Growth of the European anchovy (*Engraulis encrasicolus*) in the Strait of Sicily

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Abstract

Age structure and growth parameters for the anchovy, *Engraulis encrasicolus,* were estimated for the first time in the Strait of Sicily. The sampling was carried out from May 2000 to October 2001 on board commercial fishing vessels. The age composition of the catches was dominated by the 2nd-year-class (55–63%) and the 1st-year-class (30–41%), whereas the 0-year-class (1–5%) and the 3rd-year-class (3–5%) represented a small proportion of the catches. The von Bertalanffy growth model and back-calculation were applied to estimate anchovy growth parameters using the FISAT programme. There were no significant differences between males and females; pooled mean parameters were L_∞=18.6 cm, k=0.29 year^{-1} and t_0=–1.81 years. The estimated parameter *k* of the Sicilian anchovy was at the lower end of the range observed for this fish species in different areas, ranging from 0.26 (Algeria) to 2.44 (northern Adriatic Sea).

Keywords: anchovy, growth, population structure, otolith, back-calculation, Strait of Sicily.

1. Introduction

The European anchovy (*Engraulis encrasicolus* L. 1758) is widely distributed along the coasts of Europe, north to about Bergen, Norway, but not in the Baltic and rarely in the North Sea; in the whole Mediterranean and Black and Azov Seas; along the coast of West Africa down to South Africa (see geographical distribution in the FAO–Fishbase web page). In the Strait of Sicily, there is one of the main pelagic resources for both the purse-seine and mid-water pair-trawl fleets. Anchovies are well represented in the catch throughout the year, except in winter, when landings decrease to low levels (Mazzola *et al*., 2002). Despite the importance of the anchovy fishery in the Strait of Sicily, there is no information available, either on the age structure or on the growth of the species in this area.

Short lived pelagic fish species, like anchovy, mainly consist of a few age-classes. When the stock is overexploited, the age-classes usually decrease in number and it is important to understand the extent to which the year-to-year fluctuation in the population depends on the recruitment (0-age-class).

The aims of this study were: (1) to determine the extent to which the anchovy fishery is supported by the smallest age-classes; and (2) to obtain the first estimates of growth parameters of the anchovy population in the Strait of Sicily

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2. Methods

Samples

The present study was of the exploited anchovy population of the southern shelf of the Sicilian coast (Figure. 1). The sampling was carried out from May 2000 to October 2001 in the Port of Sciacca, which is the most important landing port, for small pelagic fish species, along the southern coast of Sicily. The sampling was based on market landing and on deck-collected specimens.

To cover the widest possible size range, especially for the smallest sizes, two different fishing gears were used, two days per month: the purse-seine and the mid-water pair-trawl. Specimens were also examined in the laboratory.

A total of 11,769 specimens was measured to the nearest millimeter, and length data were grouped by 0.5-cm length intervals (Table 1), weighed to the nearest gram; sex and maturation stages were also determined. The minimum and maximum number of individuals per sample was 72 and 854, respectively. Otoliths were removed from a sub sample of 5 specimens for each 0.5-cm length interval, up to a total of 1,700 otolith pairs. The age reading and growth analysis were carried on 1,678 specimens: 730 males, 819 females and 129 specimens of undeterminable sex.

Analyses were carried on unsexed, males and females with a view to detecting any differences in growth patterns and to avoiding a bias in the estimation of growth parameters. The undetermined sex specimens were important to get a wider range of length for fitting the growth model, so the sex ratio was estimated for each 0.5-cm length interval from the individuals sexed, and the estimated values were applied to the immature specimens to obtain the relative number of females and males for each size-class.

The otoliths were cleaned and dried and stored in black plastic labelled moulds. For age reading, the otoliths were put in a solution of alcohol and glycerin to increase the visibility of the hyaline rings under reflected light over a dark background. The alternating white and dark rings are called hyaline and opaque, respectively.

The criterion followed to determine the age of a fish was as follows: as well documented in the literature, the wider opaque ring is laid down in the summer, and the narrow hyaline ring, in the winter; the birth date was established in summer time, the first day of July, based on the peak of spawning period in the Strait of Sicily (García Lafuente *et al*., 2002; Patti *et al*., 2002). Fishes sampled before this date were assigned an age equal to the observed number of hyaline rings bordered by opaque rings, whereas, if the fish came from sampling carried out during the second part of the year, the age was established only by the number of hyaline rings. Each otolith was read twice by two independent observers and when there was a discrepancy between readings, the otolith was excluded, but only 3% of analysed sagittae were discarded. The total radius and distance between the core and the rings were measured along the post-rostrum axis under a dissecting microscope at 25× magnification.

Table 1. Monthly anchovy length–frequencies obtained from landings and deck-collected data (*n*=11,769)

Size (cm)	05/00	06/00	07/00	08/00	09/00	10/00	11/00	12/00	01/01	02/01	03/01	04/01	05/01	06/01	07/01	08/01	09/01	10/01
6.0							1											
6.5							4											
7.0							2											
7.5							11											
8.0							10											
8.5					1		14											1
9.0					9		30			3	1							0
9.5					31		19			4	12							2
10.0			1		76		19	4		15	59							16
10.5			0		106		11	53		22	129	4		2	1		2	35
11.0		4	8		104	2	18	124	3	49	205	36		14	64	3	5	33
11.5	4	9	35	1	28	8	4	127	9	33	219	160		138	170	107	4	8
12.0	47	27	102	13	10	43	6	95	13	26	187	231		296	247	348	16	6
12.5	117	63	112	68	7	53	7	87	9	25	124	254	4	241	324	456	22	5
13.0	199	131	125	137	17	127	6	94	9	20	38	146	13	92	322	267	54	24
13.5	120	134	77	159	5	135	3	58	8	14	12	60	38	45	83	104	54	58
14.0	180	222	85	125	10	140	3	48	11	31	9	40	62	32	28	47	54	173
14.5	89	180	44	57	2	74	1	18	7	40	4	14	84	23	1	20	50	128
15.0	35	60	12	20	3	15	0	6	2	20	1	10	57	14		7	26	66
15.5	8	19	5	2	1	3	0	2	0	12		2	37	2		2	7	16
16.0	4	3	1				1		1	6		2	4				5	4
16.5	1	2											1				1	
Total	804	854	607	582	410	600	170	716	72	320	1000	959	300	899	1240	1361	300	575
Samples	2	1	1	1	1	1	1	1	1	2	2	2	1	2	2	2	1	2

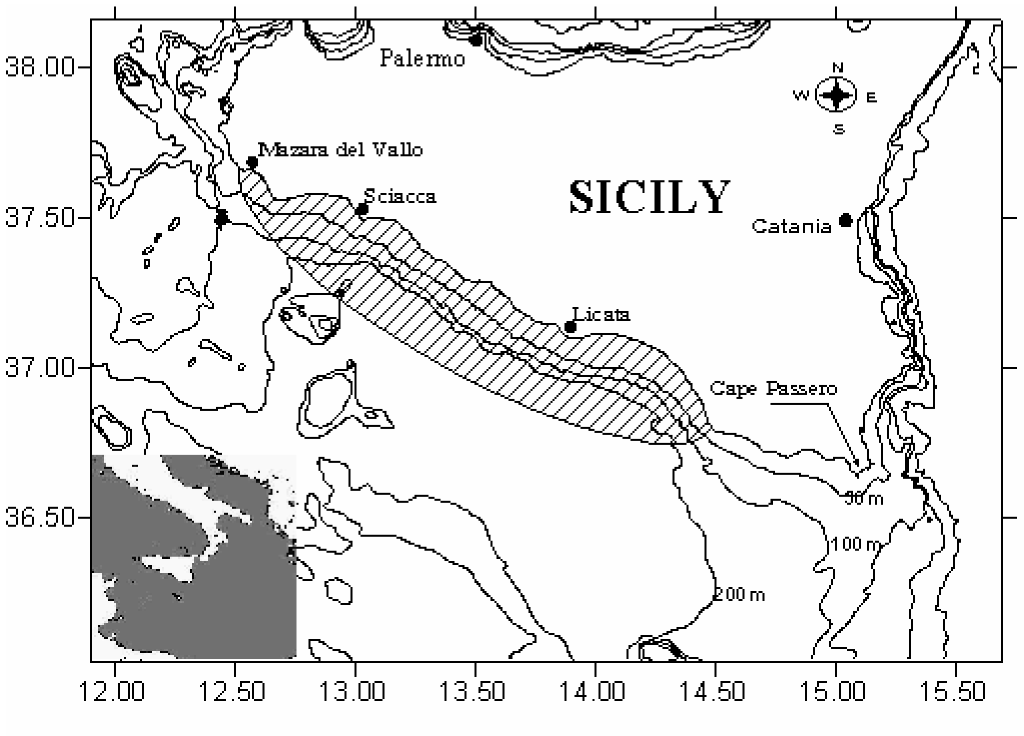

Figure 1. Sampling area (cross-hatched) and main spawning area (shadowed) on the south coast of Sicily; 50-m, 100-m and 200-m isobaths are shown.

Population age structure

The length–age key was obtained (Table 2) from fish length-at-age based on the interpretation of otolith data. By means of this key, when only length data were available, the age composition over the whole data set was computed. The total number of fish collected in each size-class was multiplied by the corresponding proportion of each length-at-age group, from the age–length key.

To avoid bias in the age composition due to the different sizes of the monthly samples, the analysis was performed on two different data sets. The first one was the whole data set and the second was composed of 200 specimens randomly selected every month. The monthly age distribution was also assessed.

Table 2. The age–length relationship obtained by otolith interpretation for *Engraulis encrasicolus*.

Total length (cm)	Age (in years)			
	0	1	2	3
7.0	2			
7.5	3			
8.0	6	1		
8.5	16	3		
9.0	14	8		
9.5	14	23		
10.0	6	38	1	
10.5	2	67	8	
11.0	2	104	27	
11.5	1	112	47	
12.0		112	94	
12.5		84	140	
13.0		70	140	5
13.5		36	140	6
14.0			137	15
14.5			91	16
15.0			55	11
15.5			12	9
16.0				3
Mean length (cm)	9.29	11.77	13.38	14.63
SD (cm)	0.84	0.1	0.1	0.78
No. of specimens	63	659	894	68

Growth estimation methods

The von Bertalanffy growth equation (VBGE) was used to estimate the growth parameters:

$$L_t = L_\infty \left(1 - \exp^{-k(t-t_0)}\right)$$

where L_t is the length (in centimetres) at the age t (in years), L_∞ the asymptotic length (the length at which growth rate is theoretically zero, in centimetres), k is the body growth-ratecoefficient (rate of asymptotic growth, in years^{-1}) and t_0 is the time when length would have been zero on the modelled growth trajectory.

An estimation of growth parameters was attempted using FiSAT software (Gayanilo and Pauly, 1997). The FiSAT package fits the VBGE function for the pooled-pair age-at-length data by means of non-linear regression analysis, based on iteration, that determines the growth parameters so as to minimize the sum of squares of deviation:

$$\sum_{i=1}^{n} \left(L_i - L_\infty \left(1 - \exp^{-k(t_i - t_0)}\right)\right)^2$$

where L_i is the length of the i^{th} fish and t_i is its observed age, and L_∞ and k are the growth parameters described above.

A complementary method was applied to compare results from the growth model estimation: the back-calculation method of Francis (1990) revisited. The back-calculation uses fish length and fish otolith radius measurements at the time of capture to infer the length at times in the past (Francis 1990). The dimensions of one or more marks in some hard part of the fish, together with its current body length, are used to estimate its length at the time of formation of each of the marks. This technique is based on the hypothesis of the linear relationship between the body size (length or weight) and the size of the hard part considered (e.g. radius of the otolith, scale, etc). The back-calculation equation is

$$L_i = \left(\frac{a + bR_i}{a + bR_c} \right) L_c$$

where *L* and *R* are the fish length and the otolith radius, respectively; *c* and *i* are the time of capture and the time of ring *i* formation, respectively. In the equation, the estimates of *a* and *b* were obtained from the linear regression of the otolith radius on the body length.

To test the overall growth performance, the phi-prime index (ϕ') was calculated (Munro and Pauly, 1983; Pauly and Munro, 1984), of which, the main advantage that it overcomes the problem of the correlation between k and L_∞:

$$\phi' = log_{10}k + 2log_{10}L_\infty$$

3. Results

The age–length key applied to the whole length–frequency distribution provided the age composition shown in Table 3, in terms of proportions for each age-class in the years 2000 and 2001. There were no significant differences between the values obtained using the individuals randomly and those obtained using the whole data set (χ^2 test, $P<0.001$). The fishery is mainly supported by the 2nd-year-class (55–63%) and the 1st-year-class (30–41%), whereas the 0-year-class (1–5%) and the 3rd-year-class (3–5%) represent only a small proportion of the catch. Specimens older than 3+ years were not observed. The monthly age composition (Figure. 2) shows that the recruitment season started in September–October, whereas the highest proportion of the 0-year-class was observed in November 2000.

Table 3. The proportions of each age-class in the anchovy fishery in 2000 and 2001 obtained from two different data sets, one randomly selected (1) and the whole data set (2).

Age	Year 2000		Year 2001	
	Dataset 1	Dataset 2	Dataset 1	Dataset 2
0	5	2	1	1
1	33	30	36	41
2	58	63	58	55
3	4	5	5	3

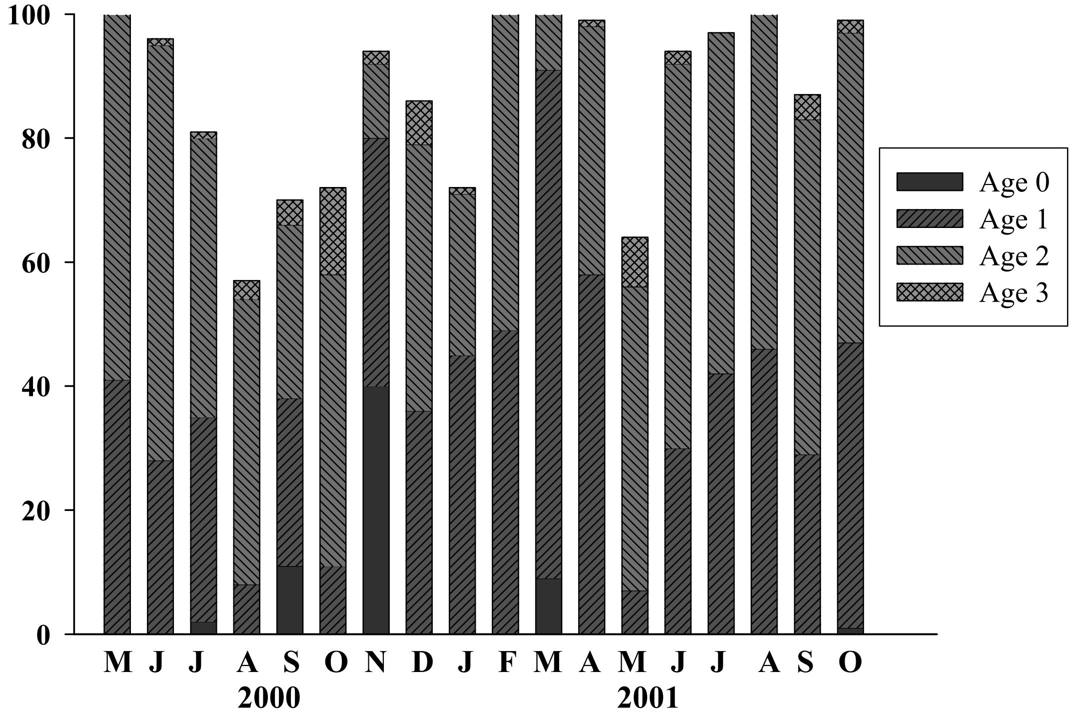

Figure 2. Monthly age composition of the catches over the study period.

The growth parameters are summarized in Table 4. An analysis of co-variance (ANCOVA), taking the length (log-transformed) as a variable, the age as a co-variable and the sex as a factor, showed that there were no significant differences in the growth parameters between males and females, if the individuals of undetermined sex are not considered ($F_{1,1301}$=1.4, P=0.24). The linear relationship between fish length and otolith radius for males and females are shown in Figure 3. An ANCOVA, taking the fish length as a co-variable and the sex as a factor, showed a significant difference between females and males ($F_{1,\ 1680}$=7.9, P=0.005).

Table 4. Von Bertalanffy growth parameters (L_∞, k and t_o) with the corresponding standard errors, estimated for anchovy; *M* males, *F* females, and *F+M* sexes combined.

Sex	**L_∞ (cm)**	**k (yr^{-1})**	**t_o (year)**
F	18.6±0.13	0.29±0.06	–1.94±0.3
M	17.5±0.11	0.33±0.06	–1.87±0.3
F+M	18.6±0.13	0.30±0.06	–1.81±0.2

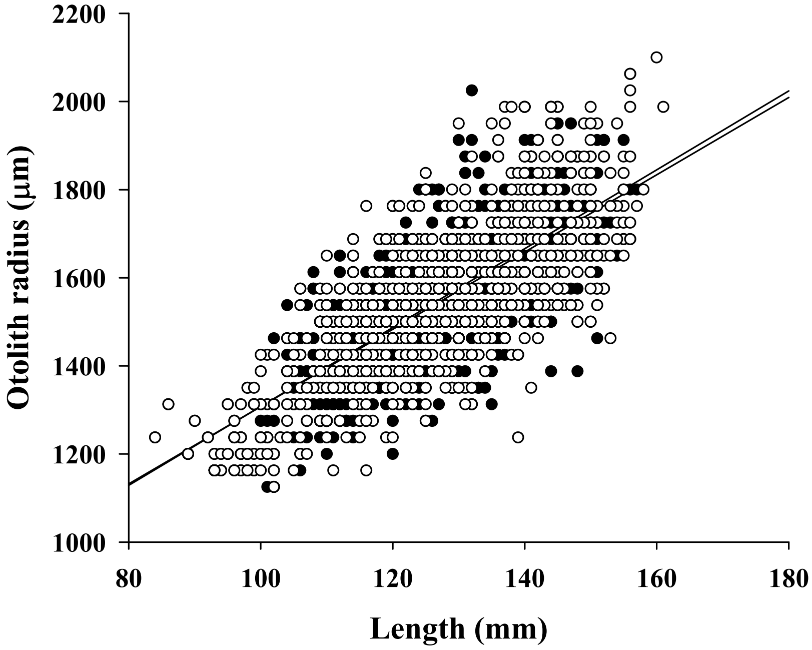

Figure 3. Otolith radius (TR in micrometres) versus total fish length (TL in millimetres); linear regression for males (● TR=413.3+8.9TL, n=803, r^2=0.52) and females (○ TR=430.5+8.77TL, n=887, r^2=0.55).

The mean size for the age-class, obtained by direct age readings, was compared with those obtained by the VBG model and by the back-calculation analysis: the results were similar (Table 5).

Table 5. The mean length, the standard deviation (s.d.), in centimetres, and the number of specimens (n) for each age-class, based on the lengths observed, estimated by back-calculation and by the von Bertalanffy equation (VBGE) for males (M) and females (F) of *Engraulis encrasicolus*.

	Observed						**Back-calculation**						**VBGE**								
Age	F	s.d.	n	M	s.d.	n	F	s.d.	n	M	s.d.	n	F	s.d	n	M	s.d	n	F+M	s.d	n
0	9.2	0.8	59	9.2	0.8	55							9.6	0.7	131	9.6	0.7	105	9.6	0.7	131
1	11.7	3.9	357	11.8	1.1	365	11.6	1.1	356	11.6	1.1	365	11.6	0.6	211	11.6	0.5	206	11.6	0.6	213
2	13.5	1.1	486	13.2	1.0	419	13.4	1.0	486	13.2	1.0	419	13.4	0.4	185	13.2	0.4	167	13.4	0.4	171
3	14.7	0.7	47	14.5	0.7	20	14.7	0.7	46	14.4	0.7	20	14.8	0.3	116	14.3	0.3	109	14.8	0.4	129
4													15.6	0.7	131	15.1	0.7	105	15.6	0.7	131

The growth parameters obtained from the literature for *Engraulis encrasicolus* in different regions are shown in Table 6. As it is now accepted that the anchovy species formerly named *Engraulis capensis* is in fact the same species as the European anchovy *Engraulis encrasicolus* (Whitehead, 1990; Hugget *et al*., 2003), the growth parameters for this species in South Africa (Waldron 1995) were also included. In most of the studies, the method used to estimate the growth parameters was based on otolith measurement, but also on length–

frequency analysis and scales. In those studies for which the method is unknown, the reason is that the information was obtained from the fish data base (http://www.fishbase.org). It has been demonstrated for the anchovy that similar growth parameters are obtained by using otolith data and length–frequency analysis (Morales-Nin and Pertierra, 1990). There are no studies comparing growth parameters obtained using otoliths and scales in anchovy, but in other pelagic fish species, such as sardine, a statistical difference between the otolith-based growth curve and the scale-based growth curve has been shown (Pertierra andMorales-Nin, 1989).

Table - 6. Growth parameters and the performance index (ϕ') in different regions for the anchovy *Engraulis encrasicolus*.

Area	L_∞ (cm)	k (yr^{-1})	ϕ'	Method	Source
Strait of Sicily	18.6	0.3	2.016	Otolith	This study
Catalonian littoral (NE Spain)	19.1	0.35	2.106	Otolith	Morales and Pertierra (1990)
Catalonian littoral (NE Spain)	19.4	0.41	2.199	Otolith	Pertierra (1987)
Gulf of Cádiz (SE Spain)	18.8	0.9	2.503	Frequency analysis	Bellido *et al*. (2000)
Northern Adriatic Sea (Po River, Italy)	15.3	2.44	2.757	Scale	Padoan (1963)
Central–northern Adriatic (Croatia)	19.4	0.57	2.331	Otolith	Sinovĉić (2000)
Algeria	18.6	0.26	1.954	Otolith	Hémida (1987)
Gulf of Lion (SE France)	19.1	0.35	2.106	Unknown	Campillo (1992)
Gulf of Lion (SE France)	20	0.42	2.225	Unknown	Lee and Juge (1965)
Gulf of Biscay	21.3	0.48	2.343	Otolith	Cendrero *et al*. (1981)
North Portugal	15.8	0.53	2.12	Otolith	Ramos and Santos (1999)
Algerian–Moroccan	20	0.39	2.2	Unknown	Arrignon (1966)
Central Ionian Sea (Greece)	17.5	0.51	2.194	Otolith	Machias *et al*. (2000)
West coast of South Africa	n.c.	1.32	n.c.	Otolith	Waldron (1995)

4. Discussion

In the study area, we found that the youngest age-class (0-year-class) represents a small proportion of the anchovy fishery. In contrast to our findings, Bellido *et al*. (2000) observed that the anchovy fishery was mainly supported by the young fish in the Gulf of Cádiz. There are two probable explanations for the low proportion of young age-classes in the Strait of Sicily fishery: sampling (by us and by the fishery) was not carried out in the nursery areas, and the fishing effort was not directed to juveniles. Garcia Lafuente *et al*. (2002) studied the link between the general circulation of the Atlantic Ionian Stream and the reproductive strategy of the anchovy in the Strait of Sicily. The main spawning ground is in the north-western part of the southern Sicilian coast. The main branch of the Atlantic Ionian Stream heads south-eastwards at the eastern end of the Sicilian coast, caryying the anchovy eggs and larvae; hence, the highest concentrations of larval anchovy were found off the south-eastern Sicilian coast, off Cape Passero. Therefore, larvae reach the juvenile stage off the south-eastern coast of Sicily, indicating that the 0-year-class anchovy was located in a region different from that in which the samples were collected for our study. Since the individuals collected during this study came from commercial fishing vessels, it means that fishing pressure is higher in the areas where adults are the predominant age-class, which is a positive factor for sustainable fishery. Therefore, although the proportion of the 0-year-class was low in the samples collected, we cannot decide whether the population is supported by the young age-classes, because the low proportion of the youngest class in the sampled population is probably due to the fact that the adults are located in a different area from the juveniles. The growth parameters obtained for our study area, compared with those from other areas, appear in the low end of the range for *k*, whereas the L_∞ value is in the higher part of the data range. Further studies on habitat conditions will be performed to try to explain the difference in growth parameters amongst areas for the same species.

The sampling programme was carried out under a European Commission-funded project: The purse-seine landing composition in the central an eastern Mediterranean Sea. Ref.: MED-99-035.

5. References

Arrignon, J. (1966) L´anchois (*Engraulis encrasicolus* L. 1758) en Côte d´Oranie. *Rev. Trav. Inst. Pêches Marit.,* Nantes 30: 317-342 pp.

Bellido, JM., Pierce, G.J., Romero, J.L., Millan, M. (2000) Use of frequency analysis methods to estimate growth of anchovy (*Engraulis encrasicolus* L. 1758) in the Gulf of Cádiz (SW Spain). *Fish. Res.,* 48: 107-115 pp.

Campillo, A. (1992) Les pêcheries françaises de Méditerannée: synthèse des connaissances. IFREMER, Sète, France. 206 pp.

Cendrero, O., Cort, J.L., de Cardenas, E. (1981) Revisión de algunos datos sobre la biología de la anchoa, *Engraulis encrasicolus* (L.) del Mar Cantábrico. *Bol. Inst. Esp. Oceanogr*., 6: 117-124 pp.

Francis, R.I.C.C. (1990) Back-calculation of fish length: a critical review. *J. Fish. Biol.*, 36: 883-902 pp.

Gayanilo, F.C. Jr., and Pauly, D. (eds.) (1997) The FAO–ICLARM Stock Assessment Tools (FiSAT) Reference Manual. *FAO Comput. Inf. Ser. (Fish.)*., 8. FAO, Rome.

Garcia Lafuente, J., Garcia, A., Mazzola, S., Quintanilla, L., Delgado, J., Cuttitta, A., Patti, B. (2002) Hydrographic phenomena influencing early life stages of the Sicilian Channel anchovy. *Fish. Oceanogr*., 11: 31-44 pp.

Hémida, F. (1987) Contribution à l´étude de l´anchois: *Engraulis encrasicolus* (Linné, 1758) dans la región d´Alger. Biologie et explotation., Thèse de Magister, USTHB, Alger. 138 pp.

Hugget, J., Fréon, P., Mullon, C., Penven, P. (2003) Modelling the transport success of anchovy *Engraulis encrasicolus* eggs and larvae in the southern Benguela: the effect of spatio-temporal spawning patterns. *Mar. Ecol. Progr. Ser.*, 250: 247-262 pp.

Lee, J.Y., Juge, C. (1965) Observations morphologiques et biologiques sur l'anchois (*Engraulis encrasicolus*) du golfe du Lion. *Rapp P.-V. Réun. Comm. Int. Explor. Sci. Médit.,* 18: 221-224 pp.

Machias, A., Somarakis, S., Kapadagakis, P., Drakopoulus, P., Giannoulaki, M., Maraveya, E., Manousakis, L., Vatsos, D., Tsimenidou, C., Tsimenides, N. (2000) Evaluation of the southern Greek anchovy stocks. European Commission, DG XIV (Fisheries). Final report contract 97/0048.

Mazzola, S., Garcia, A., Garcia Lafuente, J., Patti, B., Bonanno, A., Cuttitta, A., Basilone, G., Quintanilla, F., Delgado, J.,(2002) On the effects of SST on the interannual fluctuations of European anchovy (*Engraulis encrasicolus*) catches: first indications from the case study of the population off the southern Sicilian coast. In: Agostin,i V. and Oliver, P. (eds.) Environmental variability and small pelagic fisheries in the Mediterranean Sea. *Inf. Estud. COPEMED*, 8:58-59. Morales-Nin, B., and Pertierra, J.P. (1990) Growth rates of the anchovy *Engraulis encrasicolus* and the sardine *Sardina pilchardus* in the northwestern Mediterranean Sea. *Mar. Biol.*, 107: 349-356 pp.

Munro, J.L., and Pauly, D. (1983) A simple method for comparing growth of fishes and invertebrates. *ICLARM Fishbyte*, 1: 5-6 pp.

Padoan, P. (1963) Prime osservationi sulle acciughe (*Engraulis encrasicolus* L.) catturate al largo delle foci del Po. *ICES Rapp. Proc. Verb.*, 17: 327-332 pp.

Patti, B., Mazzola, S., Bonanno, A., Cuttitta, A., Basitone, G., Buscaino. G., Garcia, A., Garcia Lafuente, J. (2002) On the European anchovy (*Engraulis encrasicolus*) off the southern coasts. First results from an interdisciplinary research study. *Biol. Mar. Medit.*, 9(1): 778-780 pp.

Pauly, D., Munro, J.L. (1984) Once more on the comparison of growth in fish and invertebrates. *ICLARM Fishbyte,*2(1). 21 pp.

Pertierra, J.P. (1987) Crecimiento del boquerón (*Engraulis encrasicolus* L. 1758) (Pisces: Engraulidae) de la costa Cataluña (Mediterráneo noroccidental). *Invest. Pesq.*, 51: 263-275 pp.

Pertierra, J.P., and Morales-Nin, B. (1989) Sardine growth in the Catalan Sea (NW Mediterranean) determined by means of otolith interpretation and length–frequency data. *Sci. Mar.*, 53: 821-826 pp.

Ramos, S., and Santos, P. (1999) Crescimento do biqueirão (*Engraulis encrasicolus* Linnaeus, 1758) na costa norte de Portugal. *Rev. Biol.*, 17: 211-216 pp.

Sinovčić, G. (2000) Anchovy, *Engraulis encrasicolus* (Linnaeus, 1758): biology, population dynamics and fisheries case study. *Acta Adriatica*, 41: 3-53 pp.

Waldron, M.E. (1995) Evidence of reduced growth rates of anchovy recruits off South Africa in 1989 and 1991. *S. Afr. J. Mar. Sci.*, 15: 263-267 pp.

Whitehead, P.J.P. (1990) Engraulidae. In: Quéro, J.C., Hureau, J.C., Karrer, C., Post, A., Saldanha, L. (eds.) Check-list of the fishes of the eastern tropical Atlantic (CLOFETA). Vol. 1:228-229.Societas Europeae lchthyologorum (SEI). JNICT, Portugal. UNESCO, Paris.