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LARVAL FISH COMMUNITY COMPOSITION AND DISTRIBUTION OF THE CENTRAL-SOUTHERN MEDITERRANEAN UNDER SUMMER AND WINTER CONDITIONS

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Background. The Gulf of Gabès supports an important fishery which is characterized by a great diversity of fish species. Despite this importance, there has been no attempt to examine the whole larval fish assemblage in this area. The aim of this study was to investigate the larval fish communities during summer and winter seasons in the Gulf of Gabès.

Materials and methods. Two multidisciplinary surveys were carried out aboard the *R/V Hannibal* in 2009. A total of 80 and 70 stations were sampled during winter and summer surveys, respectively. Stations were arranged in a regular sampling grid of 10 × 10 nautical miles. Ichthyoplankton was sampled by oblique tows with a Bongo net of 60 cm mouth diameter, fitted with 335 µm mesh nets. Zooplankton dry weight was obtained by drying aliquots of the zooplankton sample in an oven at 60ºC, for 72 hours.

Results. In summer 34 taxa representing 24 families, were collected, whereas in winter 35 taxa, representing 16 families, were collected. Larval fish communities were dominated by small pelagic species: sardinella and anchovy in summer and sardine in winter. The results also highlight the Gulf of Gabès as an important spawning ground for many large and medium pelagic fishes, both highly migratory (*Thunnus thynnus*) and resident species (*Auxis rochei*, *Euthynnus alletteratus*). The summer/winter differences observed in species composition and abundance of the larval fish communities reflected the seasonality in fish species spawning in the Mediterranean Sea, likely influenced by the highly contrasting environmental conditions between seasons. Thus, the seasonal changes in the hydrographic conditions of the Gulf of Gabès result in different scenarios that provide suitable spawning environments for a variety of fishes, allowing them to share the Gulf as spawning habitat.

Conclusion. The Gulf of Gabès is an important fish spawning area for demersal, small pelagic, medium pelagic, and large pelagic (tunas). Larval species composition differed considerably between summer and winter surveys.

Keywords: ichthyoplankton, fish larvae, diversity, small pelagic fishes, tuna larvae

INTRODUCTION

The Gulf of Gabès supports an important fishery, characterized by a large diversity of fish species (Bradai unpublished). These species use the highly productive Gulf of Gabès shelf (Bel Hassen et al. 2009) as a nursery area. The Gulf also harbors the most extensive seagrass distributions (*Posidonia oceanica*) in the Mediterranean Sea (Batisse and Jeudy de Grissac 1998), which provides a major nursery site for several marine species (e.g., *Sardinella aurita*, *Engraulis encrasicolus*, *Auxis rochei*, *Pagrus pagrus*, *Boops boops*, *Trachurus mediterraneus,* etc.) (Hattour et al. 1995, Francour 1997). Surprisingly,

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** Bradai M.N. 2000. Diversité du peuplement ichtyque et contribution à la connaissance des Sparidés du golfe de Gabès. PhD Thesis, Science Univ. Sfax Tunisia.

the interest of fisheries exploitation in this area was not followed by research aimed to characterize the ichthyoplankton distribution, a key factor to understand the ecology and evolutionary aspects of fish populations (Moser and Smith 1993). To our knowledge, no data on ichthyoplankton distribution or larval fish ecology are available for this region.

Over the last two decades, research on the structure of larval fish communities in the Mediterranean Sea has increased. The majority of these studies, however, focus on the western Mediterranean, where there has been a significant examination of the environmental factors affecting ichthyoplankton distribution (Alemany et al. 2006, Sabatés et al. 2007, Olivar et al. 2014). This is in contrast with the central and eastern Mediterranean where information on ichthyoplankton assemblage structure and distribution is scant particularly for winter (Isari et al. 2008, Somarakis et al. 2011).

Despite the importance of larval fish assemblages to fisheries and ecosystems, we are not aware of any studies examining larval fish diversity in the Gulf of Gabès. Therefore, the objectives of this work were 1) to describe the composition and structure of the larval fish assemblages, 2) to assess the spatial distributions of the different larval fish taxa, 3) to carry out a comparative analysis between summer and winter assemblages and the factors shaping them.

MATERIALS AND METHODS

Study area. The Gulf of Gabès is located in the southern Mediterranean Sea, forming part of the Ionian Sea (33°–35°18′N and 9°30′–13°36′E) (Fig. 1). It occupies a wide and shallow continental shelf, reaching only 50 m depth up to 110 km offshore. The depth of 200 m is reached 400 km offshore (Hattab et al. 2013). This region also includes several islands (Kerkenah archipelago and Djerba) and lagoons (Bougrara and El Bibane) and is also characterized by a relatively high tidal amplitude relative to the region with values around 1 m (Abdennadher and Boukthir 2006, Sammari et al. 2006).

The biological and economic importance of the Gulf of Gabès is reflected its faunal complexity and the abundance of its fishery resources, especially small pelagic fishes, which make up 40% of exploitable biomass (Anonymous 2011). The coastline length of 700 km, account for more than half of the Tunisian coast.

The surface Atlantic water masses of recent origin flow from the western Mediterranean. After crossing the Strait of Gibraltar, recent Atlantic Water (herein referred to as AW) following Balbín et al. (2014), enter the Strait of Sicily and splits into two branches: one flows to the south-eastern Mediterranean and the second flows to the south and directly influences circulation at the mouth of the Gulf of Gabès (Grancini and Michelato 1987). The intensity of this southbound AW branch depends on seasonal variability (Béranger et al. 2004). Recent AW flow is relatively faster during winter than in summer (Ciappa 2009). Poulain and Zambianchi (2007) reported that the AW diverges into the shallow Gulf of Gabès and continues to the southeast, reaching the Libyan coastal areas, located approximately to the 200 m isobath.

Sampling on board. Two multidisciplinary surveys, named ESPOIRS 11 and 12, were carried out on board

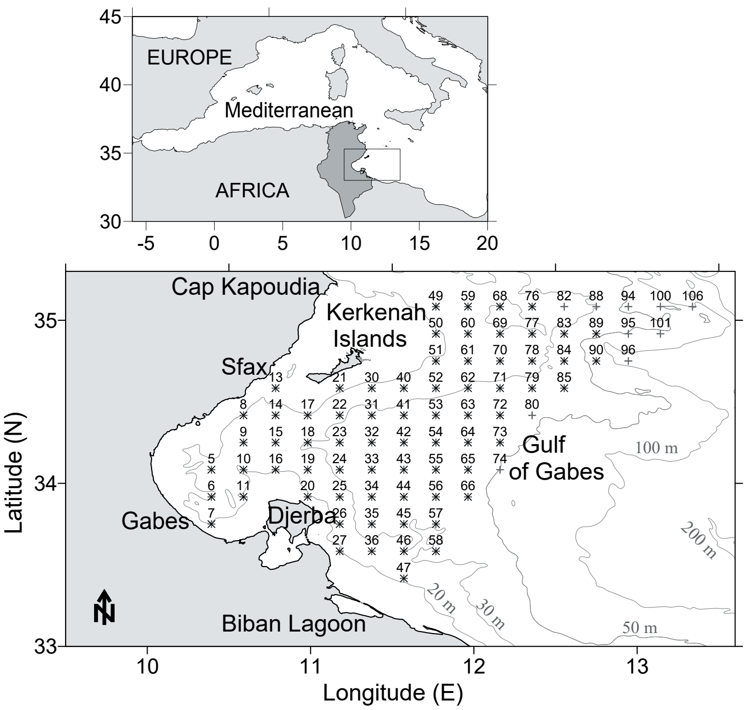

Fig. 1. Sampling stations in the Gulf of Gabès (central-southern Mediterranean) attended by *R/V Hannibal* in 2009; stations sampled in summer and in winter are marked with an asterisk; stations sampled only in summer are marked with a plus sign

of the *R/V Hannibal*. One survey was conducted during summer, from 25 June to 4 July 2009, the other during winter, from 8 to 24 December 2009. A total of 80 and 70 stations were sampled during winter and summer surveys, respectively (Fig. 1). Stations were arranged in a regular sampling grid of 10 × 10 nautical miles. The maximum bottom depths were around 230 m for ESPOIRS 11 and 117 m for ESPOIRS 12. Temperature and salinity profiles were recorded at each station using a CTD probe (Seabird 911 plus).

Ichthyoplankton was sampled via oblique tows with a Bongo net of 60 cm of mouth diameter, fitted with 335 µm mesh nets. The vessel speed was 3 knots. The sampling was deployed from the surface to 100 m depth or to 5 m above the bottom at shallower stations. Upon recovery of the sampler, the net was gently washed down with seawater. The codend was removed and the plankton was poured into a jar (volume 250 mL) and preserved in a 4% solution of seawater and formaldehyde buffered with sodium borate.

Zooplankton was sampled by a simple ring plankton net attached to the Bongo net. The mesh size was 100 µm and the mouth diameter was 25 cm. Hydro-Bios flowmeters were fixed in the mouth of Bongo and zooplankton nets to measure the volume of filtered waters. The zooplankton samples were stored at 20°C.

Laboratory analysis. Zooplankton dry weight was obtained by drying an aliquot of the zooplankton sample in an oven at a temperature of 60ºC for 72 h. Zooplankton dry weight values were standardized to $mg \cdot m^{-2}$. Zooplankton species were not identified.

Fish eggs and larvae were sorted, counted, and identified under a stereoscopic microscope to the finest possible taxonomic level. This work was conducted in the ichthyoplankton laboratory of the National Institute of Marine Sciences and Technologies. The taxonomic identification of fish eggs and larvae were based on the guides: D'Ancona et al. (1931–1956), Russell (1976), Fahay (1983). Some larvae were not identified because they were damaged. The length of the larvae was not measured. Larval fish species were classified according to adult habitat into two categories: neritic (those with their adult phase inhabiting and reproducing over the shelf) and oceanic (those with their adult phase inhabiting and reproducing off the shelf-break).

Egg and larval counts were standardized to abundances (the number of individuals per 10 m^2 of sea surface sampled).

The environmental parameters and the spatial distribution of the abundance of main taxa were mapped for each survey, using the SURFER package. Kriging was used to interpolate data and produce maps.

Data analysis. The spatial distribution of minimum values of salinity was analyzed to investigate the distribution of AW. Low salinity values (<37.6‰) are considered as characteristics of recent AW (Astraldi et al. 2002). Therefore, the isohaline of 37.7‰ has been used to define the interface between recent AW and saltier, resident AW, also of Atlantic origin but deeply modified due to a much longer residency in the Mediterranean (Bel Hassen et al. 2009).

The Shannon–Wiener and diversity indices (H' and S), of the larval fish community, was calculated for each station. A non-parametric Mann–Whitney U-test was performed to compare the diversity index values between summer and winter. The relation between larval fish abundances and mesozooplankton biomass and between larval fish abundance and larval fish diversity was assessed with the non-parametric Spearman's rank correlation coefficient. Non-parametric tests were used because of the absence of normality in the data. Differences in community structure between summer and winter were assessed with the permutational multivariate analysis of variance (PERMANOVA) (Clarke et al. 2014). This analysis was carried out on a Bray–Curtis similarity matrix, generated from the fourth-root transformed data of larval fish taxon abundances of both cruises combined. Data were transformed to down-weight the influence of more abundant taxa (Clarke et al. 2014). All tests were carried out at a significance level of 0.05.

The Mann–Whitney U-test and the Spearman's rank correlation test were performed with the STATISTICA Software (Statsoft Inc.). Diversity indices and PERMANOVAs were performed with PRIMER v7 (Clarke et al. 2014).

RESULTS

Environmental conditions. In summer, the mean of the sea surface temperature, at 10 m depth, (SST) was 24.59 ± 0.57°C. Warmer waters were found in the east of the Kerkenah Islands and in the south of the inner part of the Gulf (Fig. 2). Relatively colder waters were found offshore, north and south of the study area. Regarding sea surface salinity (SSS), saltier waters (>39‰) were found near the coast of Gabès city. Minimum salinity values were recorded offshore, north of the study area. The water column was well stratified with the seasonal thermocline ranging between 10 and 50 m depth, with a vertical difference in temperature up to 8°C (Fig. 3).

In winter, the mean SST was 18.46 ± 0.74°C. Relatively colder waters (<17.5°C) were found in the inner part of the Gulf and the off Kerkenah Islands. Saltier waters (>39‰) were found in the inner part of the Gulf and in the south of the Kerkenah Islands where the water column had relatively constant temperature from surface to bottom but vertical variation in salinity (Fig. 3).

The influence of AW in the Gulf of Gabès seems to be more important in summer than in winter. Accordingly, waters with salinity lower than 37.7‰ covered a large part of the Gulf in summer, but only around a quarter of its surface in winter.

Zooplankton biomass followed an irregular spatial distribution pattern (Fig. 4). In summer higher values (>50 $g \cdot 10\ m^{-2}$) were registered in the south of Sfax City, in the north and north-east of Djerba and in the north-east of the study area. Winter higher values (>200 $g \cdot 10\ m^{-2}$) occurred in the east of Djerba Island.

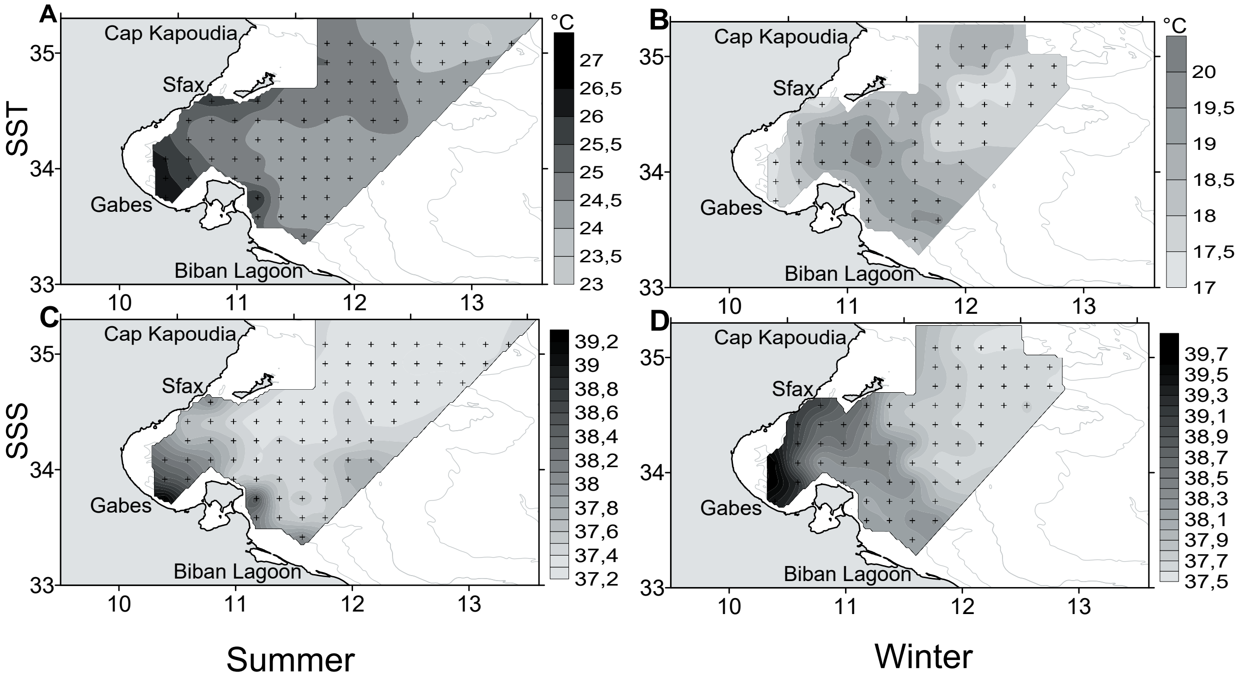

Fig. 2. Spatial distribution of sea surface temperature (SST, temperature ºC at 10 m depth) during the summer cruises (**A**) and during the winter cruises (**B**); sea surface salinity (SSS, salinity at 10 m depth) during the summer cruises (**C**) and during the winter cruises (**D**), in the Gulf of Gabès (central-southern Mediterranean) in 2009

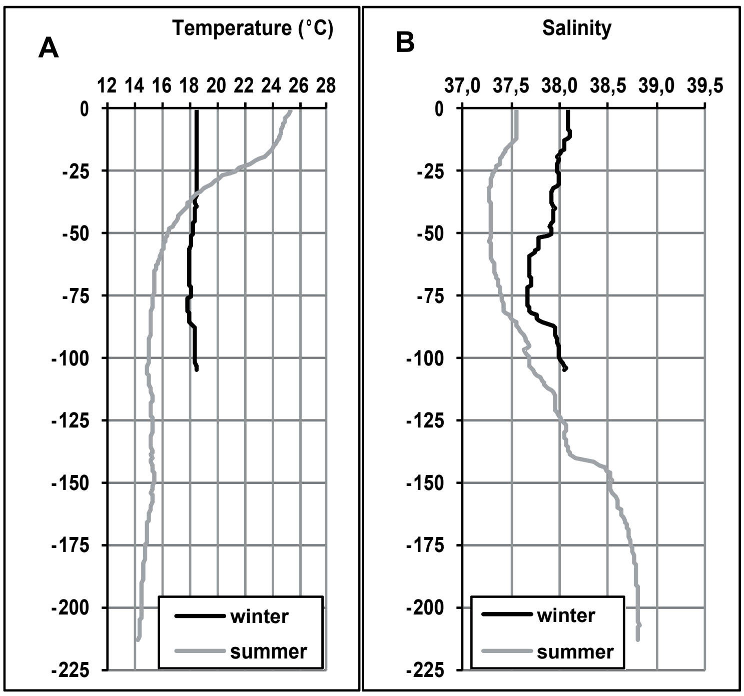

Fig. 3. Vertical profiles of mean temperature (**A**) and mean salinity (**B**) in the Gulf of Gabès (central-southern Mediterranean) in summer and winter of 2009

Larval fish community composition. In summer, a total of 2073 fish larvae representing 34 taxa grouped in 24 families, were collected, whereas in winter 879 larvae, belonging to 35 taxa in 16 families were collected.

Egg and larval fish abundances were significantly higher in summer, reaching the mean value of 967 eggs per 10 m^{-2} and 194 larvae per 10 m^{-2}, than in winter, and the mean value of 81 eggs per 10 m^{-2} and 35 larvae per 10 m^{-2} (Mann–Whitney *U*-test, $P < 0.01$, in both cases). In both seasons, larvae of the families Clupeidae and Sparidae were dominant with percentages of abundances of 30.48% and 17.66% in summer and 47.58% and 25.64% in winter, respectively.

The most abundant species in summer was *Sardinella aurita* (62.46 larvae per 10 m^{-2}), followed by *Pagrus*

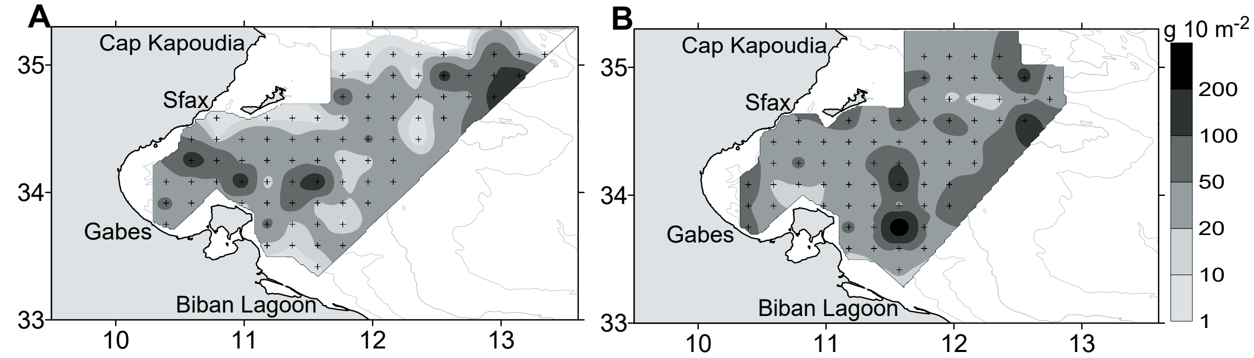

Fig. 4. Spatial patterns of zooplankton biomass in summer (**A**) and winter (**B**) of 2009, in the Gulf of Gabès (central-southern Mediterranean)

pagrus (36.20 larvae per 10 m^{-2}), and *Serranus hepatus* (15.88 larvae per 10 m^{-2}) (Table 1). In winter, the most abundant larvae were those of *Sardina pilchardus* (16.36 larvae per 10 m^{-2}), followed by *Diplodus* spp. (2.12 larvae per 10 m^{-2}) and *Trachurus trachurus* (2.39 larvae per 10 m^{-2}). Abundances of the other species were lower than 2 larvae per 10 m^{-2} (Table 1). The most diverse families in summer were Labridae, Myctophidae, and Scombridae and in winter were Labridae, Myctophidae, and Sparidae. Some species were present both in summer and winter (*Engraulis encrasicolus*, *Benthosema glaciale*, *Lampanyctus crocodilus*, *Pagrus pagrus*, *Xyrichthys novacula*, *Aphya minuta*); but with clear differences in abundance between seasons (Table 1). All these species, with the exception of *A. minuta*, were more abundant in summer. The larvae of the tuna species *Auxis rochei*, *Euthynnus alletteratus*, *Thunnus alalunga*, and *Thunnus thynnus*, were also collected with low abundances.

Larval diversity index values *S* and *H*′ were significantly higher (Mann–Whitney *U*-test, $P < 0.02$) in summer than in winter. However, the highest absolute values were recorded in winter. In both seasons, the higher values of these larval fish community parameters were found offshore, in the east and south-east of the Kerkenah Island (Fig. 5). In the inner part of the Gulf, medium values of diversity were recorded near the coast of Gabès city. PERMANOVA test also revealed significant differences in larval fish community structure between summer and winter ($P < 0.02$).

Spatial distributions. In summer, fish eggs and larvae were distributed over most of the study area (Fig. 6), despite fish larvae were scarcer in the inner part of the Gulf. Contrastingly, in winter the higher concentrations of fish eggs and larvae were found offshore, mainly in the north-east and south-east of the Kerkenah Islands, showing a patchy distribution.

In summer, the most ubiquitous taxon was *Spicara* spp., appearing at 58.75% of stations. *Sardinella aurita* and *P. pagrus* were also frequent, being present at 45.00% and 46.25% of the sampling stations, respectively). The spatial distributions of selected taxa for summer are shown in Fig. 7. *Sardinella aurita* larvae were concentrated in two areas, in the North East of Djerba Island and offshore, at around 90 miles east of the Kerkenah Islands (Fig. 7). The maximum abundances of *E. encrasicolus* larvae were recorded in the inner part of the Gulf, but other important concentrations were detected in the central part and offshore north of the study area. For *Trachurus mediterraneus*, all larvae were collected off the 30 m isobath. Larvae of the small tuna species *Euthynnus alletteratus* were located in the south of Kerkenah and in the east of Djerba. *Auxis rochei* larvae were mainly concentrated between the isobaths of 30 and 50 m and larvae of *Thunnus thynnus* were found offshore (80 miles east of the Kerkenah Islands). Larvae of *P. pagrus*, *Serranus hepatus*, and *Mullus barbatus* were concentrated in shallower waters.

The spatial distributions of selected taxa for winter are shown in Fig. 8. Larvae of *Sardina pilchardus* were present in more than half of the stations (55.71%) (Table 1). In the inner part of the Gulf *S. pilchardus* larvae were scarce. Larvae of *Trachurus trachurus*, *Boops boops*, *Diplodus* spp., and *Sparus aurata* showed the same pattern of spatial distribution. Larvae of these species were concentrated in the east and south-east of the Kerkenah Islands. Larvae of *Pagellus* spp. were found in the east and north-east of Djerba Island. Larvae of *Pseudaphya ferreri* and *Aphya minuta* were located near the coast and offshore of Sfax City. Larvae of *Lestidiops jayakari* were found only offshore.

The correlations between egg and larval fish abundances and mesozooplankton biomass were not significant for any of the two cruises ($P < 0.5$ in all four correlations).

DISCUSSION

During both seasons the larval fish community of the Gulf of Gabès was dominated by larvae of small pelagic species, which is typical in shelf regions of temperate seas (Sabatés et al. 2007). During the summer survey, the larval fish community was widely dominated by the summer spawning species *Sardinella aurita* and *Engraulis encrasicolus*, while during the winter cruise, it was dominated by the winter spawning species *Sardina pilchardus*. The typically large-sized spawning stocks of these species, coupled with its high fecundity, may explain the dominance of the larval fish community by larvae of

Table 1

Larval fishes collected during summer and winter cruises of *R/V Hannibal* in the Gulf of Gabès (central-southern Mediterranean), in 2009

Fish collected		Origin	Summer		Winter	
Species	Family		RA [%]	Occ [%]	RA [%]	Occ [%]
Apogon imberbis	Apogonidae	N	0.28	3.75		
Blenniidae gen. spp.	Blenniidae		2.57	8.75		
Arnoglossus spp.	Bothidae	N	2.99	11.25		
Arnoglossus thori		N			0.04	1.43
Callionymidae gen. sp. 1	Callionymidae	N	0.15	1.25		
Callionymidae gen. sp. 2		N			0.22	4.29
Capros aper	Caproidae	N	0.06	1.25		
Trachurus mediterraneus	Carangidae	N	2.64	17.50		
Trachurus trachurus		N			2.12	15.71
Spicara spp.	Centracanthidae	N	28.72	58.75		
Sardinella aurita	Clupeidae	N	62.46	45.00		
Sardina pilchardus		N			16.36	55.71
Coryphaena hippurus	Coryphaenidae	Oc	0.04	1.25		
Engraulis encrasicolus	Engraulidae	N	13.38	30.00	0.08	4.29
Gadidae gen. spp.	Gadidae		0.19	2.86		
Aphya minuta	Gobidae	N	0.10	2.50	0.67	11.43
Pseudaphia ferreri		N			0.96	15.71
Gobidae gen. spp.			6.41	26.25		
Cyclothone braueri	Gonostomatidae	Oc	0.05	1.25		
Coris julis	Labridae	N	0.36	5.00		
Xyrichthys novacula		N	0.39	5.00	0.07	2.86
Symphodus spp.		N			0.04	1.43
Labridae gen. spp.					0.15	4.29
Merluccius merluccius	Merlucciidae	N	0.10	2.86		
Mullus barbatus	Mullidae	N	8.08	28.75		
Mugilidae gen. sp. 1	Mugilidae	N	0.12	1.25		
Mugilidae gen. sp. 2		N	0.11	4.29		
Benthosema glaciale	Myctophidae	Oc	0.80	1.25	0.16	4.29
Ceratoscopelus maderensis		Oc	0.76	7.50	0.20	4.29
Lampanyctus crocodilus		Oc	0.26	1.25	0.12	2.86
Hygophum spp.		Oc			0.31	4.29
Hygophum benoiti		Oc			0.38	2.86
Lampanyctus pusillus		Oc			0.12	2.86
Lobianchia dofleini		Oc			0.06	1.43
Symbolophorus veranyi		Oc			0.05	2.86
Chromis chromis	Pomacentridae	N	0.24	5.00		
Lestidiops jayakari	Paralepididae	Oc			0.39	4.29
Lestidiops sphyrenoides		Oc			0.06	1.43
Serranus cabrilla	Serranidae	N	3.46	17.50		
Serranus hepatus		N	15.88	28.75		
Serranus spp.		N			0.23	2.86
Auxi rochei	Scombridae	N	9.25	25.00		
Euthynnus alletteratus		N	0.77	5.00		
Thunnus alalunga		Oc	0.11	1.25		
Thunnus thynnus		Oc	0.51	5.00		
Solea sp. 1	Soleidae	N			0.22	4.29
Solea sp. 2		N			0.03	1.43
Solea sp. 3		N			0.12	4.29
Soleidae gen. spp.		N	0.39	3.75		
Pagrus pagrus	Sparidae	N	36.20	46.25	0.52	7.14
Boops boops		N			1.64	14.29
Diplodus spp.		N			2.39	24.29

Table continues on next page.

Table 1 cont.

Fish collected		Origin	Summer		Winter	
Species	Family		RA [%]	Occ [%]	RA [%]	Occ [%]
Pagellus spp.		N			1.01	10.00
Oblada melanura		N			0.50	7.14
Sparus aurata		N			1.36	17.14
Sparidae gen. sp. 1			2.76	12.50		
Sparidae gen. sp. 2					1.40	14.29
Syngnathus spp.	Syngnathidae	N			0.01	1.43
Lepidotrigla cavillone	Triglidae	N	0.13	1.25		
Trachinus draco	Trachinidae	N	0.53	3.75		
Trachinidae gen. spp.			3.94	17.50	1.99	12.86

RA = taxon relative abundance, Occ = taxon percentage of occurrence; N = Neritic, Oc = oceanic; the relative abundance of each species (10 m^{-2}) was computed as the mean abundance of all stations; the percentage of occurrence was the percentage of positive stations among all stations.

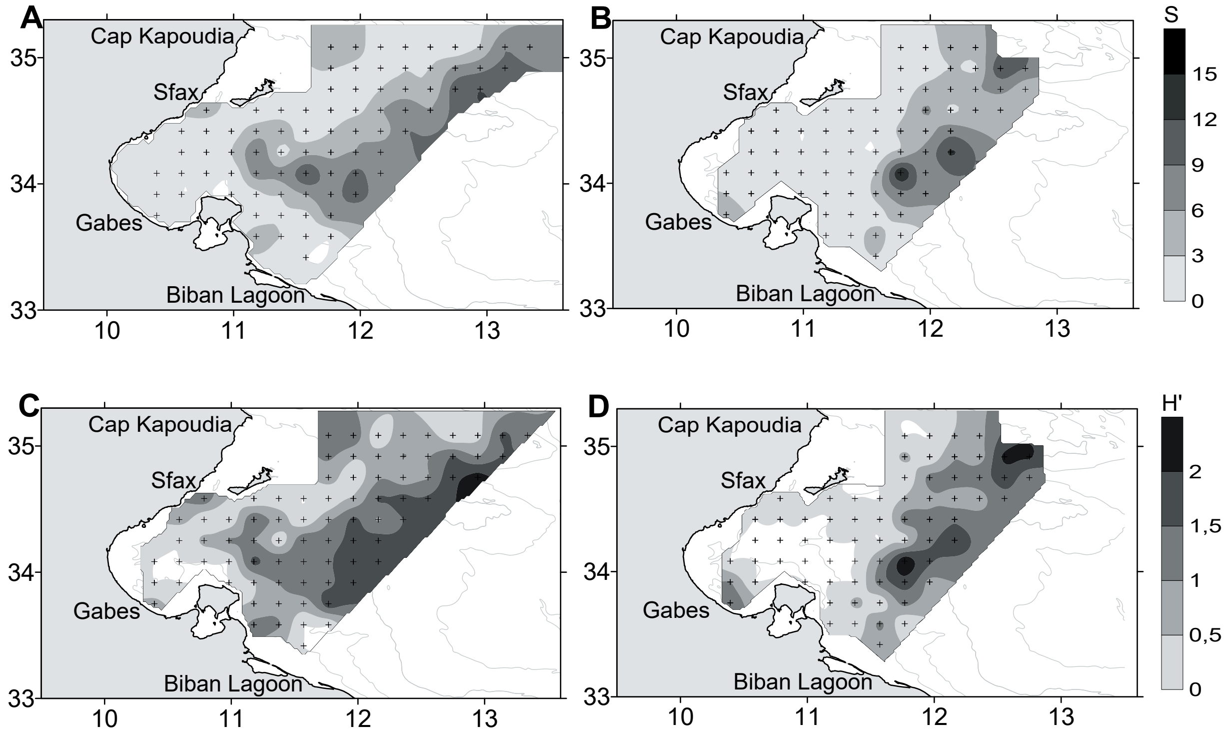

Fig. 5. Spatial distribution of Shannon–Weaver diversity index *H'* summer (**A**) and winter (**B**) of 2009, in the Gulf of Gabès (central-southern Mediterranean)

small pelagic fish species (Sabatés et al. 2007, Anonymous 2011). *Sardina pilchardus* also dominate the winter larval fish assemblage on the western and central Mediterranean Sea (Sabatés et al. 2007, Zarrad and Jarboui 2013).

The presence of larvae of tuna species (*Auxis rochei*, *Euthynnus alletteratus*, *Thunnus alalunga*, and *Thunnus thynnus*) is notable. Among these species, the presence of larvae of *T. thynnus* larvae deserves special attention. One of the main spawning areas for this species worldwide is the Balearic Sea (western Mediterranean), where it reproduces in summer (Palomera and Olivar 1996, Sabatés et al. 2007, Alemany et al. 2010). The presence of larvae of *T. thynnus* in our area of study indicates that bluefin tuna also reproduces in the Gulf of Gabès. The larvae of this species occurred offshore between 92 m and 230 m depth), in waters with relatively low SSS (37.3‰), corresponding to the AW current. This agrees with Alemany et al. (2010), Rodriguez et al. (2013), and Zarrad et al. (2013) who reported that adults of bluefin tuna follow the Atlantic current in their displacements into and across the Mediterranean Sea to spawn.

During the winter season, the presence of larvae of many mesopelagic species of the families Myctophidae and Paralepididae, is noteworthy, and probably related with the intrusion of offshore waters into the Gulf of Gabès. Adult fish species of these families are mesopelagic and reproduce in the oceanic region. The presence of larvae of these species in the relatively shallow waters of the Gulf of Gabès indicate that, because of the limited swimming ability of fish larvae (Leis 2007), they have been transported inside the Gulf by

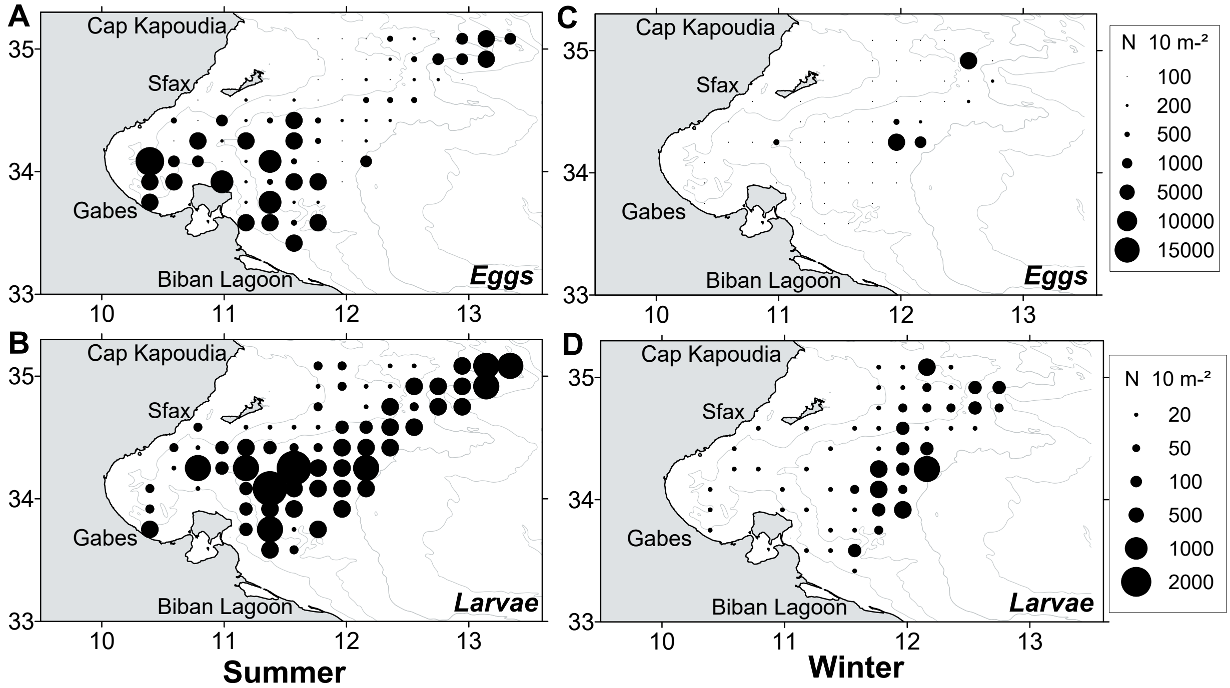

Fig. 6. Spatial distributions of fish egg and larval abundances in summer (**A–B**) and winter (**C–D**) (**A**) and winter (**B**) of 2009, in the Gulf of Gabès (central-southern Mediterranean)

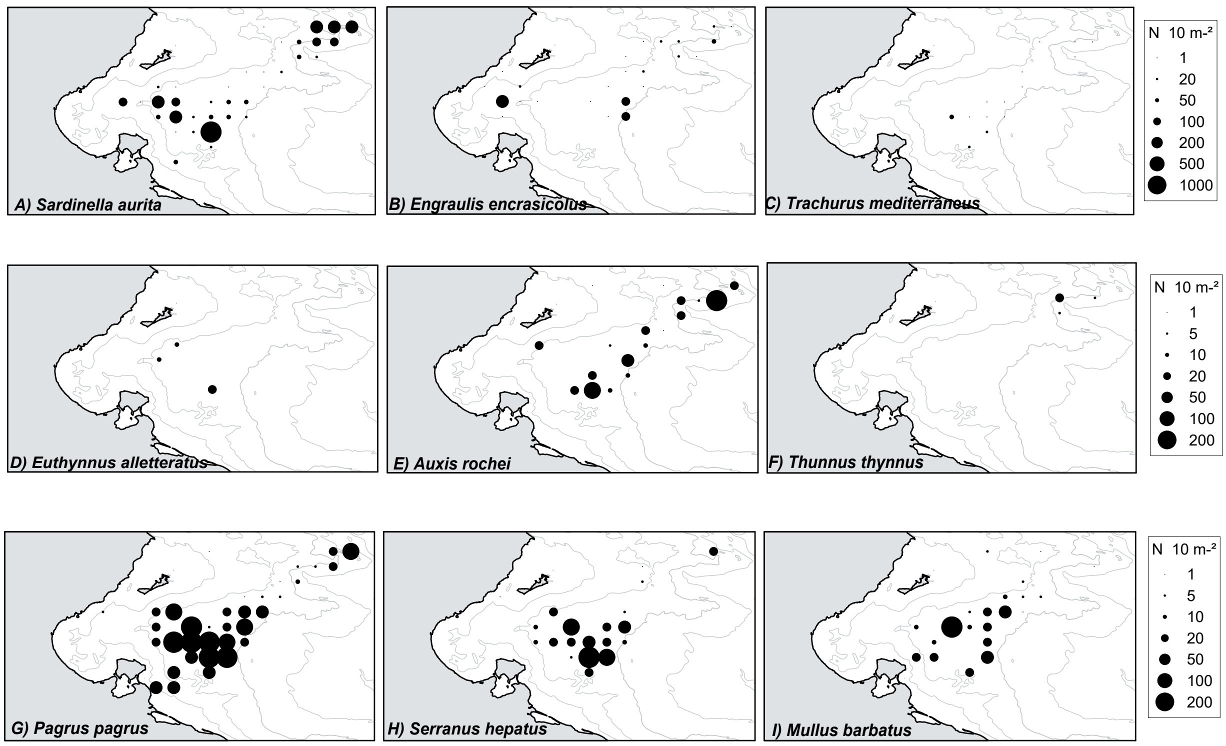

Fig. 7. Spatial distributions of larval abundances of *Sardinella aurita* (**A**), *Engraulis encrasicolus* (**B**), *Trachurus mediterraneus* (**C**), *Euthynnus alletteratus* (**D**), *Auxis rochei* (**E**), *Thunnus thynnus* (**F**), *Pagrus pagrus* (**G**), *Serranus hepatus* (**H**), and *Mullus barbatus* (**I**) in the Gulf of Gabès (central-southern Mediterranean) in summer of 2009

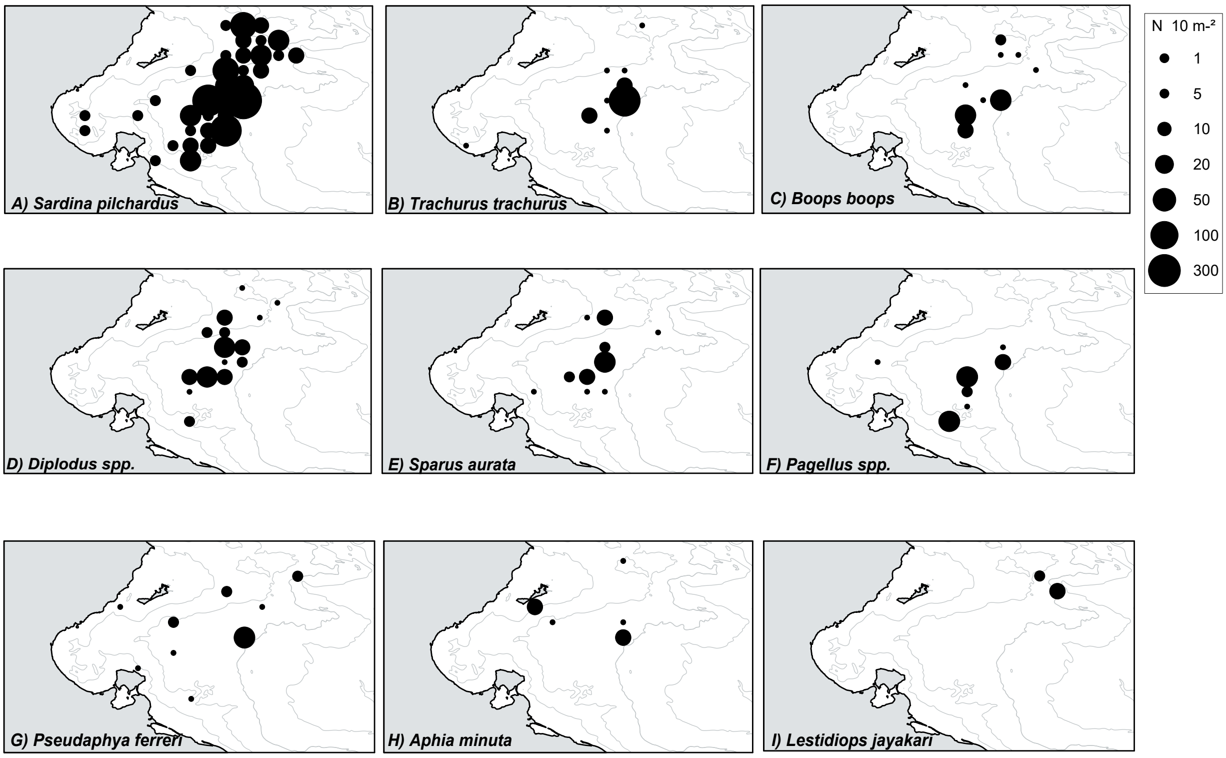

Fig. 8. Spatial distributions of larval abundances of *Sardina pilchardus* (**A**), *Trachurus trachurus* (**B**), *Boops boops* (**C**) *Diplodus* spp. (**D**), *Sparus aurata* (**E**), *Pagellus* spp. (**F**) *Pseudaphya ferreri* (**G**), *Aphia minuta* (**H**) and *Lestidiops jayakari* (**I**) in the Gulf of Gabès (central-southern Mediterranean) in winter of 2009

marine currents and/or other hydrographic processes. The importance of currents and other hydrographic processes in the distribution of fish larvae have been widely documented for the Mediterranean Sea (Sabatés and Olivar 1996, Sabatés et al. 2013) and other marine regions worldwide (Cowen 1993, Rodriguez et al. 1999). The mixture of larvae of neritic and oceanic species would account for the fact that the higher values of the larval fish diversity index were recorded offshore. Larval fish abundance and diversity were higher during the summer cruise because most fish species in the Mediterranean Sea reproduce during spring–summer (Tsikliras et al. 2010). These higher values may also account for the differences found in larval fish community structure between summer and winter, in the Gulf of Gabès.

The values of the larval fish diversity in the Gulf of Gabès were comparable to the east coast of Tunisia (Zarrad et al. 2013). They were, however, lower than those recorded in other Mediterranean Sea regions, e.g., the north-western Mediterranean, off the Balearic Islands (Alemany et al. 2006, Rodriguez et al. 2013, Álvarez et al. 2015) and in the north-eastern Mediterranean Sea (Somarakis et al. 2002, Koutrakis et al. 2004) and in winter in the north-western Mediterranean Sea (Olivar et al. 2014). Although, this ichthyoplankton community parameter must be regarded with caution the number of larval fish taxa identified in an ichthyoplankton study depends on the availability of information to identify fish larvae to species in the area of study and on the ability of the ichthyoplankton taxonomist to use this information.

The environmental conditions found during both surveys were characterized by a marked stratification of the water column during the summer cruise and a mixed water column during the winter cruise are typical of the summer and winter seasons in the Mediterranean Sea. The distribution of SSS showed the entrance and the influence of the modified AW in the Gulf of Gabès, as already reported by Bel Hassen et al. (2009). The highest values of SSS found in both seasons in the inner part of the Gulf maybe because of the shallowness of this region, which would be more influenced by high evaporation rates resulting in increased salinity values. Moreover, in this area, there are no fresh water inputs and it is distant the influence of AW currents. Thus, a clear differential distribution along an inshore-offshore gradient in summer was observed. This seems to be related to the spawning location of adults and also due to the fact that the main hydrographic features influencing larval fish distribution are found along this gradient (Sabatés and Olivar 1996, Rodríguez et al. 2009).

The temporal and spatial variability in oceanographic conditions may directly influence the reproductive activity of different species (i.e., spawning time and location, spawning duration and frequency, fecundity) and therefore affect the occurrence, distribution, and abundance of their larvae (Doyle et al. 1993). However, the bathymetric distributions of adults as well as the type of substratum selected by demersal species have been referred to being important in defining spawning habitats and controlling the composition of larval fish assemblages (Somarakis et al. 2002).

The occurrence of oceanic/slope species, such as Myctophidae, in coastal-shelf regions, is a good indicator of the presence of oceanic waters in these regions. In the surveyed area, shoreward intrusions and cross-shelf flows are probably transporting mesopelagic larvae spawned offshore onto the continental shelf, mainly in winter due to the relatively stronger effect of AW.

This work helps demonstrate that ichthyoplankton studies, specifically those of the whole fish larvae assemblages, can contribute to improved marine and fishery management in the Gulf of Gabès. Improved knowledge of planktonic-environmental processes allows making predictions about changes in the fish population structure and dynamics, as well as on the spatial and temporal distribution of essential habitats for where spawning takes place. We want to highlight that the analysis of spatial and temporal changes affecting the larval fish community in the Gulf of Gabès will constitute one of the main tasks of our future work. This paper provides baseline information on ichthyoplankton communities and could be followed by new data to measure environmental and larval change over time in the Gulf of Gabès (e.g., the appearance of new species, or disappearance of others, changes in dominance, etc.).

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