. No obstante, sugerimos que se monitoricen las estrategias pesqueras. Además, recomendamos un seguimiento anual de la evolución de las capturas.

Palabras clave: Sardina, LCA, Mediterráneo, Biomasa, Golfo de Annaba, Argelia.

(Received: 2 XII 08; Conditional acceptance: 6 III 09; Final acceptance: 9 VII 09)

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Introduction

The sardine (*Sardina pilchardus*, Walbaum, 1792) is a clupeid with a considerable halieutic potential in the gulf of Annaba, in the Eastern part of the Algerian coast. The small pelagic resources have contributed largely to the increase in stock. The rate of exploitation is about (~56%) (Bedairia et al., 2007). We were interested in studying the sardine as it is the main pelagic species in the gulf of Annaba. Indeed, in 2007 we found it represented (~44%) of the total landings of small pelagic fish.

The sardine has been the subject of many studies in the Mediterranean, such as those of Mozzi & Duo (1959), Quignard & Kartas (1976) and Álvarez (1980), and also in the Atlantic, such as those by Copace (1978), Guerault (1980), and Idrissi & Zouiri (1985).

In Algeria, the biology and the exploitation of the sardine have the subject of several papers. These include the works of Bouchereau (1981), Mouhoub (1986) and Brahmi et al. (1998).

To our knowledge, the sardine has not been studied in Annaba (eastern Algeria). Knowledge concerning the exploitation status based on the evaluation of the population dynamics is lacking. In the present study we therefore considered that an analytical model of management was essential to determine the exploitable stocks in this area.

In 2007, the species in the study zone was made up 43.58% of the total of small pelagic species landed in the port of Annaba (Bedairia et al., 2007). The purse–seine fishing industry in the study area targets small pelagic fishes, mainly anchovies and sardines, at depths of less than 60 m.

However, the Clupeidae constitute the most significant proportion of the exploitable potential. The small pelagic resources, 55.79% of the available potential (Bedairia et al., 2006), will be the main contributors to the increase and maintenance of the fishing production in Annaba in the near future. This species provides the opportunity for a permanent fishing activity in the port of Annaba. Thus, a regular follow–up of these essential resources for a rational and sustainable exploitation is needed.

Following the current state of the world fish supplies and with the recent example of the large stock collapses and the constant decline of many resources, the FAO in 1996, Caddy in 1998 and the ICES in 1998 recommended a fishing mortality limit reference point of to $F_{0.1}$. This value, also called F_{target}, is known as the Target Reference Point (TRP). It is a method which allows the maximum catches in weight, while ensuring the conservation of stock.

Following these recommendations, we considered that it would be useful to manage the current production of sardine in the gulf of Annaba based on $F_{0.1}$.

The study 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

A total of 2,859 individuals of both sexes were collected biweekly from the commercial landings of the purse–seine fleet at the fishing port of the gulf of Annaba from November 2006 to October 2007. The individuals measured between 6.5 and 20 cm, and were divided into 28 length classes with a step of 0.5 cm (fig. 1). 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.

Data were consequently used to estimate the following biological parameters: (1) monthly length–frequencies; (2) length–weight relationship; and (3) growth parameters. To analyse length frequency we used L_∞, K, t_0 of von Bertalanffy growth equation, where K is the curvature parameter, L_∞ 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

$$\text{Ln BW} = b\,\text{LnTL} + \text{Ln}\,a$$

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). TL_{50} was defined as the smallest length interval at which 50% of the specimens were mature.

The gulf of Annaba is situated between Cape of Guard in the West (7° 16'' E) and Cape Rosa in the East (8° 15'' E), a distance of 40 km with a maximum depth of 65 m. To study the dynamics of the sardine stock in the study area we used two software packages published by the FAO. The first of these was FISAT (Gayanilo et al., 2004). This software was used to assess essential parameters for population dynamics (age–length key, growth parameters and mortality rates). The second was VIT (Lleonart & 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 (i.e. a strong assumption for species, like small pelagic, with highly fluctuating abundance due to both variable recruitment and relatively low number of age classes), and requires knowledge of the catches over one year only (Lleonart & 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. (2004) (table 1). We chose this approach, firstly, because of the difficulties of age reading,

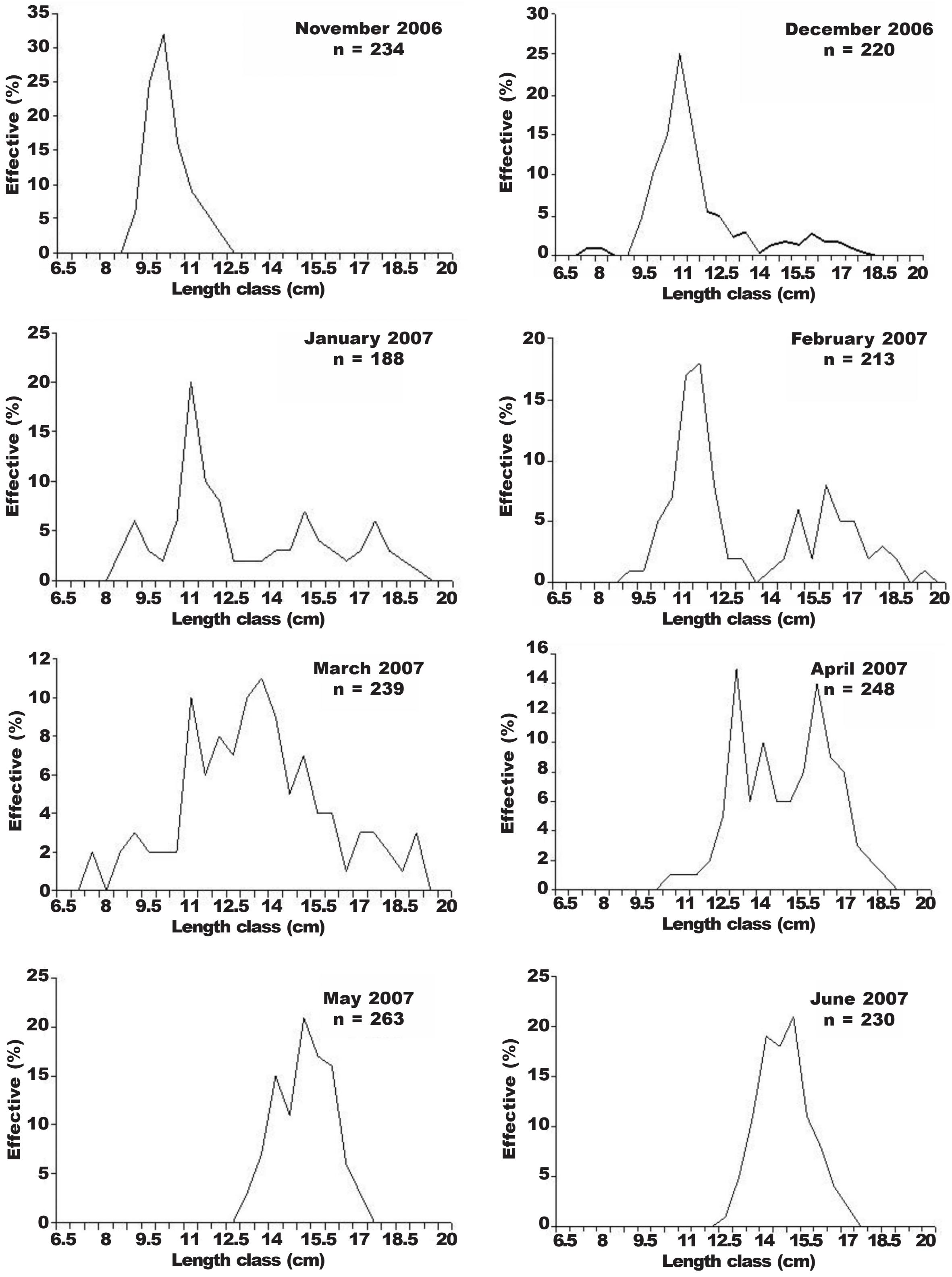
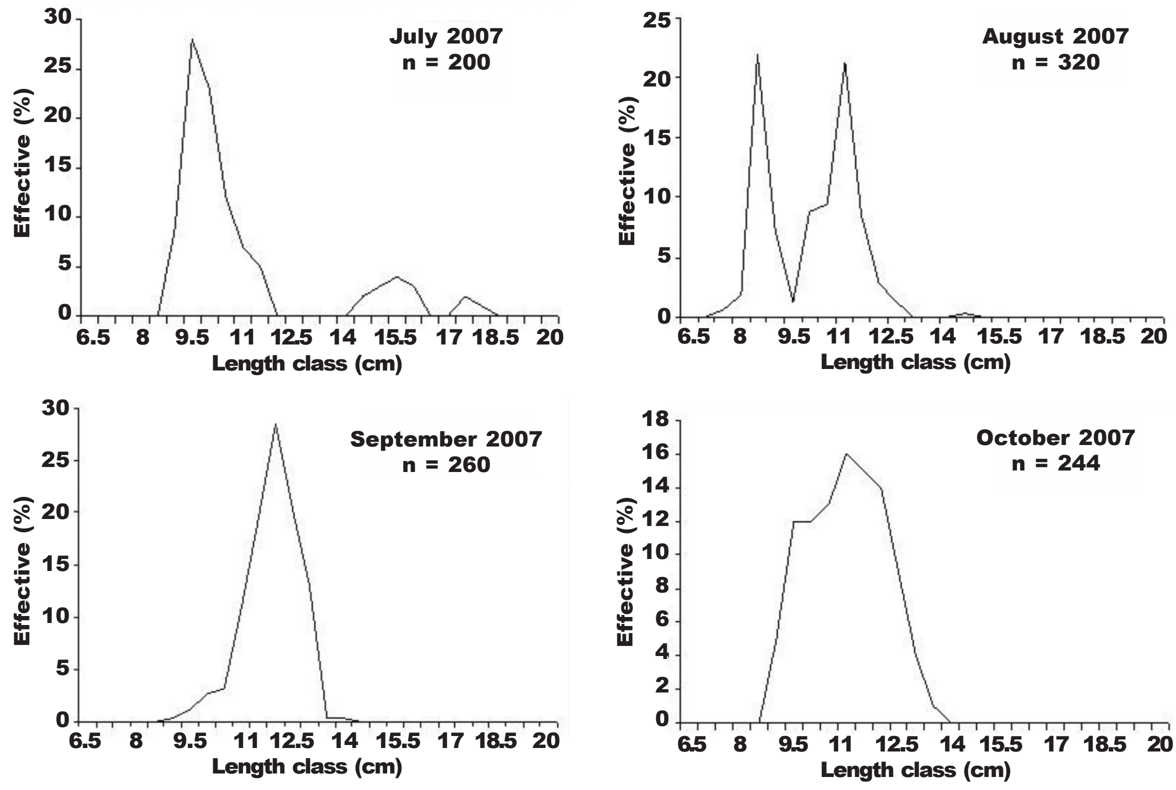


Fig. 1. Monthly length–frequency distribution of sardine (both sexes combined) in the gulf of Annaba, by 0.5 cm length class, November 2006–October 2007.

Fig. 1. Distribución mensual de la frecuencia de longitudes de la sardina (ambos sexos combinados) en el golfo de Annaba, por clases de longitud de 0,5 cm de diferencia, de noviembre del 2006 a octubre del 2007.



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 & Recasens [1995]; Alemany & Oliver [1995]).

For total mortality (Z), we retained only the method of Pauly (Length Converted Catch Curve – LCC, 1984a, 1984b, 1990) –based on the curves of catches according to lengths– as it adapted best to the sample. This method requires the reconstruction of the yearly size distribution by regrouping the monthly samples over one year and it is suitable for the species with low longevity such as sardines (Pauly, 1997). The curve is defined according to Gayanilo et al. (2004) by the following equation:

$$\ln(N_i / \Delta t_i) = a + b(t_i)$$

where N_i is the number of fish in length class i, Δt_i is the time needed for the fish to grow through length class i, t_i is the age (or the relative age, computed with $t_0 = 0$) corresponding to the mid–length of class i, and the arithmetic value of the slope *b* is an estimate of Z. Consequently, natural mortality (M) was estimated using Pauly's (1980) empirical equation based on the growth parameters and the mean annual water temperature in the study area (i.e. 21.7°C), while fishing mortality (F) from the relationship F = Z – M.

As small pelagic species usually have a high natural mortality rate (M), the values of the fishing mortality (F), which maximize the yield per recruit, are very high (Pauly & Soriano, 1986; Silvestre et al., 1991).

Results

Age composition of seasonal sampling

The TL of sardine ranged from 6.5 to 20 cm. Individuals with TL > 17 cm were recorded especially in winter and in spring: between December and May. The proportion of the individuals with TL exceeding 17 cm was important and these sardines were aged > 5 years (table 1). In summer (July–September), the catch sizes were mainly around 8.5 cm, corresponding to sardines of 1 year, or 12 cm, corresponding to 3 years (table 1, fig. 1). In autumn (October), we found a large proportion of individuals measuring between 9 and 14 cm. During this short period, we did not note the presence of sardines > 14 cm length.

The method of Bhattacharya (1967) enabled us to separate the sample of sardines into six cohorts in relation to lengths (in cm). All included both males and females (see 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 $\ln(N_i / \Delta t_i) = 13.86 - 1.88 (t_i)$ ($r^2 = 0.995$) and mortality estimates were Z = 1.88 yr^{-1} (fig. 2), M = 0.80 yr^{-1} and F = 1.08 yr^{-1}.

Table 1. Results of the age–length key of *S. pilchardus* obtained by Bhattacharya method (1967) using FISAT II software (Gayanilo et al., 2004).

Tabla 1. Resultados de la clave edad–longitud de S. pilchardus*, obtenida mediante el método Bhattacharya (1967) utilizando el software FISAT II (Gayanilo et al., 2004).*

Age (yr)	1	2	3	4	5	6
Size (cm)	7.80	10.01	12.77	15.14	16.72	18.72

Table 2. Growth parameters (FISAT II, 2004) and estimated parameters of the length–weight relationships for *S. pilchardus*, both sexes combined, in the gulf of Annaba from November 2006 to October 2007: L_∞. Asymptotic length; *a*. Equation intercept; *b*. Regression coefficient, slope; K. Curvature parameter; t_0. Theoretical age where TL = 0; $|t|_{cal}$. Statistical *t*–test based on the comparison of two slopes.

Tabla 2. Parámetros de crecimiento (FISAT II, 2004) y parámetros estimados de la relación longitud–peso para S. pilchardus*, con ambos sexos combinados, en el golfo de Annaba desde noviembre del 2006 hasta octubre del 2007: L_∞. Longitud asintótica;* a*. Intersección de la ecuación;* b*. Coeficiente de regresión, pendiente; K. Parámetro de curvatura; t_0. Edad teórica, donde TL = 0; $|t|_{cal}$. Test* t *estadístico, basado en la comparación de dos pendientes.*

vB Growth parameters			Length–weight relationship			
L_∞ (cm)	K (yr^{-1})	t_0 (yr)	*a*	*b*	*r*	$|t|_{cal.}$ (α = 5%)
22.56	0.31	0	0.00783	2.93	0.996	0.42

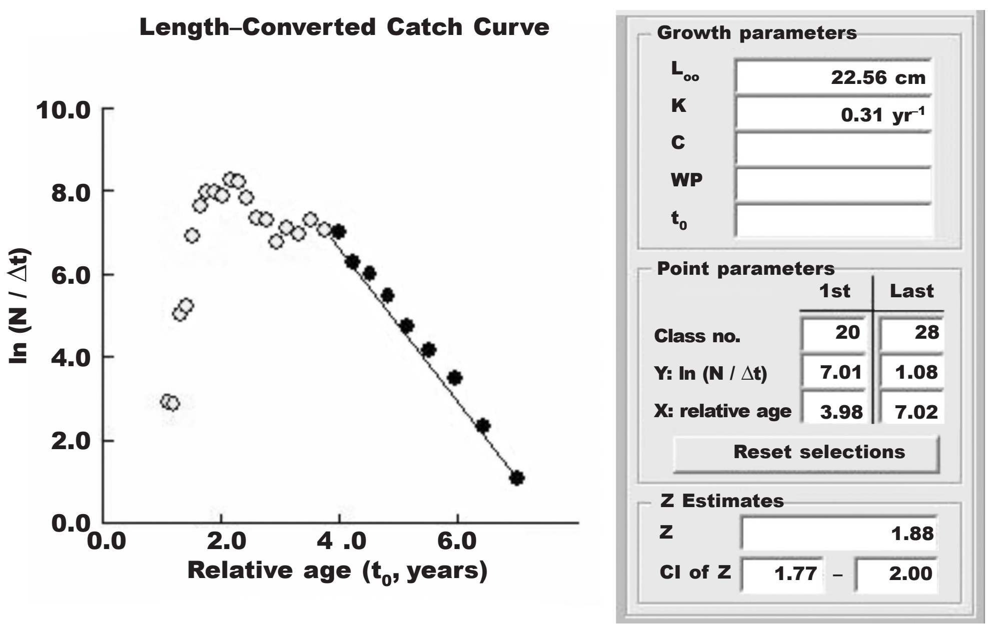


Fig. 2. Calculation of Z by Length–Converted Catch Curve for *S. pilchardus* in the gulf of Annaba (FISAT II, 2004): ● The included points in the calculation of regression.

Fig. 2. Cálculo de Z mediante la curva de captura LCC para S. pilchardus *en el golfo de Annaba (FISAT II, 2004):* ● Puntos incluidos en el cálculo de la regresión.

Table 3. Representation of catches in number and in weight of individuals according to size, obtained by the VIT (Lleonart & Salat, 2000), of *S. pilchardus* from the gulf of Annaba.

Tabla 3. Representación de las capturas en número y en peso de los individuos según su tamaño, obtenida mediante VIT (Lleonart & Salat, 2000) de S. pilchardus *del golfo de Annaba.*

Size (cm)	Catches (number)	Catches (weight in tons)
6.5	41,679.63	0.078507
7	41,679.63	0.097524
7.5	37,511.69	1,074
8	45,847.95	1,586
8.5	2,542,457.55	10,501
9	5,585,070.68	27,268
9.5	8,002,489.33	45,767
10	8,460,965.28	56,228
10.5	8,044,168.96	61,667
11	11,962,054.36	105,059
11.5	11,878,695.10	118,821
12	8,711,043.07	98,710
12.5	5,626,750.31	71,866
13	5,501,711.41	78,816
13.5	3,501,089.08	56,023
14	5,126,594.73	91,228
14.5	4,668,118.77	92,053
15	6,960,498.53	151,493
15.5	6,085,226.26	145,753
16	6,043,546.63	158,749
16.5	3,251,011.29	93,479
17	2,584,137.18	81,051
17.5	1,708,864.91	58,326
18	916,951.90	33,988
18.5	583,514.85	23,419
19	333,437.06	14,453
19.5	125,038.90	58,469
20	41,679.63	2,098
Total	119,162,067.66	1,685.50
Mean age (yr^{-1})	2.7	
Mean size (cm)	12.5	

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 sardine primarily involved individuals from the size class of 16 cm, corresponding to age 5 (table 1).The annual average product was 158.75 tons, corresponding to catches of approximately $6 \cdot 10^6$ individuals. These results also show that size and age of catches averaged 12.5 cm and 2.7 years, respectively.

Analysis of fishing mortalities

Analysis of the fishing mortalities by length showed that the sardines ranging between 6.5 and 10.5 cm had a low F. Mortality then increased with size, reaching 0.426 yr^{-1}, for the 11.5 cm size. This peak also corresponded to the size at sexual maturity which was 11.6 cm. The two main peaks corresponded to 1.122 yr^{-1} and 1.389 yr^{-1}, class sizes 16 and 19 cm respectively (table 3, fig. 3).

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 & Salat, 2000). The average fishing mortality (F) of 0.77 yr^{-1} was above the total fishing mortality (F*) that is 0.19 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 Length Cohort Analysis (LCA) based on pseudo–cohorts using length frequency data, and assuming a steady state showed that the exploitable average biomass of the sardine stock was 4,778.93 tons, of which 2,513 tons (~53%) were Spawning Stock. The size and the average age of catches were 12.5 cm and 2.7 years, respectively.

The total Biomass balance (D) was estimated at 5,508.64 tons. This corresponded to growth in weight of 4,453.77 tons (80.85%), as compared to recruitment of only 1,054.86 tons (19.15%). The natural mortality (M) corresponded to 3,823.14 tons (69.4%), while fishing mortality (F) was only 1,685.5 tons (30.6%) (table 4).

Virgin stock (B_0) or carrying capacity was characterised by a respective size and critical age of 11.75 cm and 2.4 years, reaching 8,249.42 tons (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.

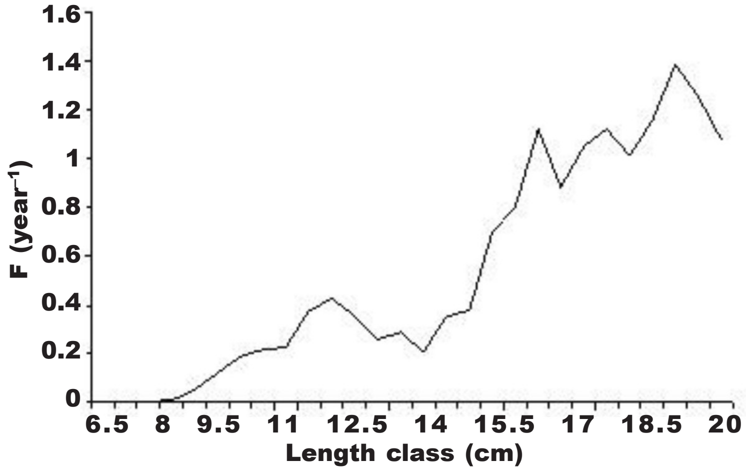


Fig. 3. Fishing mortalities according to the size, obtained by the LCA, of sardine stock, in the gulf of Annaba.

Fig. 3. Mortalidades por pesca según el tamaño, obtenidas mediante LCA, de los estocs de sardinas del golfo de Annaba.

Yield and biomass per recruit

The current yield per recruit (Y/R = 2.682 g) was lower than the maximum yield per recruit (Y_{max}/R = 3.425 g). On the other hand, the biomass per recruit (B/R = 7.604 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 = 3.425 g). The values of $Y_{0.1}$/R and $B_{0.1}$/R, corresponding to $F_{0.1}$ estimated at 1.05 yr^{-1}, were 2.749 and 7.387 g, respectively (table 5, fig. 4).

Table 4. Results of the LCA, obtained by VIT (Lleonart & Salat, 2000) according to the length of *S. pilchardus* from the gulf of Annaba.

Tabla 4. Resultados del LCA, obtenido mediante VIT (Lleonart & Salat, 2000), según la longitud, de S. pilchardus *del golfo de Annaba.*

LCA	
Age critical current stock (year)	1.9
Mean age of current stock (year)	2.1
Age critical virgin stock (year)	2.4
Mean length of current stock (cm)	9.8
Length critical current stock (cm)	10.75
Length critical virgin stock (cm)	11.75
Number of recruits (R)	636,627,604
Mean biomass (tons)	4,778.93
Spawning stock biomass (tons)	2,513
Total balanced biomass (D) (tons)	5,508.64
Natural mortality (M) (tons)	3,823.14
Biomass of virgin stock (tons)	8,249.42
Turnover D/B mean (%)	115.27

Discussion

Direct methods have not been used previously to evaluate sardine stock in the gulf of Annaba, East

Table 5. Yield and biomass per recruit of *S. pilchardus* 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.

Tabla 5. Rendimiento y biomasa por recluta de S. pilchardus *del golfo de Annaba, según F, obtenidos con VIT (Lleonart & Salat, 2000). B/R. Biomasa por recluta; Y/R. Rendimiento por recluta; F. Mortalidad por pesca.*

Type of F	F (yr^{-1})	Y/R (g)	B/R (g)
F_0	0	0	13.126
F_{curent}	1.00	2.682	7.604
$F_{0.1}$	1.05	2.749	7.387
F_{max}	5.775	3.413	3.425

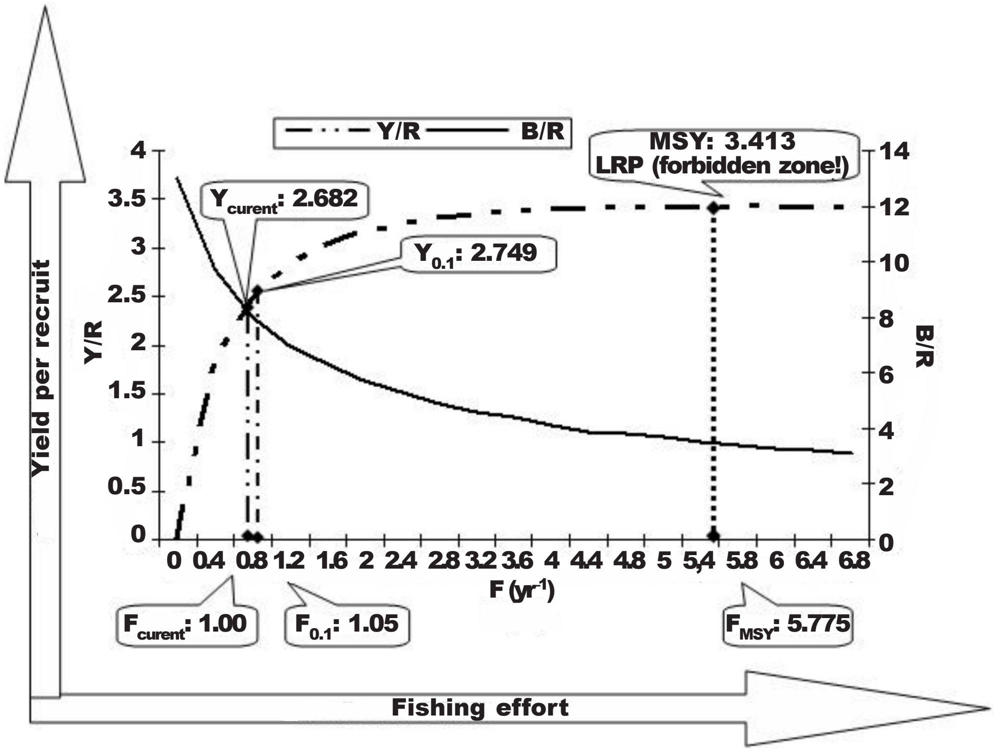


Fig. 4. Generalized evolution of the yield and biomass per recruit of sardine from the Annaba area in case of increasing the fishing effort: LRP. Limit Reference Points; Y_{curent}. Yield per recruit corresponding to current fishing mortality (F_{curent}); $Y_{0.1}$. Yield per recruit corresponding to fishing mortality ($F_{0.1}$); MSY. Maximum sustainable production corresponding to maximum fishing mortality (F_{max}).

Fig. 4. Evolución generalizada del rendimiento y la biomasa por recluta de la sardina de la zona de Annaba, en el caso de un eventual aumento de los esfuerzos pesqueros: LRP. Puntos de referencia límite; Y_{curent}.Rendimiento por recluta, correspondiente a la mortalidad por pesca actual (F_{curent}); $Y_{0.1}$. Rendimiento por recluta correspondiente a la mortalidad por pesca ($F_{0.1}$); MSY. Producción maxima sostenible, correspondiente a una mortalidad por pesca maxima (F_{max}).

Algeria. This study thus presents the first attempt to assess the state of exploitation of sardine caught by purse–seine in the gulf of Annaba 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 of catches, estimated at 12.5 cm for an age of 2.7 years, was greater than the average length at first sexual maturity (L_{50}), 11.6 cm for both sexes combined.

It is reassuring that the sardine has a high capacity to reproduce and regenerate (turnover of 115.27%). Protecting sardine 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 2,513 tons, that is to say 52.56% of the mean biomass is around 4,778.93 tons.

Sardine populations across the Atlantic and Mediterranean waters show large variation in vB growth parameters and maximum age. The longevity of sardine in the Atlantic is higher than in the Mediterranean. In the Mediterranean, the ages recorded show a maximum of 6 years and correspond to values of L_∞ of 19.44 and 22.58, respectively from Bou–Ismail in Algiers (Mouhoub, 1986) and Galicia in Spain (Álvarez, 1980). In the Atlantic, however, longevity is eight years, which corresponds to asymptotic lengths of 25.5 cm in the Bay of Biscay (Guerault, 1980) and 24 cm in the east Atlantic (Copace, 1978).

In the present study LWR analysis revealed that the value of the parameter *b* was not significantly different from 3. It can therefore be assumed that both sexes of sardine have isometric growth. Our results are comparable with a previous study by Kartas (1981) in Tunisia, who found similar isometric growth results (*a* = 0.00488; *b* = 3.055). However, Gueraut & Avrilla (1978) recorded positive allometric growth (*a* = 0.00395;

b = 3.24) in the gulf of Gascogne and Bouchereau (1981) reported similar results (*a* = 0.0096; *b* = 3.48) in the Bay of Oran, and Brahmi et al. (1998) (*a* = 0.00385; *b* = 3.20) in Algiers. A number of factors such as growth phase, season, degree of stomach fullness, gonad maturity, sex, size range, health and general fish condition, and preservation techniques are known to influence the LWR in fishes.

In the gulf of Annaba waters, the average age of catches for which the cohort reaches its maximum biomass is very close to the critical age of the current stock, and was estimated at 2.1 years for a critical length of 10.75 cm. This diagnosis is in close agreement with the papers of Dardignac (1989) and Abella (1995), which indicated that if one wants to increase production from a stock, it is desirable that the age of the catch is very close to the critical age.

According to the FAO recommendations (1996), the reference point $F_{0.1}$ is an acceptable target value for management for a rational exploitation of the resources. It provides almost as much production per recruit as F_{max}, but has a lower level of fishing mortality (F).

Although there are good reasons to cease using F_{max} as a target reference point (TRP), it can be regarded as a higher limit for F, like a PRL for stock. Since the eighties, $F_{0.1}$ has been adopted as a long–term objective by several international commissions on fishing and by the EU (Cadima, 2002).

In biological terms concerning conservation of the exploited marine resources, our results indicate that fishing should not exceed the current rate ($F = 1.0\ yr^{-1}$). Exceeding the biological reference point ($F_{0.1}$), which corresponds to a production per recruit of 2.749 g, would put the population at risk.

In conclusion**,** the sardine stock in the area analysed is under–exploited with reference to Y/R_{max} and very near with reference to $Y/R_{0.1}$. Furthermore, $F_{0.1}$ is 82% lower than F_{max} and yet it results in a yield per recruit only 19% smaller than that at F_{max}. It is usually the case that $F_{0.1}$ gives almost as much yield per recruit as F_{max} but at considerably lower effort levels. Because of this, $F_{0.1}$ has been used in many fisheries as a target reference point, being a more conservative benchmark than F_{max}. Nevertheless, the LCA steady state assumption, the great sardine recruitment fluctuations, the uncertain natural mortality value and the LCA are highly sensitive to the input parameters, producing a strong bias in the assessment. Results are therefore an approximation of the population dynamics and they should therefore be considered with caution. The data presented in this study would be useful to ensure the sustainable management of the sardine fishery in the in the gulf of Annaba.

Based on our preliminary results we can offer several recommendations: (1) fishing activities should not be increased beyond current levels and fishing effort data should be collected; (2) assessments should be improved. More information should be acquired on the growth and reproductive parameters of sardine and present exploitation patterns. This would be particularly useful for selecting target values for fishing mortality, determining minimum values for spawning biomass and for estimating long–term sustainable yields in a moderately conservative fashion; and (3). Data acquisition should continue and proceeding towards other indirect methods of assessment, such as tuned VPA.

Acknowledgements

The research tasks were carried out in the Laboratory of Ecobiology of the Marine and Littoral Environments (EMMAL), Department of the Marine Sciences, University Badji Mokhtar–Annaba, Algeria. The authors are thankful for advice and help from Prof. C. Abdennour, Prof. M. S. Boulaakoud and Dr. Alberto Santojanni for their useful comment and suggestions CNR–ISMAR, Ancona, Italy. This work was made possible with the financial support of the ‘Agence Nationale pour le Développement de la Recherche en Santé’.

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