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Co-occurrence of *Engraulis encrasicolus* and *Sardinella aurita* eggs and larvae in the northwestern Mediterranean*

ISABEL PALOMERA & ANA SABATÉS

Instituto de Ciencias del Mar. P. Nacional, s/n. 08039 Barcelona. Spain.

RESUMEN: COINCIDENCIA DE HUEVOS Y LARVAS DE *E. encrasicolus* y *S. aurita* EN EL MEDITERRÁNEO NOROCCIDENTAL. — Se analiza la distribución espacio-temporal de huevos y larvas de *E. encrasicolus* y *S. aurita* procedentes de muestreos de plancton realizados a lo largo de la plataforma continental catalana desde 1983 a 1985, con el fin de comparar sus estrategias de puesta. El período reproductor de *S. aurita* se inicia en verano, con posterioridad al máximo de puesta de *E. encrasicolus*, cuando la temperatura superficial del agua es más elevada (23-26 °C). En ambas especies, la puesta finaliza en el mes de octubre. Los huevos y larvas de *E. encrasicolus* se distribuyen por toda el área, con las máximas concentraciones sobre el límite de la plataforma continental. Por el contrario, los huevos y larvas de *S. aurita* muestran una distribución marcadamente costera, limitada principalmente a la mitad sur del área.

Palabras clave: ictioplancton, clupeideos, Mediterráneo.

SUMMARY: We analyze the spatial and temporal distributions of *E. encarsicolus* and *S. aurita* eggs and larvae, from plankton collections made in Catalan coastal waters (Western Mediterranean) from 1983 to 1985, in order to compare their spawning strategies. The spawning period of gilt sardine begins in early summer after peak spawning of anchovy when surface water reaches the maximum temperature (23-26 °C). Both species end their reproductive period by October. Anchovy eggs and larvae were widely distributed over the area, with greatest concentrations near the outer limit of the shelf. In contrast, gilt sardine eggs and larvae showed a markedly coastal distribution mainly limited to the southern half of the area.

Key words: ichthyoplankton, clupeoids, Mediterranean

INTRODUCTION

The European anchovy, *Engraulis encrasicolus* (Linnaeus, 1758) and the gilt sardine, *Sardinella aurita* Valenciennes, 1847, are two pelagic spawning clupeoid species that spawn in the summer along the Catalan coast (NW Mediterranean). Two other clupeoid species inhabiting this area, the sardine, *Sardina pilchardus* and the sprat, *Sprattus sprattus*, are winter spawners. The anchovy and the sardine are the most abundant and economically most important species in the Catalan coast, comprising about 50 % of the total landings (SARDÁ and MARTÍN, 1986).

Previous research on the reproduction and egg and larval distribution of the anchovy and gilt sardine in the western Mediterranean is sparse and, in the case of the gilt sardine outdated. DEMIR (1965), in his review of the biology of the anchovy in the western Mediterranean, located the reproduction of the anchovy between April and October. ALDEBERT & TOURNIER (1971) and PA-

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LOMERA (1981, 1986, 1989) studied the egg and larval distribution of the anchovy in the Gulf of Lion, and the Catalan Sea, respectively. BEN-TUVIA (1960) reviewed the available information on the biology of the gilt sardine. He indicated that the reproductive period of the gilt sardine spans the months with higher water temperatures. According to NAVARRO (1932), this occurs from July to September for the Catalan sea.

The two species studied have a coastal pelagic habitat (WHITEHEAD, 1984). The anchovy is abundant in the whole Mediterranean and neighbouring seas, and tolerates a wide salinity range (5 to 40; DEMIR, 1965). The gilt sardine is abundant in the southern Mediterranean and rare in the northern Mediterranean (BEN-TUVIA, 1960), and only occurs in waters with salinities > 35 (LONGHURST, 1971).

The great difference in abundance of adult *Engraulis encrasicolus* and *Sardinella aurita* on the Catalan coast, and the overlap in their spawning periods suggested a study of their spawning strategies in the area. To achieve this, we analyze the spatio-temporal distribution patterns of anchovy and gilt sardine eggs and larvae along the Catalan coast.

MATERIALS AND METHODS

Study site

The Catalan coast (NW Mediterranean) is an area of great topographic and hydrographic heterogeneity.

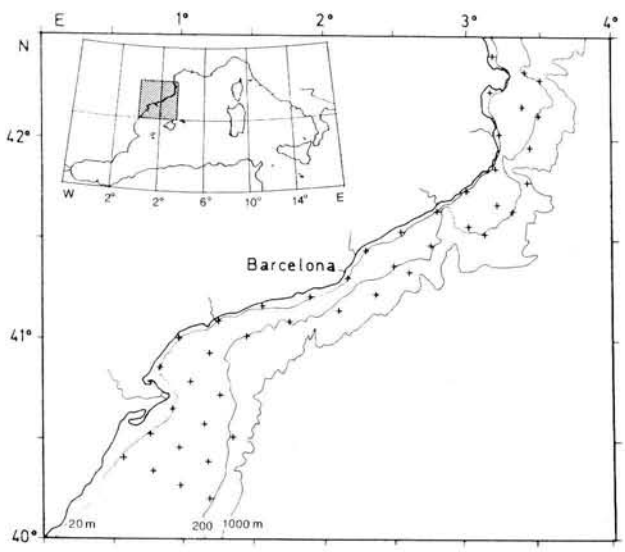

FIG. 1.— Studied area showing the distribution of sampling stations.

The northern zone of the coast has three major submarine canyons, that approach the slope zone some 5 miles offshore. The continental shelf between them has an average width of 40 miles. Along the central zone the continental shelf is rather narrow, and topographically simple; the width of the continental shelf increases towards the southern zone of the Catalan coast to reach 40 miles off the Ebro Delta. The Rhône river in the North, and the Ebro river in the southern fringe are the most important sources of continental water to the Catalan coast. Water current flows towards the south, parallel to the coast at a distance of 30 miles offshore along the shelf break (FONT, 1986). This circulation pattern is associated with a shelf-slope salinity front which separates coastal waters from the more saline open sea waters (SALAT & FONT, 1987; FONT *et al.* 1986).

Sampling procedures

Plankton samples were collected during 11 scientific cruises along the Catalan coast (Western Mediterranean, 42° 24′ N - 40° 13′ S; Fig. 1). The cruises were performed throughout the spawning periods of the anchovy and gilt sardine (i.e., April to October) in 1983 and 1984. In addition, we included in this study samples obtained in a cruise carried out in June 1985 (Table 1). A grid of 39 stations was sampled on each cruise, with additional offshore stations sampled on the cruises undertaken in 1983 and 1985. Plankton tows were done using a Bongo net (40 cm diameter, mesh size = 333 μm) fitted with a flow meter. The samples were collected in oblique hauls from 200 meters, or near the bottom in shallower stations, to the surface.

Hydrographic sampling (i.e., water temperature and salinity) was made using a Neil Brown CTD for 5 of the cruises, and using Niskin bottles fitted with inversion thermometers in the remainder.

Identification of *Engraulis encrasicolus* and *Sardinella aurita* eggs and larvae, was done following d'ANCONA (1931) and CONAND and FAGETTI (1971). Egg and larval abundances were expressed as number under 10 m^2 of sea surface using flowmeter readings to calculate the water volume filtered.

Differences in egg and larval abundance in relation to station depth were evaluated using ANOVA, with the pooled abundances along four depth intervals (i.e., 0-50, 50-100, 100-200, and > 200 m) as the treatment categories. Egg and larval abundances were log-transformed to accommodate the data distribution to the assumptions of ANOVA.

TABLE 1.— Summarized data on cruises on the Catalan coast, 1983-1985; (x) mean abundance and (sd) standard deviation of anchovy and gilt sardine eggs and larvae.

		Anchovy				*Gilt sardine*			
		eggs		*larvae*		*eggs*		*larvae*	
data cruise	*N.º Stat.*	*x*	*sd*	*x*	*sd*	*x*	*sd*	*x*	*sd*
14-26 Apr. 83	45	56.1	148.5	0	0	0	0	0	0
14-20 May 83	44	815.6	2035.8	468.0	1291.5	0	0	0	0
8-12 June 83	44	2135.4	3279.0	1515.7	2138.7	0	0	0	0
19-25 July 83	44	951.1	3121.8	2242.9	2843.1	21.0	63.9	66.7	375.0
7-14 Sept. 83	44	29.4	140.4	133.1	194.6	46.5	128.7	249.6	711.9
4-10 Oct. 83	44	3.8	12.0	9.8	26.6	2.8	6.4	6.9	17.2
27 Apr.-3 May 84	39	53.4	122.3	0	0	0	0	0	0
16-21 June 84	35	755.8	1215.6	198.2	360.0	0	0	0	0
17-22 Aug. 84	42	125.4	468.2	232.2	516.9	71.5	305.1	70.9	145.4
30 Sept.-5 Oct. 84	40	1.1	3.2	18.5	26.9	0	0	2.8	7.7
12-20 June 85	54	420.9	745.2	305.4	523.0	98.54	422.5	3.8	11.8

RESULTS

Anchovy

Anchovy eggs were found in all cruises. The average abundance varied greatly within the spawning period, with the peak abundance in June, and also among years, with the greatest abundances being recorded in 1983 (Table 1).

The spatial and temporal distribution of anchovy eggs during 1983 and 1984 showed that spawning in the southern zone began in April, when surface water temperatures exceed 13 °C. Spawning extended Northward as water temperature increased from South to North. The greatest egg abundance were found between May and July, with surface water temperatures between 17 and 25 °C (Fig. 2). Spawning ended in September for the northern part, concurrent with a marked temperature decrease in this area (Fig. 2). September water temperatures were 2 °C lower in the Northern zone than in the south, where spawning continued in October, albeit with reduced intensity.

Both eggs and larvae were widespread along the entire area studied during the months of peak abundance (May to July). The greater egg concentrations were located along the shelf break, with a wide distribution in the broader shelf of the southern zone, off the Ebro Delta. Larval distribution was more extended than that of eggs, with a tendency towards open-sea dispersion. Minimal abundances, both of eggs and larvae, were located along the coast line, particularly off Barcelona (Figs. 3 and 4).

Analysis of variance demonstrated significant differences among depth zones, both for egg ($P < 0.01$) and larval ($P < 0.001$) abundance. The greatest average egg and larval abundance occurred at stations with depths between 50 and 200 m, with a secondary larval maximum in stations deeper than 200 m (Table 2).

TABLE 2.— General statistics of *Engraulis encraiscolus*, anchovy, and *S. aurita*, gilt sardine, eggs and larve abundance vs. depth.
x = mean of ln of abundance.
sd = standard deviation of ln of abundances.
P = probability of no difference between depths.
*level of significance 0.01, **level of significance 0.001.

	Anchovy				*Gilt sardine*			
	eggs		*larvae*		*eggs*		*larvae*	
(depth)	*x*	*sd*	*x*	*sd*	*x*	*sd*	*x*	*sd*
9-50 m	0.747	0.124	0.964	0.125	0.627	0.082	0.655	0.095
50-100 m	1.213	0.120	1.847	0.122	0.302	0.079	0.652	0.092
100-200 m	1.055	0.155	1.816	0.156	0.073	0.102	0.362	0.118
> 200 m	0.531	0.143	1.669	0.144	0.127	0.094	0.238	0.109
P	0.0014*		0.00001**		0.00003**		0.0035*	

Anchovy eggs and larvae were collected in waters with salinities ranging from 29 to 38 (Fig. 5). Water

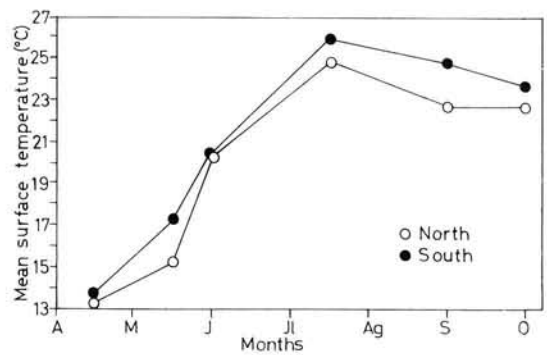

FIG. 2.— Monthly values of surface water temperature in 1983.

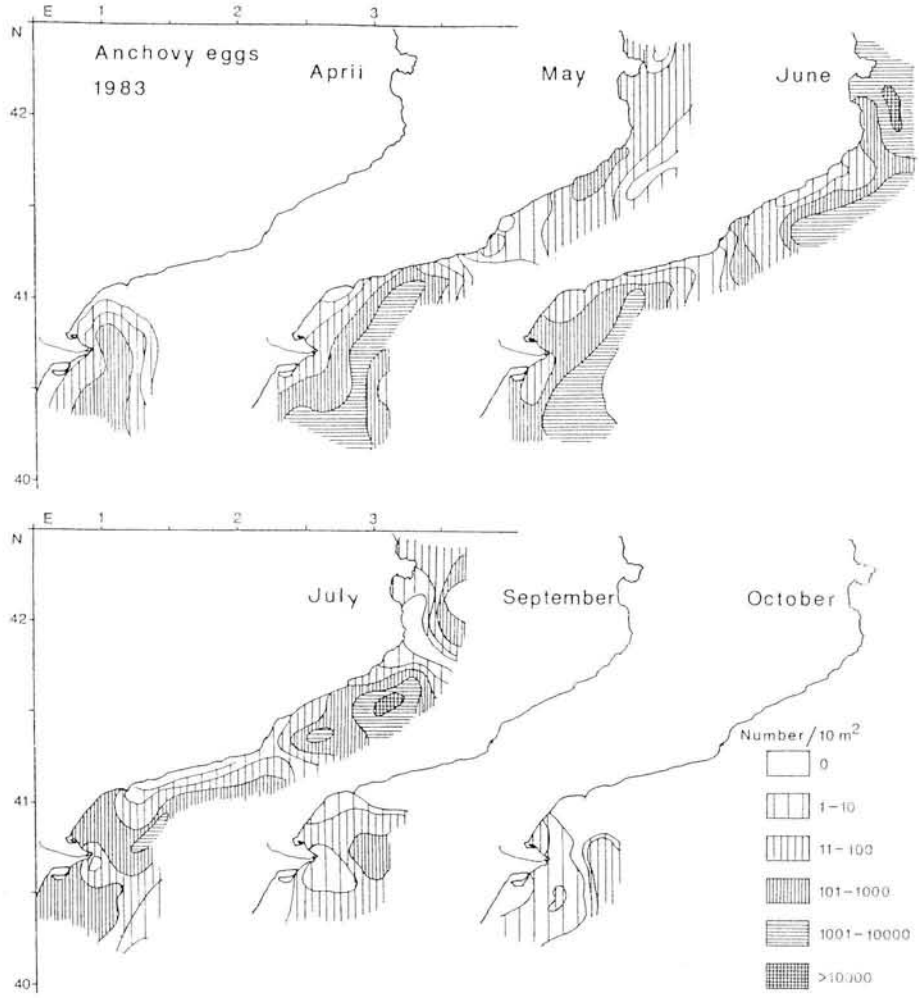

FIG. 3.— Distribution and abundance of anchovy eggs in 1983. The values correspond to numbers under 10 m^2.

salinities below 36 were sporadic, although they were often associated with high anchovy egg and larvae abundances. For instance, very high anchovy egg and larvae concentrations were recorded near the Gulf of Lions in June 1983, associated with the presence of a superficial intrusion of low salinity water (29) derived from the Rhône river discharge (CASTELLÓN *et al.*, 1985).

Gilt sardine

Eggs and larvae of gilt sardine were found between June and October, with peak abundance occurring in August and September. There were, however, some differences in the duration of reproduction between years, apparently related to temperature differences. Egg and larval abundance were quite high in June 1985 (Table 1), in contrast with their absence in June 1983 and June 1984. Surface water temperature at those stations where *S. aurita* eggs and larvae were collected during June 1985 ranged between 20.6 and 21.6 °C, whereas, the average surface temperature was < 20 °C in June in previous years.

Gilt sardine eggs and larvae were found from July to October of 1983, with peak abundance recorded during September. Unfortunately, in 1984 no samples were collected in July and early September. In this year we found eggs and larvae in August, and only larvae in October. Surface water temperatures during peak spawning ranged from 23.1 to 26.6 °C (Fig. 2), in agreement with the results reported by NAVARRO (1932) for a nearby area. Gilt sardine eggs and larvae were found in waters with salinities ranging from 36.2 to 38.2 (Fig. 5).

The eggs of *S. aurita* were distributed along the

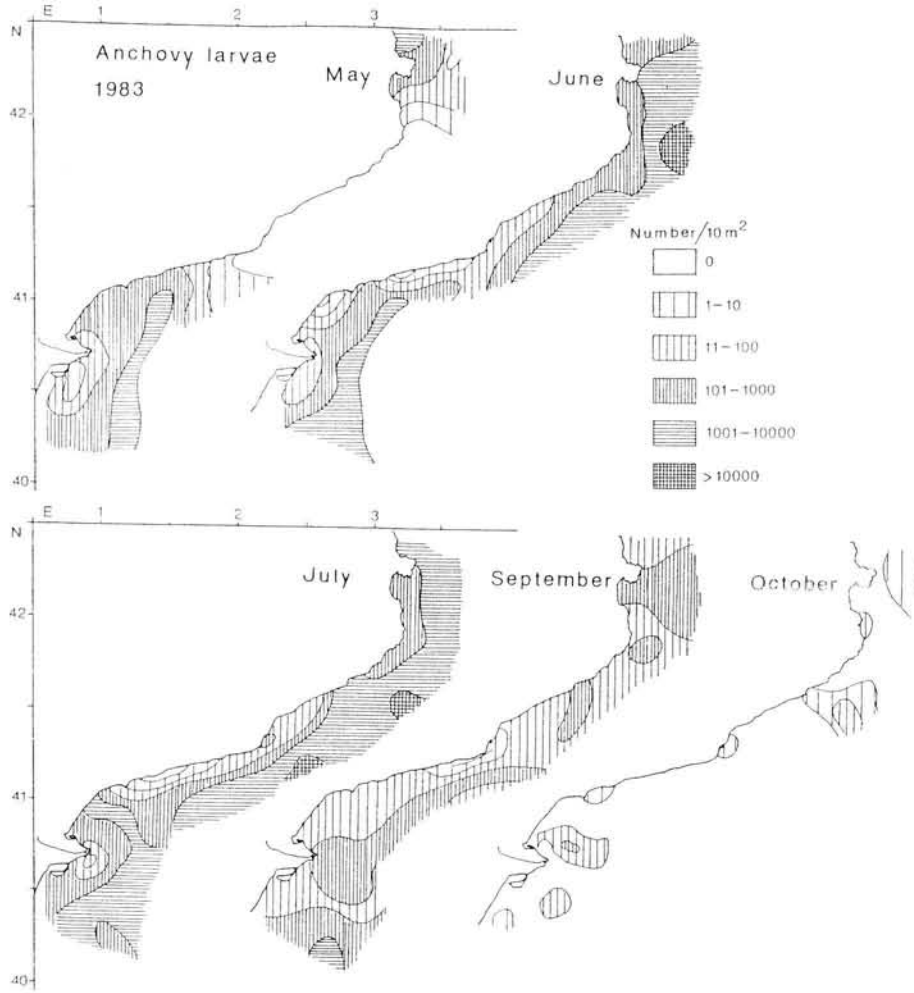

FIG. 4.—Distribution and abundance of anchovy larvae in 1983. The values correspond to numbers under 10 m^2.

coastal zone, in stations not deeper than 100 m. Higher egg concentrations were found in the central zone and north of the Ebro Delta. Larvae showed a wider distribution, reaching further from the coast (Fig. 6). Analysis of variance demonstrates significant differences in egg ($P < 0.001$) and larval ($P < 0.01$) abundance among depth classes. Examination of the average egg abundance for different depth contours revealed greater average abundances shallower than 50 m, whereas average larvae densities were also high between 50 and 100 m depth (Table 2). We found larvae in August and September along the northern area, although no eggs were found (Fig. 6). The presence of larvae in this area suggests the occurrence of sporadic spawning events, rather than passive larval transport, if we consider the pre-

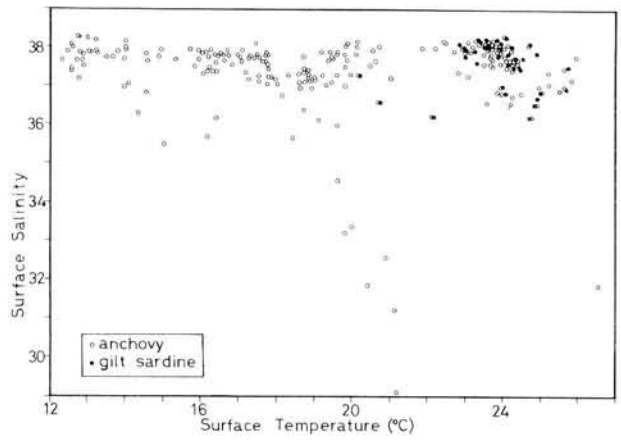

FIG. 5.— Surface temperature and salinity at stations where anchovy and gilt sardine eggs were collected at least once, during 1983-1985 cruises.

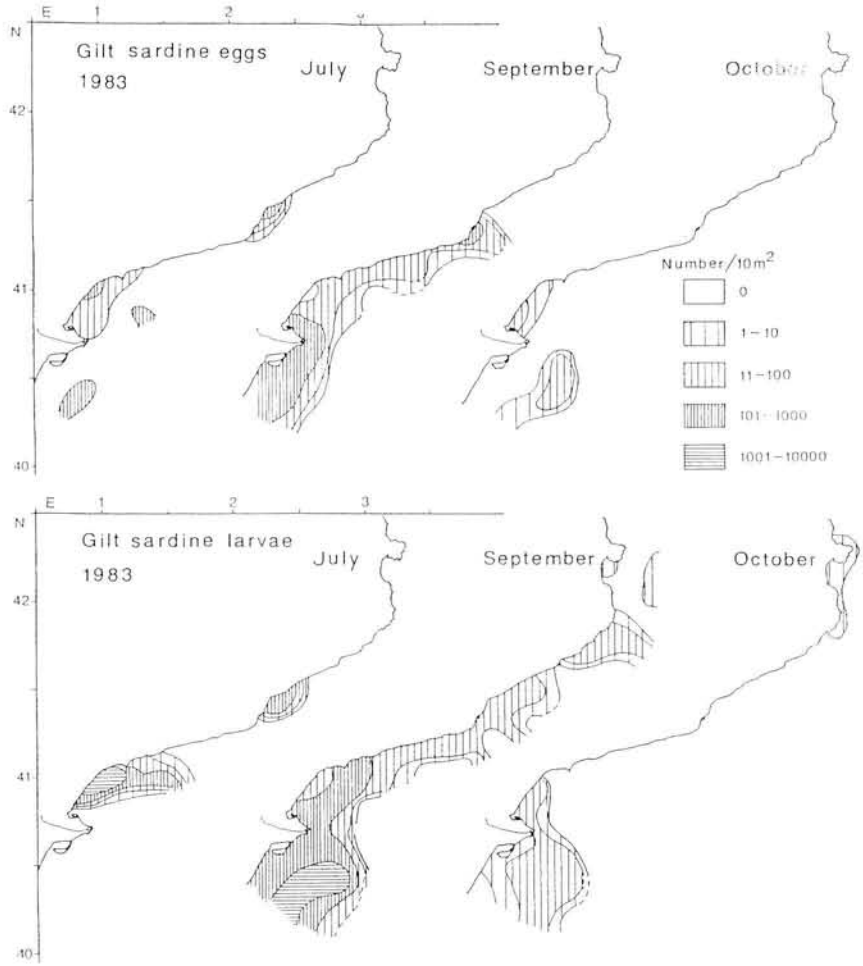

FIG. 6.— Distribution and abundance of gilt sardine eggs and larvae in 1983. The values correspond to numbers under 10 m^2.

dominant SW current flow and the fact that the area studied represents the northernmost limit of the gilt sardine distribution (BEN TUVIA, 1960).

DISCUSSION

The data presented show that the reproductive period of *S. aurita* begins in early summer, after peak spawning of *E. encrasicolus*, both species ended their reproductive phase by October (Fig. 7). Peak spawning of gilt sardine off the Catalan coast occurs at temperatures ranging from 23 to 25 °C, that are only reached in summer. Spawning of gilt sardine along the Northwest African coasts, where this species is abundant (POSTEL, 1960; CONAND, 1976), lasts longer and extends over a wider temperature range (18 to 30 °C, CONAND, 1976), although peak spawning is also associated with temperatures between 22 and 25 °C. The difference in the minimum spawning temperatures between these two areas suggests that the presence of anchovy and sardine, two competitive (DEMIR, 1965; LARRAÑETA, 1960) and dominant species, could be responsible for the short reproductive phase of *S. aurita*, which end by the time the *Sardina pilchardus* spawning period begins, when water temperatures start to decline (ALDEBERT & TOURNIER, 1971).

The spatial distribution of eggs and larvae of the two species indicates some degree of spatial segregation of their spawning areas, with maximum densities of anchovy on the shelf break associated with the shelf-slope hydrographic front. This area supports greater zooplankton concentrations and, at the same time, the largest concentrations of fish larvae and highest specific richness (SABATÉS, 1990). The abun-

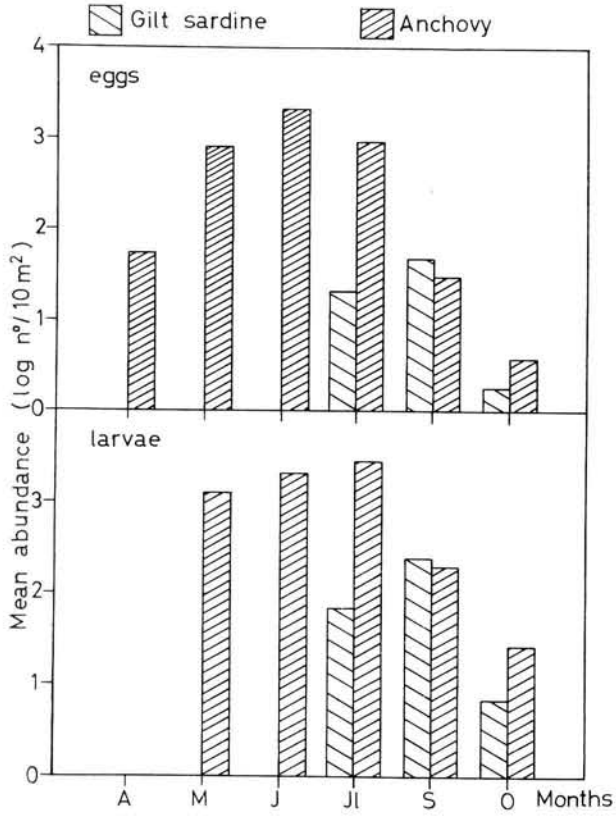

FIG. 7.— Monthly abundance of anchovy and gilt sardine eggs and larvae in 1983.

dance, of *E. encrasicolus* eggs and larvae offshore seems to determine the more coastal nature of *S. aurita* spawning. In general, the stations closest to shore, and thereby the shallowest stations, support the lowest ichthyoplankton and zooplankton concentrations (SABATES *et al.*, 1989), particularly in the southern area where the spawning of gilt sardine occurs. The numerical dominance of anchovy over gilt sardine could be responsible for the displacement of gilt sardine spawning to the areas of the Catalan coast that exhibit the poorer conditions. On the west African coast, CURY & FONTANA (1988) reported a wide plasticity and adaptability of *S. aurita* to enviromental fluctuations.

The results of this study show different distributional patterns of anchovy and gilt sardine eggs and larvae. It seems that the two species have different spawning strategies which allow them to avoid overlapping during their planktonic phases.

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