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A N I N T E R N A T I O N A L J O U R N A L

Interannual Variation of Larval Fish Assemblages in the Gulf of Cádiz (SW Iberian Peninsula) in Relation to Summer Oceanographic Conditions

Paulo Mafalda Júnior[1*] and Juan Perez de Rubín[2]

[1]Universidade Federal da Bahia - UFBA; Instituto de Biologia; Laboratório de Plâncton; 40.210-020; pomafa@ufba.br; Salvador -BA - Brasil. [2]Instituto Español de Oceanografía - IEO; Muelle pesquero, s/n; apdo 285, 29640, jprubín@ma.ieo.es; Fuengirola - MA - España

ABSTRACT

Two ichthyoplankton surveys were conducted during July 1994 and July 1995 in the Gulf of Cádiz with the aim of describing composition, abundance, distribution patterns and interannual variations of larval fish assemblages. Interannual differences were found in this study. In 1994, higher salinities were observed at external sites, though in 1995, higher values were observed at intermediate sites. The upper water column was warmer in 1994 and had less fish larvae density. During 1994, **Sardinella aurita** *and* **Engraulis encrasicolus** *were abundant but spatial location was opposite. In 1995, abundance of both species was very different, but with similar spatial pattern. Cluster analysis revealed well-defined groups of stations and assemblages of larvae, primarily related to bathymetry. The "inshore assemblage" occupied the shallow coast area; its characteristics species being closely related to the estuarine system, mainly comprising* **Engraulis encrasicolus** *and Gobiidae. The "shelf assemblage" occupied the continental shelf and its characteristics species consisted of larvae whose adults inhabited the shelf province and spawn in the same zone, like* **Sardinella aurita** *and* **Trachurus** spp. *Interannual variations in composition and extension of the subgroups could be attributed to the main circulation patterns, continental water discharge and spawning strategies of fishes.*

Key words: Larval fish assemblages, *Sardinella aurita*, *Engraulis encrasicolus*, Gulf of Cádiz

INTRODUCTION

An ichthyoplankton assemblage is by definition transient because it is restricted to the egg and larval phases. However, the multiespecies larval associations may be adaptive and result from similar responses among species to the pelagic environment (Frank and Legett, 1983; Somarakis et al., 2000). Interannual variability in the assemblage of fish larvae might trace the variation in physical processes and be particularly useful in highlighting shared or contrasting adaptations of species to the pelagic environment (Somarakis et al., 2002). Thus, the distribution and abundance patterns of fish larvae can contribute significantly to an understanding of the biology and ecology of fish populations (Doyle et al., 2002).

Yet, attention to this matter in the Gulf of Cádiz has been limited despite it supports large, economically valuable fisheries resources, and provision for nursery areas for many fish species (Rodrigues-Roda, 1970, 1977; Garcia and Moyano, 1991; Rubín et al., 1999). Preliminary results were published for the global area (Rubín

[*] Author for correspondence

et al., 1997, 1999; García et al., 2002) and the interannual changes were only studied for some neritic sectors of the Gulf of Cádiz (Salmerón and Rubín, 1997a,b). These studies provide a starting point but do not reflect the interannual variability in the composition and structure of ichthyoplanktonic groups.

This paper presents results of the first meso-scale multiespecies larval fish investigation in the Gulf of Cádiz. It involves the definition of early summer larval fish assemblages, their composition, the dominant species, the major distributions patterns, both across and along the continental shelf, and the principal characteristics of the water column that control this patterns.

STUDY AREA

The Gulf of Cádiz strategically located connecting the open Atlantic Ocean with the Mediterranean Sea, through the Strait of Gibraltar (Fig. 1), has been scarcely studied, particularly from the viewpoint of physical-biological coupling (García et al., 2002). The area of the Gulf of Cádiz is characterized by an ample continental shelf, around 50 km wide, except at the west of the Guadiana river, where it has only 130 m of wide (Abrantes, 1990). The most important rivers are the Guadalquivir and the Guadiana and the continental runoff reach the lowest values in summer (Garcia and Moyano, 1991). Temperature distribution and dynamic topography indicate the existence of anticyclonic circulation following the bottom contours running from NW to SE (Stevenson, 1977; Folkard et al., 1997; García et al., 2002). When prevailing winds in the Gulf are from the west, an upwelling area is found east of Cape Santa María in Portugal (Folkard et al., 1997). The upwelled waters form a cold tongue that separates from the coast and flows offshore in the SW direction, towards the Strait of Gibraltar. The "Huelva Front" separates this colder water from warmer waters of the central part of the gulf (Vargas et al., 2003). Stevenson (1977) describes the "Huelva Front" as a warm-cold-warm frontal structure running in the SE-NW direction offshore, approximately between the cities of Cádiz and Huelva. Another upwelling area is also evident at the southwest of the Strait of Gibraltar (Vargas et al., 2003).

MATERIAL AND METHODS

During July 8 to 15, 1994 and July 10 to 17, 1995, a regular sampling grid of 35 stations was occupied in the Gulf of Cádiz (Fig. 1). Each station consisted of a CTD cast plus ichthyoplankton hauls. A Bongo net, with 40 cm diameter (Rubín, 1992), equipped with two independent flowmeters and one depth meter gauge was employed to carry out "double-oblique" trawls from the surface to 100 m depth. The samples obtained were preserved in 5% buffered formalin.

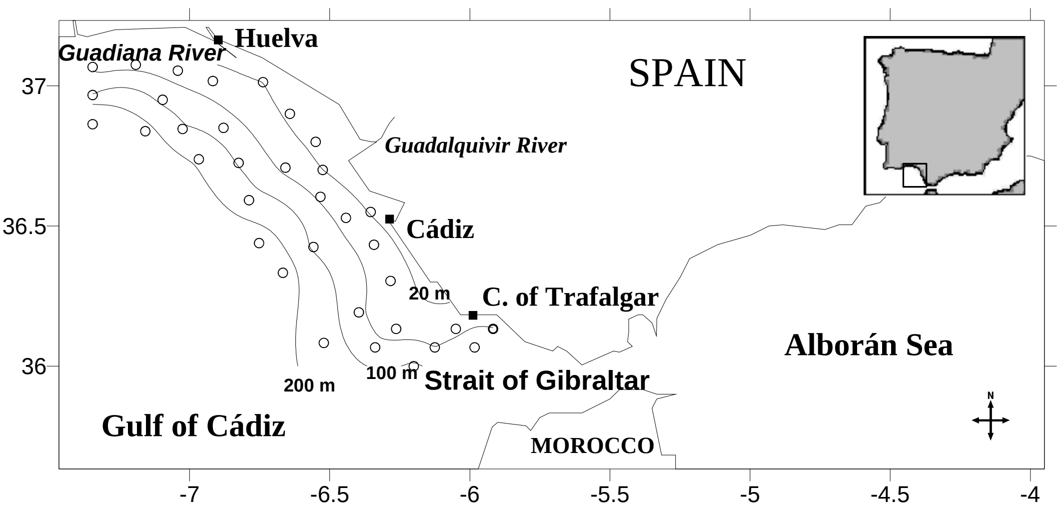

Figure 1 - Study area showing bathymetry and the sampling stations.

Zooplankton displacement volume (ZDV) was measured for each sampling site from the catch of the 250 µm mesh bongo net (Ahlstrom and Thrailkill, 1963). ZDV values were standardized to ml per m^3. Material collected with 335 µm mesh net were used to make the taxonomic identification of the ichthyoplankton. The number of fish larvae and eggs collected was standardized to 10 m^2 (Smith and Richardson, 1979). Fish larvae were identified to the lowest possible taxonomic level and grouped into three categories, "demersal", "epipelagic" and "mesopelagic", according adult fish habitat.

Data analysis

Interannual differences in the abundance of different taxa were tested using the non-parametric Wilcoxon Test (Siegel, 1982). Similarity among sampling sites and taxa were measured using Manhattan distances and were grouped by the Ward's method (Pielou, 1984) to produce dendrograms. Prior to analysis, logarithmic transformation ln(x+1) of the larval abundance (x) was performed to homogenize the variance (Taylor, 1961). In this analysis, were included only those eleven taxa that contributed more than 0.5% of the total abundance in both two years. The relationship between water depth, ZDV, salinity, temperature, fish larvae, taxa number and station groups from the cluster analysis was explored by performing non-parametric Kruskal-Wallis Test (Siegel, 1982) using median among station groups for each cruise. Post-hoc pairwise multiple comparisions of median among station groups were also performed.

RESULTS

Environmental Conditions

Rubín et al. (1997; 1999) described the environmental conditions of two oceanographic surveys and only a brief summary was presented there. The water column was generally well stratified and the thermocline was located at a mean depth of 20 m. Due to mesoescale variability, the termocline depth varied, having a tendency to move downward in anticyclonic area in the slope and continental shelf, in front of Cádiz Bay.

During these two years, warmer temperatures (22 - 23º C) were observed at the inshore sites of the Cádiz Bay and Huelva, at the area north. Southern area, in front of the Cape of Trafalgar, was generally cooler than the rest of surveyed area. Yet, at the offshore sites, the north area was cooler than the south area. In 1994, higher salinities (> 36.4 ups) were observed at the north area and offshore, though in July 1995, higher values were observed around Cádiz bay.

Taxonomic composition and abundance of fish larvae

A total of 16 taxa (Table 1) were identified (13 taxa in 1994 and 16 taxa en 1995). Furthermore, the interannual differences between taxa number were not significant ($p > 0.05$). Mean larvae density was higher ($p < 0.01$) in 1995 (0-12610 larvae.10 m^{-2}, average = 1962) than 1994 (0-1920 larvae.10 m^{-2} , average = 768.5). The abundance of demersals fish (Gobiidae, Labridae, Sparidae, Callionymus spp., *Serranus* spp, *Cepola rubescens* and *Arnoglossus* spp) was similar between the two years ($p > 0.05$), and Gobiidae was the demersal dominant taxa. Larvae of different pelagic species (i.e. *Sardinella aurita*, *Trachurus* spp. *and Capros aper*) were more abundant in the 1995 collections ($p < 0.05$), but anchovy (*Engraulis encrassicolus*) was more abundant in 1994 (Table I).

Individual species distribution

Several demersal taxa, such as Gobiidae, Labridae, Sparidae, Callionymus spp., *Arnoglossus* spp, *Cepola rubescens* and pelagics species, such as, *Trachurus* spp and *Capros aper* did not show any marked interannual differences in their horizontal distribution (however their abundance might have been different between the two years, e.g. the abundance of pelagics). Although larvae of demersal *Serranus* spp "shift" from inshore area to continental shelf area your abundance was equal between years ($p > 0.05$).

Anchovy larvae, *Engraulis encrassicolus*, and gilt sardine larvae, *Sardinella aurita*, showed interannual differences ($p < 0.05$) in their abundance and horizontal distribution. During 1994, for both species were abundant (> 400 larvae.10 m^{-2}) but spatial location was opposite. Gilt sardine larvae appeared in a neritic station at the north sector (surface temperature = 22.5° C). Whereas, the maximum abundances of larvae of anchovy have been located south of Cádiz, in warmer waters (> 23º C). On the other hand, in 1995 abundance of both species was very different (gilt sardine: 4000 to 6000 larvae.10 m^{-2} ; anchovy 200 to 300 larvae.10 m^{-2}), but with similar spatial pattern (middle shelf off Cádiz, 22º C).

Comparison of sampling sites

Cluster analysis of sampling sites produced three distinct groups in 1994 and 1995 (Fig. 2). Group 1 comprised inshore sites, group 2 (intermediate) and 3 (external) were predominantly continental shelf stations. The Kruskal-Wallis Test (Table 2) using water depth shows a significant station group effect ($p < 0.001$). The pair-wise comparison of means shows that station group 3 located at the mid-shelf was significantly different from all other stations groups at the 1 % level. In both years (Table 2), the inshore sites presented the major ZDV values ($p < 0.001$). In 1994 (Table 2), the major salinity values were found at external sites ($p < 0.0001$) but, in 1995, they were located at intermediate sites ($p < 0.05$). The temperature (Table 2) was similar between stations groups in 1994 ($p > 0.05$). In 1995, the major temperature values were located at the intermediate sites ($p < 0.05$).

Larval assemblages

Eleven taxa were abundant in both year collections and were used to ecological classification. Three groups of species were defined in the two years. They correspond to the station groups identified in the clustered analysis of sampling sites. Species present in these groups integrated into well defined assemblages, named “inshore” and “shelf” which were generally persistent in their respective zones (Fig. 3).

INSHORE ASSEMBLAGE: Probably influenced by riverine inputs (Rubín et al., 1999), occupied mainly the shallow stations (Group 1).

The sector occupied by this assemblage varied throughout the years. In 1994, it comprised the area from Guadiana river mouth to the Cape of Trafalgar, in depths less than 40 m. In 1995, the area was smaller, extending from Guadiana river mouth to Cádiz, in depth less than 28 m. In 1995 (Table 2), this assemblage presented less taxa ($p < 0.001$) and larvae density ($p < 0.001$).

Table 1 - List of larval fish taxa identified, their taxa ecology (D – demersal, EP – epipelagic, MP - mesopelagic), relative abundance (A%), frequency of occurrence (F%), mean density (X = larvae 10 m^{-2}) and their code in the Cluster analysis.

		1994				1995		
Taxa	**Origin**	**A%**	**F%**	**X**	**Code**	**A%**	**F%**	**X**
GOBIIDAE	D	19,03	88,6	147,8	GOB	9,57	94,1	179,5
LABRIDAE	D	14,80	91,4	120,8	LAB	7,00	79,4	141,6
Engraulis encrassicolus	EP	14,18	68,6	112,0	ENG	3,86	82,4	72,2
SPARIDAE	D	11,90	80,0	88,9	SPA	6,19	88,2	125,2
Callionymus spp.	D	8,00	74,3	57,3	CAL	4,04	82,4	78,1
Serranus sp	D	5,78	71,4	46,9	SER	4,43	61,8	92,2
Sardinella aurita	EP	4,88	45,7	33,9	SAR	33,66	58,8	671,7
Cepola rubescens	D	3,10	42,9	23,4	CEP	3,72	67,6	72,7
Arnoglossus spp.	D	2,34	60,0	16,6	ARN	2,62	64,7	52,0
Trachurus spp.	EP	1,10	31,4	6,9	TRA	1,65	44,1	31,9
Capros aper	MP	0,60	22,9	4,0	CAP	1,58	50,0	29,4
BLENNIIDAE	D	0,54	22,9	5,0	-	0,35	32,4	7,4
ACHIRIIDAE	D	0,25	17,1	2,1	-	1,37	26,5	22,7
Cyclothone sp	MP	0,00	0,0	0,0	-	0,08	8,8	2,1
Hippocampus sp.	D	0,00	0,0	0,0	-	0.01	2,6	0,3
Mullus surmuletus	D	0,00	0,0	0,0	-	0.01	2,6	0,3

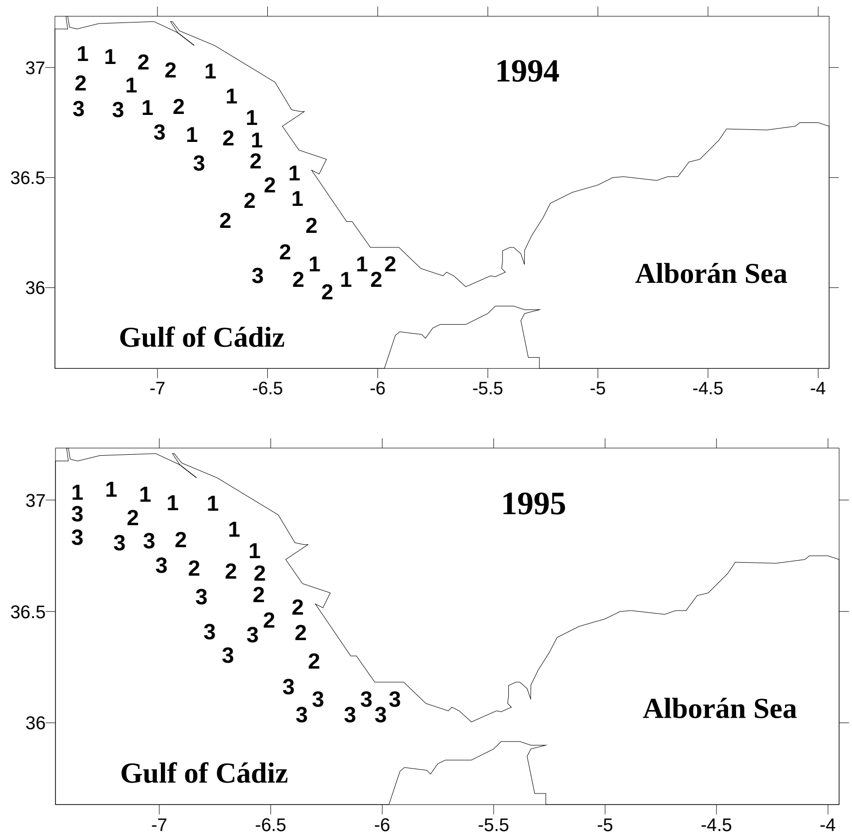

Figure 2 - Geographic distribution of station groups defined by cluster analysis. 1, Inshore sites; 2, Intermediate sites; 3, External sites.

Table 2 - Averages and standard deviation for depth (m), ZDV (ml.m^{-3}), salinity (ups), temperature (°C), fish larvae density (larvae.10m^{-2}) and number of taxa in larval fish assemblages.

Assemblage	1994			1995		
	Inshore	**Intermediate**	**External**	**Inshore**	**Intermediate**	**External**
Depth	40.2 +/- 28.5	77.6 +/- 56.0	221.8 +/- 118.8	2.8.2 +/- 11.1	47.3 +/- 26.3	136.6 +/- 112.4
ZDV	28.9 +/- 20.2	16 +/- 8.8	3.6 +/- 1.1	24,6 +/- 12.3	22.8 +/- 9.8	12.4 +/- 3.6
Sal	36.29 +/- 0.05	36.33 +/- 0.05	36.41 +/- 0.06	36.23 +/- 0.04	36.38 +/- 0.16	36.23 +/- 0.1
Temp	22.27 +/- 0.80	22.35 +/- 0.81	21.80 +/- 0.80	21.37 +/- 0.57	21.84 +/- 0.92	20.70 +/- 0.64
Density	428 +/- 288	1198 +/- 549	27.9 +/- 34.8	376 +/- 206	4609 +/- 4175	1119 +/- 939
Taxa	7.4 +/- 1.8	10.3 +/- 1.3	2 +/- 1.6	5.3 +/- 0.8	10.3 +/- 1.8	9.3 +/- 1.6

The taxa characterizing this assemblage included demersals (Gobiidae, Labridae, Sparidae and Callionymus spp.) and anchovy (*Engraulis encrassicolus*). The between-year differences involved a “shift” of *Serranus* spp larvae from inshore to shelf assemblage, in 1995.

SHELF ASSEMBLAGE: Predominantly occupied this continental shelf stations in depths upper than 100 m. It had two subgroups, variable in extension between years. They were orientation from the coast to the ocean, and were designated as intermediate shelf assemblage and external shelf assemblage. The intermediate shelf assemblage comprised inner shelf group of stations (Group 2) and was characterized by the epipelagic species (*Sardinella aurita* and *Trachurus* spp).

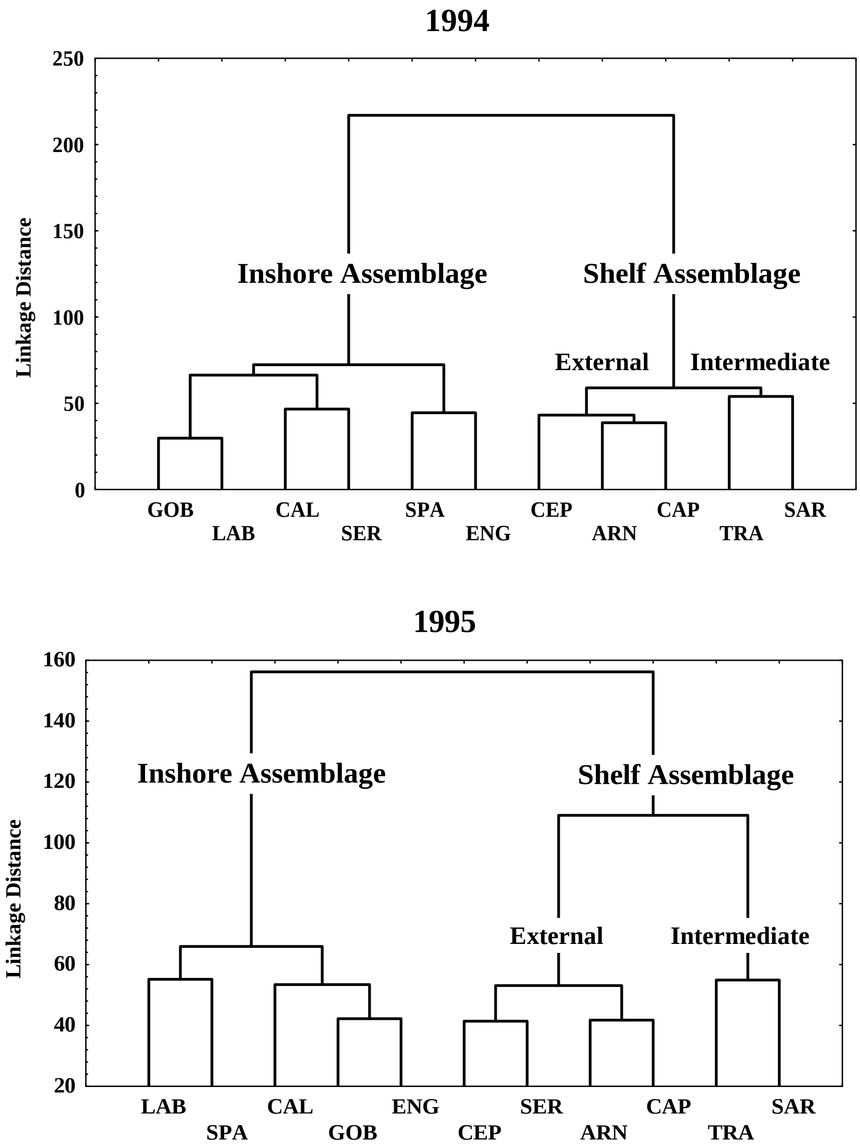

Figure 3 - Dendrogram representing fish larvae assemblages in the Gulf of Cádiz during summer of 1994 and 1995.

In 1994 and 1995 (Table 2), it presented the major taxa number ($p < 0.001$) and larvae density ($p < 0.001$). In both years, the gilt sardine (*Sardinella aurita*) was the dominant species and showed a conspicuous peak of abundance in 1995.

In 1995, the area occupied was smaller than 1994. The external assemblage was located in the mid-shelf group of stations (Group 3) and was formed by demersal taxa such as *Arnoglossus* spp, *Cepola rubescens*, *Serranus* spp (only in 1995). The mesopelagic *Capros aper* was presented but always at low densities. In 1994 (Table 2) this assemblage presented the less taxa number ($p < 0.0001$) and larvae density ($p < 0.0001$).

DISCUSSION

Hydrology

The horizontal distribution of surface salinity showed interannual changes in both years. In 1994, higher salinities were observed at external sites, though in 1995, higher values were observed at intermediate sites, in front of Cádiz Bay. In

1995, the more elevated values of salinity and temperature found in the surroundings of the bay of Cádiz could be explained by the fact to be outside the influence of the Atlantic current coming from Portugal and because 1995, was a particularly dry year, which supported the hypothesis of a greater solar heating and a greater evaporation (Rubín et al., 1999).

In the intermediate layers, however, the topography of 15 °C isotherms suggested anticyclonic circulation near the continental slope edge (Rubín et al., 1997, 1999). This coincidence of the subsurface circulation with the edge of the continental slope would corroborate the notion that anticyclonic circulation in this area seemed to be a permanent feature in summer time (Garcia et al., 2002).

Between year differences

There were differences in the abiotic and biotic environment between 1994 and 1995. The interannual differences between surface salinity and ZDV were not significant ($p > 0.05$). The upper water column was warmer ($p < 0.05$), in 1994 and had less fish larvae density ($p < 0.01$). Concurrently, larvae of anchovy (*E. encrasicolus*) were more abundant in 1994 than in 1995 ($p < 0.05$). In contrast, larvae of *S. aurita* and *Trachurus* spp were significantly more abundant in 1995 ($p < 0.05$), occupied in the shelf, and were almost absent in the inshore zone. Such distribution was strongly related to bathymetry and imitated adult distribution (Rubín, 1992). Similar interannual differences was observed during summer of 1995-1996, in the northern Aegean Sea (eastern Mediterranean) and was attributed to differences in reproductive strategies among epipelagic fishes (Somarakis et al., 2000).

Larval fish assemblages

During summer of 1994 and 1995, two larval fish assemblages were distinguished in the Gulf of Cádiz: Inshore and Shelf, primarily related to bathymetry. This was supported by the results of the Kruskal-Wallis Test of water depth among stations group that resulted from numerical classification of larval fish abundance data. Coastal and Neritic ichthyoplankton assemblages were identified in the southern gulf of Mexico (Flores-Coto et al., 2000; Sanvicente-Añorve et al., 1998). Two ichthyoplankton assemblages characterisitics of the Chesapeake Bay plume and inner-continental shelf waters were defined by Reiss and McConaugha (1999).

The "inshore assemblage" occupied the shallow coast area and comprising mainly *E.encrasicolus* and Gobiidae. The species that characterized this assemblage generally spawn in inshore waters and even in estuaries and inshore lagoons. Gobiid and engraulid larvae too had the highest average density in inshore assemblage of the gulf of Mexico (Flores-Coto et al., 2000; Quintal-Lizama et al., 2000). High engraulid densities area usually associated with river mouths; In the Catalan Sea main spawning areas for anchovy area located in the vicinity of the mouths of Rhône and Ebro rivers (Palomera and Sabatés, 1990). High densities of *Engraulis mordax* characterize the Columbia river plume assemblage (Doyle et al., 1993). In the Adriatic Sea preferential spawning by anchovies in the region influenced by run-off from the Po river (Coombs et al., 1997).

The area occupied by the inshore assemblage varied depending on the extension of continental waters into the marine environment that was more important in 1994 than 1995 (Rubín et al., 1999). However, the wide larval distribution of these taxa (especially gobies and anchovy), might be a consequence of a high larval drift from the shallow areas where massive spawning occurs. According Thorrold and McKinnon (1995) increased river runoff can expand low-salinity plumes seaward, increasing the spatial distribution of inshore species on the shelf. In the Catalan Sea was observed that although the anchovy larvae are advected away from the spawning area, they remain together in a favourable habitat for their development (Sabatés et al., 2001). In the Chesapeake Bay the inshore upwelling provided the mechanism for rapid transport of the plume to the shelf and was the responsible for the mesoscale spatial pattern and heterogeneity of ichthyoplankton on the shelf (Reiss and McConaugha, 1999).

The "shelf assemblage" was formed by demersal (i.e. *Arnoglossus* spp) and epipelagic species (i.e. *S. aurita* and *Trachurus*) whose adults live and spawn in the continental shelf. Flores-Coto et al. (1989) reported that the main spawning area corresponds to the inner and mid regions of the shelf. Taxa whose adults are mesopelagic, such as *C.aper*, was also present in the shelf assemblage. This is not surprising because it was frequent on shelf of Alborán Sea an Gulf of Cádiz (Rubín, 1992; Rubín and Abad, 1994).

In the Gulf of Mexico (Flores-Coto et al., 1988) and Mediterranean Sea (Sabatés, 1990) highest spawning period occurs in summer. In Gulf of Cádiz the high abundance of fish larvae suggest that summer too coincides with the onset of the reproductive season of many fishes.

The largest differences in larval fish assemblages during both years were found in the inshore-shelf gradient. Results suggested that depth (reflecting the distribution and spawning patterns of adult fish population) was the main factor separating the inshore from shelf assemblage. These results were consistent with other ichthyoplankton studies on continental shelves around the world (Richardson et al., 1980; Young et al., 1986; Sabatés, 1990; Moser and Smith, 1993; Mafalda Jr., 2000; Vidal Peñas, 2001; Doyle et al., 2002; Somarakis et al., 2002).

However, variations in the extension and formation of the subgroups between years was not so obvious, although it could be attributed in general to spawning strategies of adult fishes, the main circulation patterns, the continental waters runoff, and to the oceanographic processes of mixing, which have been relevant factors mentioned by others authors (Richardson et al., 1980; Olivar and Shelton, 1993; Thorrold and McWilliams, 1996; Sanvicente-Añorve et al., 1998; Flores-Coto et al., 2000; Mafalda Jr., 2000).

In general, the assemblages defined might be considered indicators for the different environments which they inhabited. Species of the coastal assemblages showed a strong ecophysiological dependence upon the lagoon-estuarine systems and the members of the coastal and neritic assemblage were mainly plankitivores related to high primary production (Sanvicente-Añorve et al., 1998).

This is, to our knowledge, the first meso-scale, multiespecies ichthyoplankton study in the Gulf of Cádiz and it suggest that interannual variability in assemblage structure during summer may reflect meteorological, physical and biological processes.

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RESUMO

Duas amostragens de ictioplâncton foram realizadas durante Julho de 1994 e Julho de 1995, no Golfo de Cádiz, com o objetivo de descrever a composição, abundância, padrões de distribuição e variações interanuais das associações de larvas de peixes. Diferenças interanuais foram encontradas neste estudo. Em 1994 salinidades mais elevadas foram observadas nas estações da plataforma externa, enquanto que, em 1995 os valores mais elevados foram encontrados nas estações da plataforma interna. A coluna de água foi mais quente em 1994 e apresentou menor densidade de larvas de peixes. Durante 1994 *Sardinella aurita* e *Engraulis encrasicolus* foram abundantes, porém com localização espacial oposta. Em 1995, a abundância de ambas as espécies foi muito diferente, mas com padrão espacial semelhante. A análise de cluster revelou grupos bem definidos de estações e associações de larvas, primariamente relacionadas com a batimetria. A "associação costeira" ocupou as zonas menos profundas; suas espécies características, vinculadas a sistemas estuarinos, compreenderam principalmente *Engraulis encrassicolus* e Gobiidae. A "associação de plataforma" esteve formada por larvas cujos adultos habitam a plataforma continental e desovam nesta mesma zona, tais como: *Sardinella aurita* e *Trachurus* spp. Variações interanuais na composição e extensão dos subgrupos podem ser atribuídas aos principais padrões de circulação, vazão de águas continentais e as estratégias de desova dos peixes.

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