

## Acoustic estimation of abundance and distribution of anchovy in the NW Mediterranean\*

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**SUMMARY:** In order to estimate the abundance and the distribution of the anchovy in the Northwest Mediterranean, a standardised series of acoustic evaluation cruises was carried out in 1990, 1991, 1992, 1993 and 1995. The series showed that there was agreement between the biomass estimations and the registered landings in the area. On the other hand, some areas were identified where the recruits were largely localised.

**Key words:** NW Mediterranean, anchovy, acoustic estimation.

**RESUMEN:** ESTIMACIÓN ACÚSTICA DE LA ABUNDANCIA Y DISTRIBUCIÓN DE ANCHOA EN EL NOROESTE MEDITERRÁNEO. – Una serie estandarizada de campañas de evaluación acústica ha sido realizada durante los años 1990, 1991, 1992, 1993 y 1995, para estimar la abundancia y distribución de la anchoa en el Noroeste del Mediterráneo. La serie mostró que hay consistencia entre las estimaciones de biomasa y los desembarcos registrados en el área. Por otro lado, se identificaron áreas en las que los reclutas son localizados mayoritariamente.

**Palabras clave:** NW Mediterráneo, anchoa, estimación acústica.

### INTRODUCTION

The anchovy (*Engraulis encrasicolus*, Linnaeus, 1758) is the target species for the seine net and some trawlers of the Catalan coast, as well as of the semi-pelagic seiners and trawlers in the Gulf of Lyons, because of its economic importance.

The official annual landings for this species registered in Catalanian ports have varied in recent years, between 8900 tonnes in 1990 and 12828 tonnes in 1994, and between 9611 tonnes in 1989 and 4854 tonnes in 1991 for the Gulf of Lyons (García *et al.*, 1994).

The topography of the continental shelf is very variable in this zone. In the Gulf of Lions it extends up to 42 miles from the coast with the slope having numerous canyons. On the north coast of Catalonia the shelf is very narrow, the slope is 14 miles from the coast, and with, as in the Gulf of Lyons, submarine canyons. On the other hand, the shelf widens in the zone south of the Catalan coast, reaching 24 miles in front of the mouth of the Ebro River (Fig.1).

A permanent shelf-edge front is the dominant oceanographic feature of the north-western Mediterranean Sea (Font *et al.*, 1988). Essentially, it is a salinity front separating low salinity shelf water from the more saline offshore water. The front intersects the seabed at depths of nearly 300 m and is

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usually observed at the surface near the 1000 m isobath (García *et al.*, 1994). The frontal structure is associated with a current running just offshore, in a south-westerly direction at speeds of 20-30 cm/s. The whole oceanographic system is subject to high spatio-temporal instability characterised by the frequent appearance of energetic eddies, filaments and mid-depth intrusions (Wang *et al.*, 1988; La Violette *et al.*, 1990; Tintoré *et al.*, 1990).

The nutrient richness in the zone is due, principally, to the inputs of the Rhone and Ebro rivers, as well as to the “upwelling” associated with the coastal winds (Millot, 1990), and to the permanent “upwelling” originating from the intrusion of water from the open sea towards the shelf in the mouth of the ‘Ebro (Font *et al.*, 1990).

Several studies have been carried out on the biological aspects of the species, such as areas and periods of reproduction (Aldebert & Tournier, 1968; Palomera, 1986, 1989, 1992; García *et al.*, 1994; Palomera *et al.*, 1995), batch fecundity (Pertierra, 1992), growth (Palomera *et al.*, 1988; Pertierra, 1987, 1992; Morales-Nin and Pertierra, 1990), larval mortality (Palomera and Lleonart, 1989) and feeding (Tudela and Palomera, 1995).

The abundance estimations for this species in the area have been carried out by means of indirect methods, using models based on size distributions (Pertierra, 1992; García *et al.*, 1994; Pertierra and Lleonart, 1995), and by direct methods, such as the daily egg production method (DEPM) (Palomera and Pertierra, 1993; García *et al.*, 1994). In addition, acoustic evaluation cruises have been carried out both in the spring and summer months (Miquel *et al.*, 1991; García *et al.*, 1994) and in the autumn months (Pertierra and Castellón, 1987; Abad *et al.*, 1991, 1992).

In the present study results are considered from five evaluation cruises in this zone using acoustic methods carried out by the Spanish Oceanographic Institute (I.E.O.) between 1990 and 1995. Data are presented for the abundance of anchovy and its interannual fluctuation, as well as the distribution areas for the juvenile and adult individuals.

## MATERIAL AND METHODS

The cruises were carried out in the Northwest Mediterranean Sea (Balearic Sea and Gulf of Lions), between the 30 and 200 m contours, during the months of October-November in 1990, 1991, 1992, 1993 and

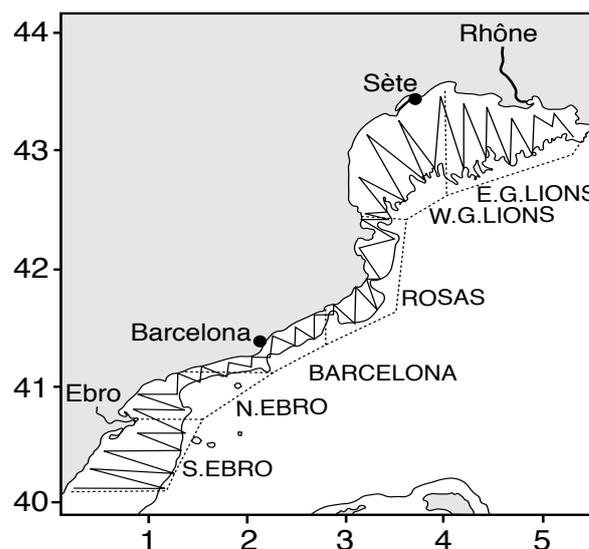


FIG. 1. – Surveyed area showing the tracks, sectors and the 200 m isobath.

1995 off the Catalanian coast and 1990 and 1992 in the Gulf of Lions (Fig.1). The months in which the cruises were carried out were established based on the recruitment season for the anchovy in the zone.

The abundance estimations for the species were carried out by applying a standardised methodology. Therefore, the echointegration system (MacLennan and Simmonds, 1992) was SIMRAD EK-500 acoustic equipment, working at a frequency of 38 KHz, with a split-beam transducer. A copper sphere was used as a reference control for its calibration (Foote *et al.*, 1983). The elementary distance sampling unit (EDSU) was one nautical mile. The fishing gear used in the sampling was a pelagic trawl with a 20 m vertical opening, equipped with a netsonde (SIMRAD, FR-500). In the five cruises a total of 80 echo identification hauls were carried out, 70 of which showed the presence of anchovy (Table 1).

TABLE 1. – Fishing stations by survey, with an indication of the number of them with anchovy present.

Survey dates	Total fishing stations	Fishing stations with anchovy presence
07-11-90/20-11-90	14	13
03-11-91/31-11-91	13	12
28-10-92/10-11-92	16	15
08-11-93/13-11-93	13	12
03-11-95/10-11-95	24	18
Total	80	70

A system of zig-zag transects was followed, with a separation at the turning points of 10 miles. This sampling design has to be used when the shelf is narrow, as was the case in the majority of areas studied. Also the length of the transects must not exceed five times the distance between the 'turning points' (Simmonds *et al.*, 1992; MacLennan and Simmonds, 1992). However, this design makes the statistical treatment of the data difficult with the aim of obtaining a variance in the transects for the integration values, since they cannot be considered independent from each other. In fact, the zig-zag survey design provides a higher local sampling intensity per unit area at the turns compared with other portions of the track (Simmonds *et al.*, 1992).

The sampled area was divided into six sectors (South Ebro Delta, North Ebro Delta, Barcelona, Rosas, West Gulf of Lions and East Gulf of Lions), and each one was subdivided into two strata, the first between a depth of 30 and 100 m contours and the second between 100 and 200 m contours. The results were grouped into the two widest zones based on the two large spawning areas (Aldebert and Tournier, 1968; Palomera, 1992). These were the south zone, which included the three first sectors mentioned and the north zone which included the other sectors.

The average echointegration values for each sector and stratum corresponding to the target species were calculated based on the proportion of each species in the catches related to the total catch, according to the third method for mixed species proposed by MacLennan and Simmonds (1992). Only the nocturnal hauls were used, since they were carried out when the shoals were dispersed.

The target strength (TS) used was that of the herring from the North Sea (20 logL- 72.6; Anonymous, 1986). The TS estimated *in situ* for the anchovy (Abad *et al.*, 1991, 1992) is not considered valid due to an overestimation of its value having been observed (Soule *et al.*, 1995).

The individuals with a total length (TL) less or equal to 10.5 cm are considered juveniles and those greater than 10.5 cm are adults (Perterra, 1992). For the determination of the fishing maps of the juveniles and adults, the criterion adopted was to consider as juvenile catches those in which the mode was less than 10.5 cm and the number of specimens larger than this size was less than 30%. The other catches with higher modes and a greater proportion of large sizes were considered as adults.

## RESULTS

The estimated biomasses by sector and year are shown in Table 2. A global range between 7090 and 23400 tonnes was observed in the south zone, which was sampled every year, but with low levels in 1991 and 1995. In the north zone, the years with available data indicated similar biomass levels, although clear differences between sectors were noticed.

The results of the estimated biomass levels in the south zone followed similar fluctuations to the recorded landings in the ports of the same zone during the 12 months following the cruises (Fig.2).

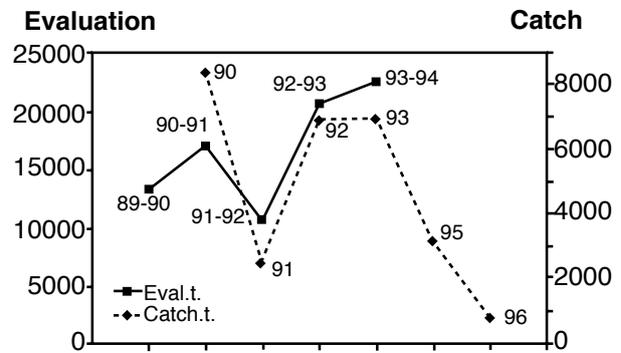


FIG. 2. – *Engraulis encrasicolus*. Annual evolution of biomass (t) estimated (u) and landings (t) (n) in the South zone (see text for landings explanation).

TABLE 2. – *Engraulis encrasicolus*. Biomass (t) estimated by sector and year.

	S. Ebro	N.Ebro	Barcelona	Total South	Rosas	W.G. Lions	E.G. Lions	Total North
1990	6912	12447	4048	23407	1291	18428	15796	35515
1991	3518	1415	2157	7090	664	5913		
1992	2513	4798	11872	19183	77	30886	3226	34189
1993	10120	2172	7104	19396	13723			
1995	2413	838	5465	8716	7329			

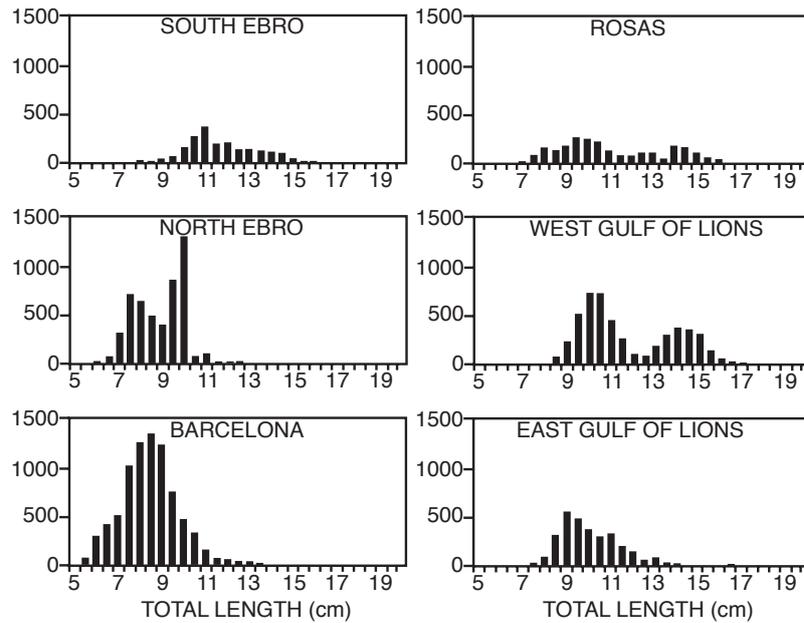


FIG. 3. – *Engraulis encrasicolus*. Accumulated abundances (number of individuals  $\times 10^6$ ) by length classes and sectors (1990-1995, except 1994). Gulf of Lyons was sampled only in 1990 and 1992.

A similar situation was observed in the north zone. Thus, the landings in the Gulf of Lions in 1990 and 1992 were 9938 tonnes and 9208 tonnes respectively, whereas the estimated biomass in the area was 35515 and 34189 tonnes (Table 2).

Figure 3 shows the accumulated abundances by size classes and sectors. It was observed that in the North Ebro and Barcelona sectors only the presence of juveniles was detected whereas in the other sectors they appeared mixed with adults. The proportions of juveniles and adults in each of the two considered zones are shown in Table 3. It was observed that in the south zone the juveniles were largely present, with abundance levels almost higher than 70%. In the north zone, the two years sampled showed very different values.

TABLE 3. – *Engraulis encrasicolus*. Percentage of juveniles (<10.5 cm TL) and adults (>10.5 cm TL) by year and zone.

	South Zone		North Zone	
	Juveniles	Adult	Juveniles	Adults
1990	86%	14%	69%	31%
1991	69%	31%		
1992	95%	5%	37%	63%
1993	76%	24%		
1995	84%	16%		

In relation to the modes obtained for the size distributions in the catches, a tendency towards a differential bathymetric distribution by size was observed (Fig.4; Table 4). The juveniles were distributed slightly more in coastal areas, with a general depth range of 45-95 m, whereas the adults were mainly detected between 55 and 110 m. This differential distribution was more obvious in zones where the shelf was smoother and wider, such as around the mouth of the Ebro.

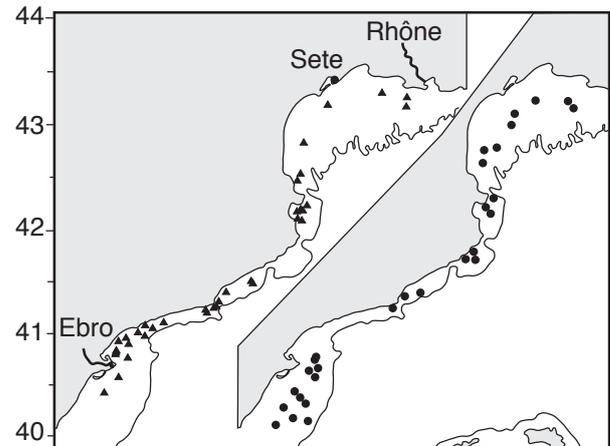


FIG. 4. – *Engraulis encrasicolus*. Location of fishing stations from all surveys. (s) refers to samples where mean TL < 10.5 cm (juveniles), and abundance of adults was less than 30%. (l) refers to samples where mean TL > 10.5 cm (adults) and the abundance of juveniles was less than 30%.

TABLE 4. – Depth (m) range of fishing stations with anchovy present. a) refers to samples where mean TL<10.5 cm and the abundance of adults was less than 30%. b) refers to samples where mean TL>10.5 cm and the abundance of juveniles was less than 30%.

Depth range (meters)	a	b
South and North Ebro River	54-88	66-95
Barcelona	49-86	53-110
Rosas	53-94	83-110
Gulf of Lyons	46-83	67-90

## DISCUSSION

The biomass of anchovy in the north-eastern Mediterranean has been estimated acoustically during the recruitment season. In recent years this area has shown high levels of landings in comparison with other areas of the Spanish Mediterranean where levels have been minimal, such as from the Alboran Sea (Giraldez and Abad, 1991).

The error of the abundance estimate is due to the sampling error (precision) and the systematic error (bias), which affects all the observations equally. In this work only a systematic error, such as the assumed value of the TS, is examined. Thus, 'if the TS value estimated by Barange *et al.* (1995) for *Engraulis capensis* (TS=20 logL - 76) is applied, the estimated biomasses would double, whereas if we apply the TS value used for herring and small pelagics (TS=20 logL - 72.6; Anonymous 1983) a decrease in the biomass of 27.6% would be obtained. Therefore, the results have to be treated as relative abundance indices (Hampton, 1992) despite the application of a standardised methodology in the same period of the year giving consistency to the series of obtained values.

In July 1993 an acoustic evaluation cruise was carried out for anchovy (García *et al.*, 1994), covering the same area and applying a TS=20 logL - 71.2 (Anonymous, 1983). The estimated abundance was 32830 tonnes, which was a very similar value to the one obtained by another simultaneous cruise based on the DEPM that estimated an abundance of 30565 tonnes. Applying the same TS (71.2) to our results, obtained during the acoustic cruise in November 1992, an estimation for the anchovy biomass of 38740 tonnes was obtained. On the other hand, the number of individuals estimated in November 1992 was  $6377 \cdot 10^6$ , of which 75% were individuals with a total size smaller than 10.5 cm. The number of individuals estimated in July 1993 was  $2471 \cdot 10^6$ , of

which more than 90% were greater than 10.5 cm. These results are not inconsistent, despite the limitations of the comparison.

Despite the existence of other abundance estimations, based on the application of the DEPM and the acoustic methodology, the spatial coverage and the lack of temporal coincidence do not allow comparisons with the results presented in this study to be made. Nevertheless, abundances of 52557 tonnes in the Catalonia-Gulf of Lions area and 11044 tonnes in the Catalonia-South Gulf of Valencia area were estimated in 1994 (Palomera *et al.*, 1995).

Qualitative support for the estimates comes from a comparison with commercial landings (Fig.2). Between 1990 and 1993, the total landings of anchovy taken from the south zone over a period of twelve months following the survey, has ranged between 38% and 55% of the biomass estimated for the zone. A correction for each cruise should be considered in relation to the bottoms with a depth of less than 30 m. This would probably mean an increase in biomass for the juveniles. At the same time, it is assumed that large migratory movements do not exist, since the zones where the adults are located coincide in distinct periods of the year. Evidence for this could be the catch of largely juvenile anchovy by trawlers in the zone, at least in the February-June period (Alvarez, 1990).

On the other hand, the sampling of the landings from the Barcelona seine net fleet shows size distributions (Fig.5) that reflect the fluctuations of abundance estimated for juveniles in the fishing area of the fleet. A high level of recruitment was detected in 1992 and its influence was seen in the catches of the following twelve months (Fig.2).

Considering the abundance by zones, it has to be pointed out that in the Gulf of Lions there are short periods with strong winds from the N-NE which are frequent during the cruise season. This situation led to the cancellation of the 1991 cruise, whereas in 1992 this zone was sampled after a period of strong winds. In this year, the unequal distribution of the biomasses (Table 2), could have a relationship with the hydrodynamic changes caused by such a situation, with a high biomass in the west of the Gulf of Lions. In this area an anticyclonic circulation is formed, whereas in the east of the Gulf coastal upwellings are generated (Millot, 1990). The effects of environmental parameters, such as the wind force, on the available pelagic resources have been described in the Gulf of Biscay (Littaye-Mariette, 1990). In this area it was estimated that the variability of such parameters explains most of the variability in the catches of sardine within a range of a few days.

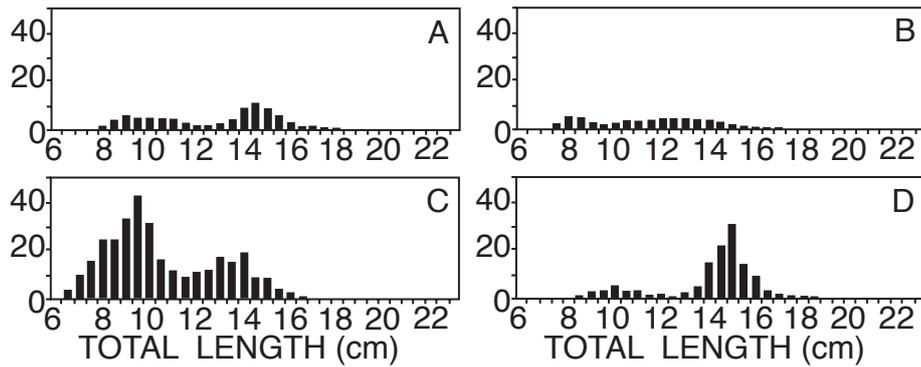


FIG. 5. – *Engraulis encrasicolus*. Length distribution of landings from the port of Barcelona ( $n^{\circ}$  individuals  $\times 10^6$ ). The landings refer to the twelve months following the surveys. A) October 1990-September 1991. B) October 1991-September 1992. C) October 1992-September 1993. D) October 1993-September 1994.

The spatial distribution of adults found during the cruise (Fig.4) is very similar to that of the spawning season, which suggests that there are no large migratory movements of adults between the two periods considered. At the same time, the juveniles were largely located to the north of the Ebro Delta (Gulf of San Jorge), Bahía de Rosas and shallower zones of the Gulf of Lions. This distribution is consistent with the general scheme of small pelagics in other areas, where juveniles tend to concentrate in bays sheltered from prevailing winds and in areas with a wider shelf (Roy *et al.*, 1989).

In conclusion, the results seem to indicate that the acoustic method, despite its shortcomings, should reflect the major changes in anchovy recruitment biomass which have occurred in the north-western mediterranean during the past five years. In addition, the areas where recruits are mostly located have been shown.

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