The TRANSBORAN-0220 Cruise

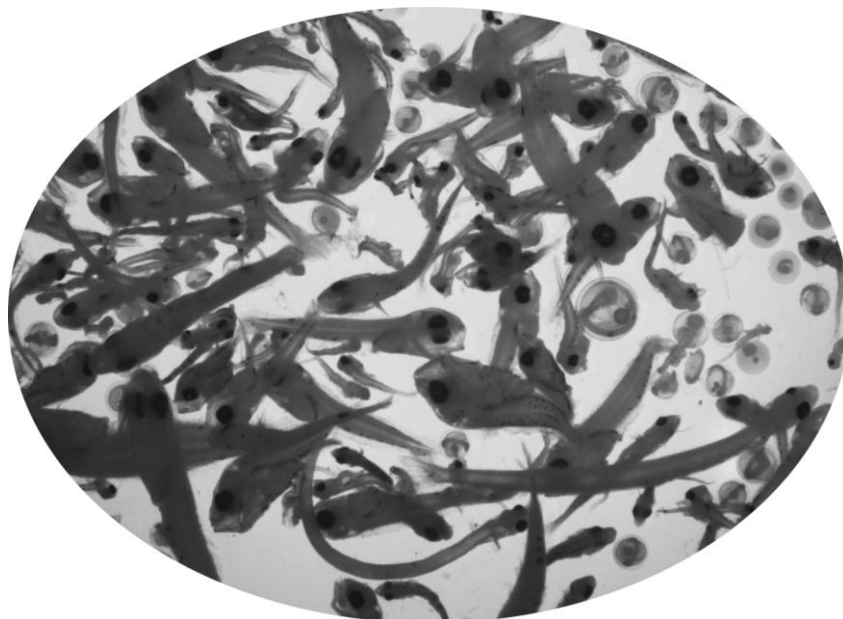## Ichthyoplankton Report

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ABSTRACT

In this report, we show the results of the study of the ichthyoplankton captured during the TRANSBORAN 0220 cruise.

A total of 16,364 fish eggs and 8,836 fish larvae was captured, and 92 larval fish taxa were identified. The most numerous fish species was the myctophid *Benthosema glaciale*, followed by *Sardina pilchardus* and *Myctophum punctaum*. 45.70% of the fish larvae in 51 taxa belonged to the neritic realm, 53.61% of the larvae in 21 taxa belonged to the oceanic real and 0.69% of the larvae in 10 taxa were of unknown origin.

Fish egg and larval abundances were generally higher in the neritic region of the whole area of study. Differences in fish eggs abundances between regions were not significant. However, larval abundances were significantly lower in the Atlantic south region.

S. pilchardus was the second most abundant larval fish species. However, larval abundances were very low for the other two species objective of the TRANSBORAN project, *Merluccius merluccius* and *Pagellus bogaraveo*.

The structuring of the larval fish community into two assemblages, a coastal and an outer assemblage is common to many other regions.

Taking into consideration the hydrography of the area of study, the vertical distribution of fish larvae, the swimming capacity of fish larvae, with maxima swimming speeds recorded of about 30 cm^{-1}, the connection between the fish populations located in the Atlantic region and the Alboran Sea could only be unidirectional, from the Atlantic Ocean towards the Alboran Sea. More precisely, considering the sea surface circulation in the Atlantic region, these larvae would come from the Gulf of Cadiz and would be transported by the Atlantic jet that enters the Alboran Sea.

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1. INTRODUCTION

1.1 The area of study

The area of study included the Alboran Sea and the adjacent Atlantic region, divided into the Gulf of Cadiz and the area off the northernmost-western African coast (Fig. 1). The continental shelf is narrow in the Alboran Sea, widens off the African coast, reaching its maximum amplitude in the Gulf of Cadiz (Fig. 1-1).
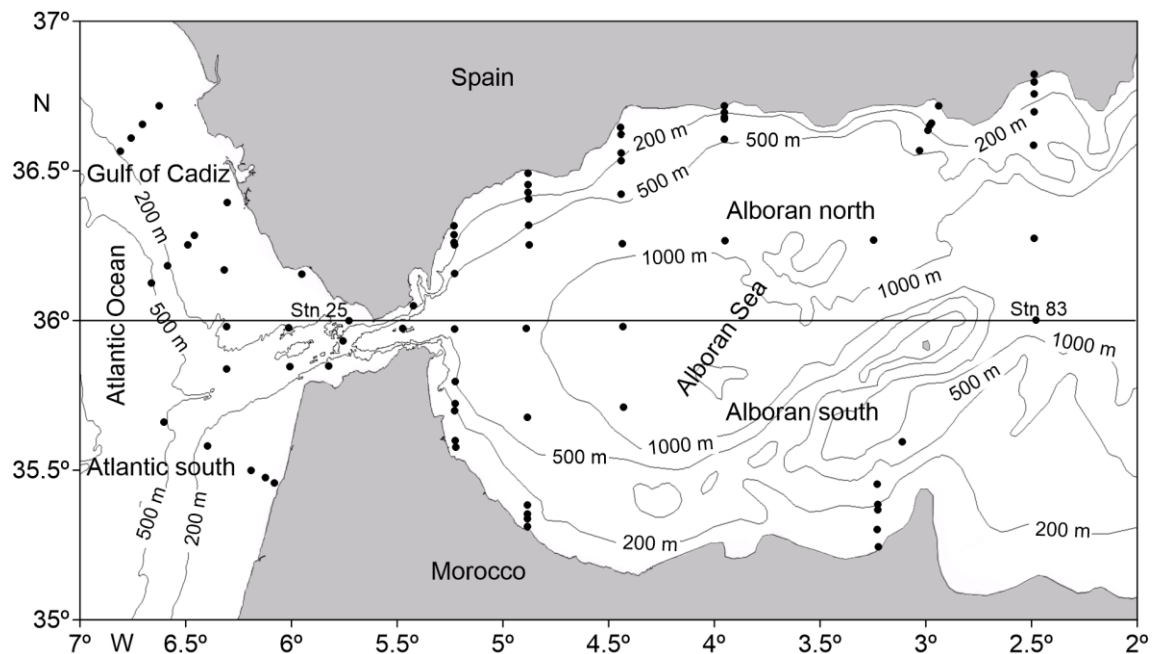
Figure 1-1. Map of the area of study with the sampling stations (●). Stations 25 and 83 were not considered in the study of the larval fish assemblages

1.2 Hydrography of the area of study

The Gulf of Cadiz is located between the northeastern Atlantic Ocean and the Mediterranean, connecting the open Atlantic Ocean with the Mediterranean Sea, through the Strait of Gibraltar.

Because of its location, the surface circulation in the Gulf o Cadiz is linked to the northeastern part of the North Atlantic subtropical gyre, formed by the Azores and the Canary currents (Figure 1.2a). The Azores current is a zonal meandering flow that stretches across a large extent of the North Atlantic, and the Canary current is a equatorward, slowly moving flow that constitutes the eastern boundary of the North

Atlantic subtropical gyre (García Lafuente and Ruiz, 2007 and references herein). Part of the flow that enters the Gulf of Cadiz feeds the Atlantic inflow (Br3 in Figure 1.2a) into the Mediterranean Sea forming the Atlantic jet, and part recilculates anticyclonically (Br1 and Br2 in Figure 1.2a) to merge with the Azores and the Canary Currents further south (García Lafuente and Ruiz, 2007). While region off the north-westernmost Africa, is under the influence of the Canary current (Figure 1.2b) (Lovecchio *et al.*, 2017).
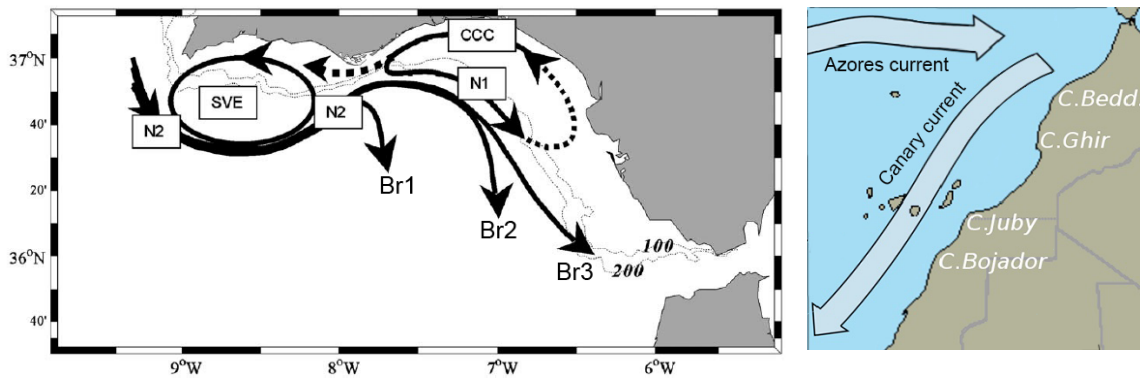
Figure 1-2. Schemes of the sea surface circulation in the Atlantic region: (a) Gulf of Cadiz (taken from Garcia-Lafuente *et al.*, 2007) and (b) off the north-westernmost African coast (adapted from Lovecchio *et al.*, 2017). Br3 in (a) represents the Atlantic jet that enters the Gulf of Cadiz, for the meaning of the other labels see Garcia-Lafuente *et al.* (2007)

The relatively fresh surface Atlantic water enters the Alboran Sea (the Atlantic jet) to compensate the excess of evaporation over the Mediterranean basin and drives a two-layer baroclinic exchange through the Strait of Gibraltar (Soto-Navarro *et al.*, 2016 and references herein). The Atlantic jet that enters the Alboran Sea flows eastward at a speed of about 1 m.s^{-1} in the upper layer, while the cooler and saltier Mediterranean outflow leaves the strait flowing westward in the lower layer The interface between both water masses would be located around 300 m depth (Criado-Aldeanueva *et al.*, 2006).

There is a general agreement about the surface circulation pattern in the Alboran Sea. The inflowing Atlantic water through the Strait of Gibraltar follows a wave-like path towards the east, enclosing and feeding two anticyclonic gyres in which Atlantic water accumulates (Figure 1.3). These are known as the western and eastern Alboran gyres. While the western gyre seems to be a rather permanent feature, there is some

controversy about the permanency of the eastern gyre, which sometimes has not been detected. Also in autumn-spring, a central cyclonic gyre has been detected between the western and eastern gyres (Figure 1.3) (García Lafuente *et al.*, 1998; Vargas-Yáñez *et al.*, 2002; Renault *et al.*, 2012).
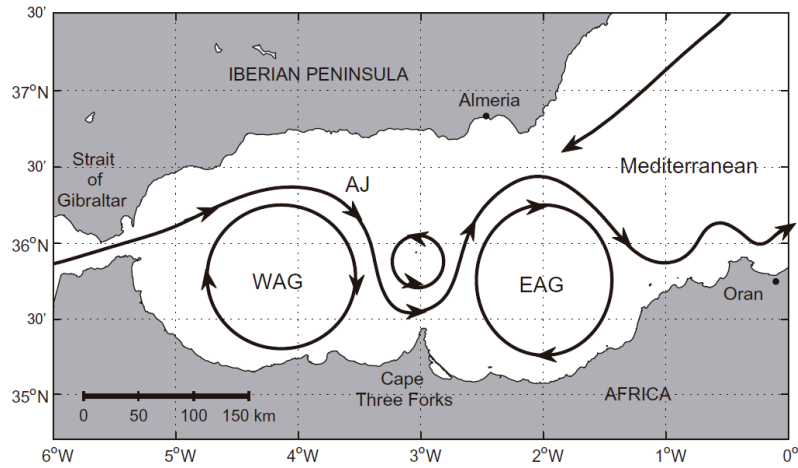
Figure 1-3. Scheme of the sea surface circulation in the Alboran Sea showing the western and eastern Alboran gyres (WAG and EAG) as well as the jet of Atlantic waters (AJ) (taken from Sánchez-Garrido *et al.*, 2013)

1.3. Relationship between hydrography and ichthyoplankton

The composition and structure of the ichthyoplankton community found in an area during a study depends on the adult fish species that are reproducing at the time of the study, on the mortality rates of their offspring and on the fish egg and larval dispersal from the area of study and on the larval fish transport from other places to the area of study. The hydrographic processes involved in the horizontal distribution of fish eggs and larvae are marine currents, Ekman transport, upwelling filaments, fronts and eddies, among other mesoscale hydrographic features (Lobel and Robinson, 1986; Heath, 1989; Sabates and Maso, 1990; Roy, 1998; Rodriguez *et al.*, 1999; Smith and Suthers, 1999). Biological factors, such as the spawning location, the spawning strategy, the vertical distribution of fish larvae in the water column (most of them located in the very surface layer and practically all of them in the upper 200 m of the water column) and the larval vertical migratory behaviour also play a role in the ichthyoplankton distribution and survival. And, therefore, in defining the composition and structure of the ichthyoplankton community of an area (Parrish *et al.*, 1981; Norcross and Shaw, 1984;

Gorbunova *et al.*, 1986; Myers and Drinkwater, 1989; Frank *et al.*, 1992; Olivar and Sabates, 1997). Consequently, fish larvae are dispersed in the ocean via an interplay between physical and biological processes (Cowen and Sponaugle, 2009) Moreover, knowledge of fish population connectivity requires understanding the origin and trajectories of dispersing eggs and larvae among subpopulations (Pineda *et al.*, 2015).

1.4. Previous studies on ichthyoplankton in the Alboran Sea and the adjacent Atlantic region

Previous studies on ichthyoplankton in our area of study are scarce and many of them were focused on species of commercial interest. As examples of the ichthyoplankton studies carried in the Alboran Sea, we would highlight those of García *et al.* (1987; 1988); Rubin (1992), Rubín *et al.* (1992), Garcia and Palomera (1996), Rubin (1997), Rubín *et al.* (1997) and Marina *et al.* (2015). A special mention deserves that of Vargas-Yáñez and Sabatés (2007), the only study that deals with the vertical distribution of the ichthyoplankton in the Alboran Sea. For the adjacent Atlantic region, studies of the ichthyoplankton community are even scarcer. We would highlight only those of Catalán *et al.* (2006) and Mafalda and Rubín (2006) for the Gulf of Cadiz.

1.5. The TRANSBORAN project

The TRANSBORAN project, "*Transboundary population structure of Sardine and European hake and blackspot seabream in the Alboran Sea and adjacent waters: a multidisciplinary approach*", has as the main objective to investigate the spatial population structure and to identify the most plausible stock units of sardine (*S. pilchardus*), European hake (*Merluccius merlucius*) and black-spot seabream (*Pagellus bogaraveo*) in the Alboran Sea, according to a multidisciplinary approach. This is a project co-funded by the FAO, through the COPEMED II Fisheries Cooperation Project, by the General Fisheries Commission of the Mediterranean Sea (CGPM) and by the Spanish Institute of Oceanography. The TRANSBORAN-0220 cruise was also supported by the General Secretary of Fisheries of the Spanish Ministry of Agriculture
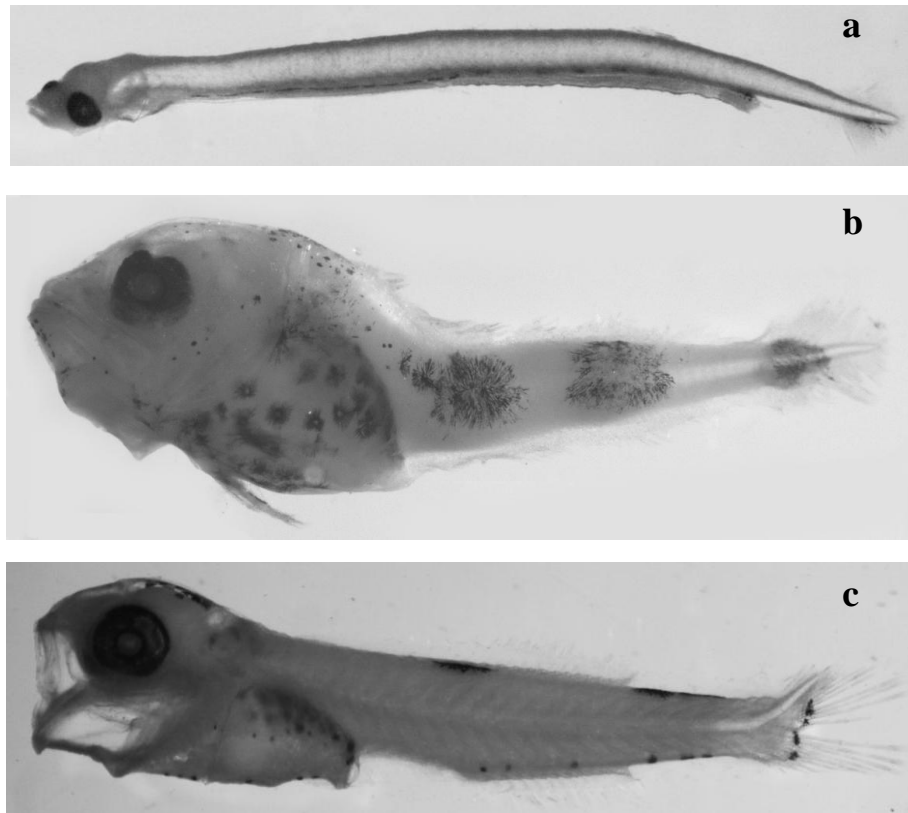
Figure 1-4. Photos of the larvae of the species objective of the TRANSBORAN project: (**a**) *Sardina pilchardus* of 6.9 mm standard length (SD); (**b**) *Merluccius merluccius* of 7.0 mm SD and (**c**) *Pagellus bogaraveo* of 8.0 mm SD

To delimitate the spatial population structure and stocks boundaries of fish species, the connection between population units and stocks through the early life stages of fishes has to be investigated. In this report, we present the composition and structure of the ichthyoplankton community found during the TRANSBORAN-20 cruise.

2. MATERIAL AND METHODS

2.1. Sampling and data collection

The TRANSBORAN-0220 survey was carried out in the frame of the TRANSBORAN project, from February 20 to March 14, 2020, on board the R/V Emma Bardan. A total of 81 stations, arranged in 14 transects perpendicular to the coastline, were sampled

(Figure 1-1). Each transect included 5 stations located at ~30, ~70, ~100, ~200 and ~500 m bottom depth (Figure 1-1).

Ichthyoplankton samples were collected with a Bongo net of 60 cm of mouth diameter and 500 μm mesh size. Each mouth of the Bongo net was equipped with a Hydrobios flowmeter, to measure the volume of water filtered. Ichthyoplankton tows were oblique, from 100 m depth (or from ~5 m above the bottom at shallower stations) to the surface. One of the Bongo samples was preserved in ethanol 97% for further larval growth and genetic studies. The other sample, the later used for the ichthyoplankton community studies, was sorted on board for sardine and anchovy larvae. After that, samples were immediately preserved in a 4% solution of buffered formalin and seawater.

In the laboratory, fish eggs and larvae were sorted from the formalin-preserved samples. All fish larvae were identified to the lowest taxonomic level possible, while only *Sardina pilchardus* and *Engraulis encrasicolus* eggs were identified to the species level. Fish egg and larval counts were standardized to number per 10 m^2 of sea surface (abundance). Larval fish taxa were grouped into three categories, based on the habitat of adult fishes and on the region where they reproduce: neritic, in which adult fishes roughly inhabit and reproduce over the shelf, oceanic, in which adult fishes roughly inhabit and reproduce off the shelfbreak and unknown. This category included not identified larvae and larvae identified to the family level in families with neritic and oceanic species.

2.2. Data analysis

The study area was divided into four regions: Alboran north, Alboran south, Gulf of Cadiz and Atlantic south (Figure 1-1), which a priori it was expected to be inhabited by different ichthyoplankton populations. The border between the north and south regions was considered to be the 36ºN parallel, the latitude of the Strait of Gibraltar (García Lafuente and Ruiz, 2007). As consequence, the sampling stations 25 and 83, located over this latitude, were not included in the statistical analyses.

Larval fish diversity was calculated using the Shannon–Wiener diversity index.

Differences in ichthyoplankton abundances, larval fish taxon richness and diversity between the four regions were tested with ANOVA followed, when necessary, by a post hoc Student-Newman-Keuls test. Prior to the statistical analyses, variables were tested for normality (Kolmogorov–Smirnov test) and homogeneity of variances (Levene's test). As a result of these tests, total egg and larval abundances and *S. pilch*ardus egg and larval abundances were $\log_{10}$ transformed before the analyses.

One-way analysis of similarities (ANOSIM) was used to test for the significances in difference in the larval fish community structure between regions. The specific hypothesis was that the same larval fish community inhabited the four regions. ANOSIM was carried out with a Bray-Curtis similarity matrix generated from the fourth root-transformed data of larval fish taxon abundances. Data were transformed to down-weight the influence of the more abundant taxa and to accentuate the effect of rare species (Field *et al.*, 1982; Clarke *et al.*, 2014). Because significant differences in community structure between the four regions were detected (see 'Results'), in a second step, cluster analysis was used to identify LFAs within each region. Cluster analysis was performed on four (one per region) Bray-Curtis similarity matrices generated from the fourth root-transformed data of larval fish taxon abundances. Hierarchical agglomerative clustering with group-average linking, carried out with the above similarity matrices, was used to delineate larval fish assemblages. Dendrograms were cut off at arbitrary levels to produce ecologically interpretable clusters (Field *et al.*, 1982; Auth and Brodeur, 2006). The adequacy of the classification analysis was checked by superimposing cluster results on non-metric multidimensional scaling (nMDS) ordination plots, generated from the same similarity matrices (Clarke, 1993; Clarke *et al.*, 2014). A 2-dimensional ordination approach was adopted because stress levels (≤0.15) were acceptably low (Clarke, 1993; Clarke *et al.*, 2014). Rare taxa (those found at fewer than 5% of the sampling stations in each region) were neither included in the cluster analyses nor in the nMDS ordination (Field *et al.*, 1982; Clarke *et al.*, 2014).

Only larvae identified to at least the genus level were included in the analyses of the larval fish community structure. Additionally, in all statistical analyses, the level of statistical significance (α) was set at 0.05.

Diversity index calculation, ANOSIM and cluster analysis were performed with PRIMER v741,43. ANOVA analyses was performed with IBM SPSS Statistics version 19.

3. RESULTS

3.1 The ichthyoplankton community

A total of 16364 fish eggs and 8836 fish larvae was captured. O the fish eggs collected, 7.30% belonged to *S. pilchardus* and only 0.01% (2 eggs) belonged to *E. encrasicolus*. A total of 92 larval fish taxa (65 species, 11 genera, 7 families, 9 taxa identified as distinct species within families and 2 identified as distinct species but it was not possible to assign them to any known taxa) were identified (Table 3-1). The most numerous larval fish species was *Benthosema glaciale*, followed by *S. pilchardus* and *Myctophum punctatum* that accounted for 24.2%, 14.4% and 13.3% of the total number of larval fish captured, respectively (Table 3-1). As for the other two species objective of the TRANSBORAN project *P. bogareveo* and *M. merluccius* accounted for 0.22% and 0.10% of the total number of the larval fish captured, respectively (Table 3-1). Other relevant species from the fisheries point of view, *Engraulis encrasicolus* and *Pagellus acarne* accounted for 2.94% and 0.12% of the total number of larval fish captured, respectively (Table 3-1). The most ubiquitous species was *S. pilchardus*, followed by *Maurolicus muelleri* and *M. punctatum* (Table 3-1). *P. bogaraveo*, *M. merluccius, E. encrasicolus* and *P acarne* were collected at 16.25%, 6.25%, 33.75% and 10.00% of the sampled stations, respectively. As for the origin of the species, 45.70% of the larvae in 51 taxa belonged to the neritic realm, 53.61% in 29 taxa belonged to the oceanic realm and 0.69% in 10 taxa were of unknown origin (Table 3-1).

Fish egg abundances ranged from 23.61 and 4622.29 eggs 10 m^{-2} with a mean of 783.63 eggs 10 m^{-2} ($\pm$816.67 SD). The highest fish egg abundances were generally recorded in the neritic region (Figure 3-1a). Differences in fish egg abundances between regions were not significant (ANOVA, F = 0.05, p > 0.05).

Table 3-1. Alphabetical list of larval fish families and species collected during the TRANSBORAN 2020 cruise. Origin (N: neritic; Oc: oceanic); RF: taxon relative frequency; RA: taxon relative abundance. %Occ: taxon percentage of occurrence

Family and species	Origin	RF	RA	%Occ
Argentinidae				
Argentina sphyraena	N	0.01	0.01	1.25
Glossanodon leioglossus	N	0.01	0.15	1.25
Blennidae				
Lipophrys pholis	N	0.01	0.01	1.25
Parablennius pilicornis	N	0.02	0.02	2.50
Bothidae				
Arnoglossus imperialis	N	0.03	0.42	3.75
Arnoglossus laterna	N	0.42	0.32	18.75
Arnoglossus thori	N	0.32	0.18	20.00
Arnoglossus spp	N	0.01	0.01	1.25
Bramidae				
Brama brama	Oc	0.03	0.03	3.75
Callionymidae				
Callionymus spp	N	0.49	0.52	33.75
Carangidae				
Trachurus mediterraneus	N	0.06	0.06	3.75
Trachurus trachurus	N	1.77	1.77	50.00
Carapidae				
Echiodon denatus	N	0.01	0.19	1.25
Cepolidae				
Cepola rubescens	N	0.01	0.49	1.25
Chauliodontidae				
Chauliodus sloani	Oc	0.02	0.01	2.50
Clupeidae				
Sardina pilchardus	N	14.40	14.40	77.50
Engraulidae				
Engraulis encrasicolus	N	2.94	0.01	33.75
Gadidae				
Gadiculus argenteus	Oc	0.02	0.11	2.50
Unidentified spp	Unk	0.15	0.02	10.00
Gobiesocidae				
Lepadogaster lepadogaster	N	0.01	0.36	1.25
Diplecogaster bimaculata	N	0.03	0.07	3.75
Gobiidae				
Lebetus guilleti	N	0.36	0.01	8.75
Pomatoschistus microps	N	0.15	0.15	3.75
Pomatoschistus minutus	N	0.07	0.07	5.00
Pomatoschistus spp	N	4.59	4.59	23.75
Unidentified spp	N	0.33	0.01	18.75

Family and species	Origin	RF	RA	%Occ
Gonostomatidae				
Cyclothone braueri	Oc	0.31	0.02	25
Cyclothone pigmea	Oc	0.02	0.31	2.50
Lophiidae				
Lophius piscatorius	N	0.03	0.03	3.75
Lotidae				
Gaidropsarus mediterraneus	N	0.02	0.02	2.50
Gaidropsaurus biscayensis	N	0.51	0.22	30.00
Gaidropsarus vulgaris	N	0.22	0.51	17.50
Lotidae sp 1	Unk	0.01	0.01	1.25
Macrorhamphosidae				
Macroramphosus scolopax	Oc	0.60	0.60	26.25
Macrouridae				
Macrouridae sp 1	Oc	0.01	0.01	1.25
Merlucciidae				
Merluccius merluccius	N	0.10	0.10	6.25
Moronidae				
Dicentrarchus labrax	N	0.02	0.02	2.50
Myctophidae				
Benthosema glaciale	Oc	24.19	24.19	63.75
Cerastocopelus maderensis	Oc	0.06	0.06	6.25
Diogenichthys atlanticus	Oc	0.07	0.02	7.50
Hygophum reinhardtii	Oc	0.01	0.43	1.25
Hygophum spp	Oc	0.32	0.01	23.75
Lampanyctus crocodilus	Oc	3.37	0.35	51.25
Lampanyctus pusillus	Oc	0.45	3.37	18.75
Lampanyctus sp 2	Oc	0.01	0.45	1.25
Lobiancha dofleini	Oc	9.80	9.80	65.00
Myctophum punctatum	Oc	13.34	0.03	68.75
Notoscopelus spp	Oc	3.18	3.18	48.75
Symbolophorus veranyi	Oc	0.02	0.02	2.50
Unidentified spp	Oc	0.03	13.34	2.50
Ophidiidae				
Ophidiidae sp 1	Unk	0.02	0.02	2.50
Paralepididae				
Lestidiops jayakari	Oc	2.25	0.01	43.75
Lestidiops sphiraenoides	Oc	0.01	2.25	1.25
Notolepis rissoi	Oc	0.03	0.03	3.75
Paralepis coregonoides	Oc	0.03	0.03	2.50
Phosichthydae				
Vinciguerria attenuata	Oc	0.71	0.71	30.00
Vinciguerria nimbaria	Oc	0.02	0.02	1.25
Vincdiguerria poweriae	Oc	0.02	0.02	2.50

Family and species	Origin	RF	RA	%Occ
Phycidae				
Phycis blennoides	N	0.01	0.01	1.25
Phycis phycis	N	0.02	0.02	2.50
Pleuronectidae				
Buglossidium luteum	N	0.52	0.03	22.50
Pleuronectidae sp 1	N	0.02	0.02	2.50
Scombridae				
Scomber colias	N	0.09	0.09	3.75
Scophthalmidae				
Scophthalmus rhombus	N	0.01	0.01	1.25
Scorpaenidae				
Helicolenus dactylopterus	Oc	0.43	0.33	25.00
Scorpaenidae sp 2	Unk	0.01	0.01	1.25
Soleidae				
Microchirus spp	N	0.11	0.11	10.00
Solea solea	N	0.07	0.07	3.75
Soleidae sp 1	Unk	0.02	0.02	1.25
Sparidae				
Boops boops	N	2.54	0.01	51.25
Diplodus spp	N	0.19	0.03	13.75
Pagellus acarne	N	0.12	0.05	10.00
Pagellus bogaraveo	N	0.22	0.01	16.25
Pagellus erythrinus	N	0.07	0.12	3.75
Pagrus pagrus	N	0.05	0.22	3.75
Pagrus spp	N	0.01	0.07	1.25
Spondyliosoma cantharus	N	1.08	1.08	21.25
Sparidae sp 2	N	0.02	0.02	1.25
Unidentified spp	N	0.10	0.10	5.00
Sternoptychidae				
Argyropelecus hemigymnus	Oc	0.18	0.03	13.75
Maurolicus muelleri	Oc	6.36	6.36	70.00
Stomiidae				
Stomias boa boa	Oc	1.00	1.00	37.50
Stomias brevibarbatus?	Oc	0.08	0.08	3.95
Triglidae				
Eutrigla gurnardus	N	0.11	2.94	7.50
Triglidae sp 2	N	0.01	0.01	1.25
Triglidae sp 3	N	0.01	0.01	1.25
Trichiuridae				
Lepidopus caudatus	N	0.01	0.01	1.25
Unidentified sp 19	Unk	0.05	0.32	5.00
Unidentified sp 20	Unk	0.02	0.05	1.25
Unidentified spp	Unk	0.35	0.02	22.50

Larval fish abundances ranged from 5.73 to 2036.38 larvae 10 m^{-2}, with an average of 453.8 larvae 10 m^{-2} ($\pm$456.00 SD). The highest larval fish abundances were, generally recorded in the shelf region (Figure 3-1b). Although, relatively high abundances were also recorded in the off-shelf region of the NW Alboran Sea (Figure 3-1b). Differences in larval fish abundances between regions were significant (ANOVA, F= 7.01, p < 0.01), being lower in the Atlantic south region (SNK test: Atlantic south < Gulf of Cadiz = Alboran north = Alboran south).

Larvae of neritic species showed the highest abundances in the neritic region, as expected (Figure 3-1c). However, only three oceanic stations, located in the Atlantic region (Figure 3-1c), were negative for neritic larvae. As for larvae of oceanic species, they were widespread across the Alboran Sea, showing relatively high abundances even in coastal stations (Figure 3-1d). While in the Atlantic region abundances of oceanic larvae were lower and in general were absent or showed lower abundances in the neritic stations (Figure 3-1d).

S. pilchardus egg abundance ranged from 0 to 644.50 eggs 10 m^{-2} ($\pm$ 124.32 SD). The highest *S. pilchardus* egg abundance was recorded in the coastal region of the northwestern Alboran Sea (Figure 3-1e). However, differences in *S. pilchadus* egg abundance between the four regions were not significant (ANOVA, F = 0.10, p > 0.05). It draws attention the relatively high number of negative stations (stations with 0 eggs) recorded in the neritic region of the whole sampled area and also the relatively high abundances recorded in the oceanic region of the eastern Alboran north (Figure 3-1e). Larvae of *S. pilchardus* were the second most abundant (the most abundant of the species objective of the TRANSBORAN project) and the most ubiquitous larval fish species (Table 3-1). *S. pichardus* larval abundances ranged from 0 to 799.12 larvae 10 m^{-2}, with an average of 67.19 larvae 10 m^{-2} ($\pm$143. 97 SD). Differences in *S. pilchardus* larval abundances between regions were significant (ANOVA, F = 8.16, p < 0.01). Post hoc contrast indicated that abundances where higher in the Gulf of Cadiz (SNK test: Gulf of Cadiz > Atlantic south = Alboran north = Alboran south). This was clear in the horizontal distribution of *S. pilchardus* larval abundances (Figure 3-1f). In this distribution, the high number of positive stations for larvae of this species in the oceanic region of the Alboran Sea stands out (Figure 3-1f).
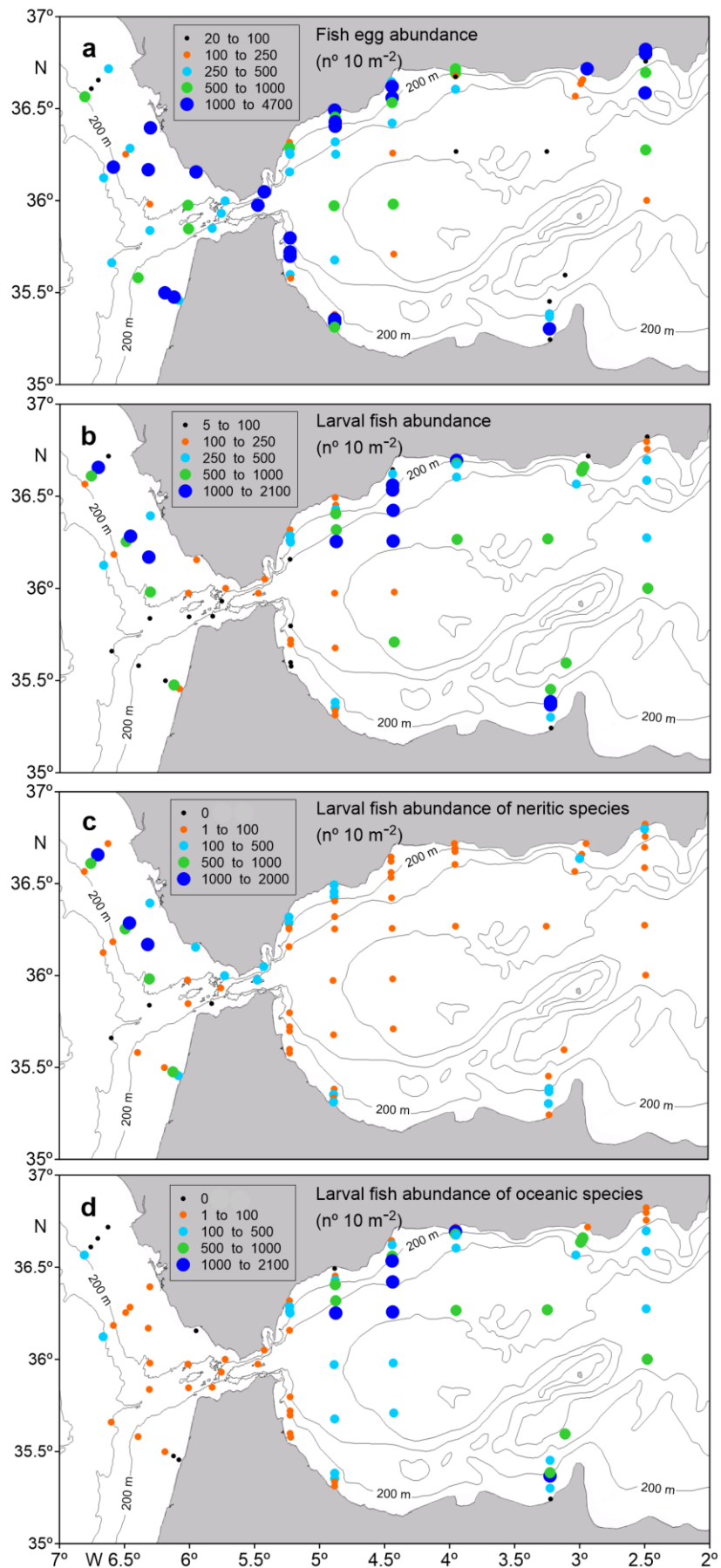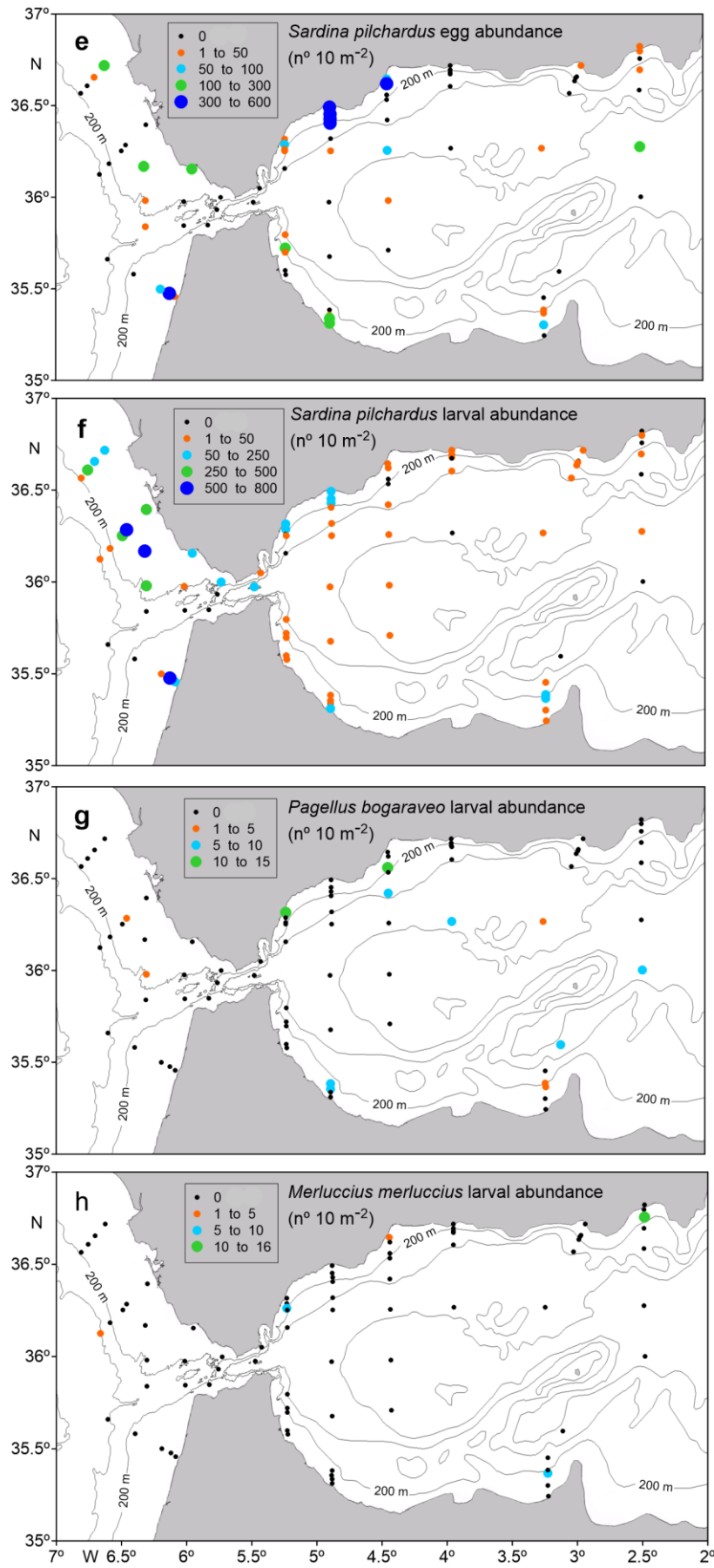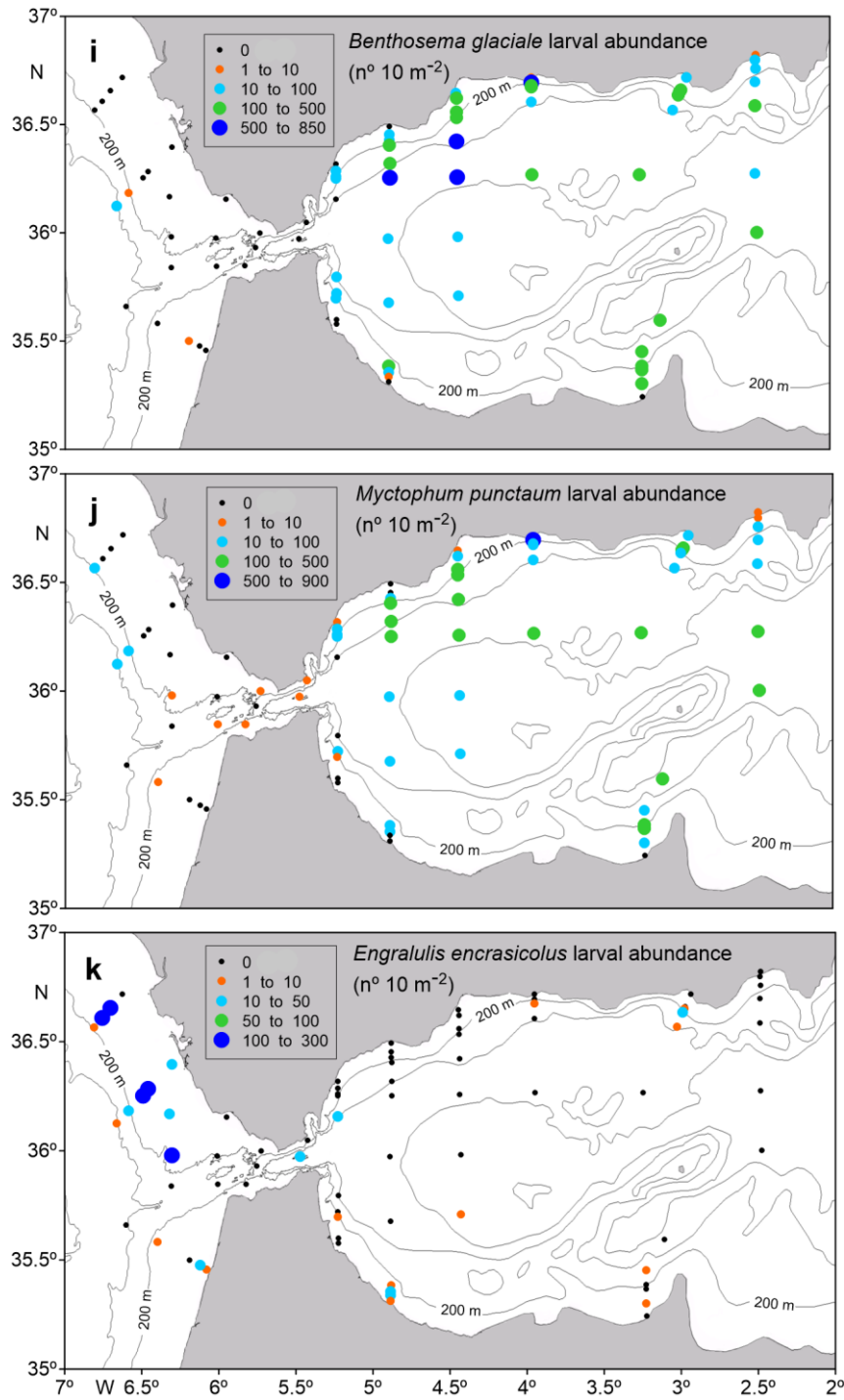
Figure 3-1. Horizontal distribution of fish egg and larval abundances

P. bogaraveo showed a slightly higher abundance than *M. merlucius*, ranging from 0 to 14.96 larvae 10 m^{-2} with an average of 1.03 larvae 10 m^{-2} ($\pm$2.83 SD). Larvae of *P. bogaraveo* were collected at 16.25% of the sampled stations (Table 3-1). In the Atlantic region, the larvae of this species were restricted to the neritic region (Figure 3-1g). However, in the Alboran Sea several stations located in the oceanic region were positive for *P. bogaraveo* larvae (Figure 3-1g). The abundance of *M. merluccius* larvae ranged from 0 to 15.28 larvae 10 m^{-2}, with an average of 0.44 larvae 10 m^{-2} ($\pm$2.09 SD). Only five stations were positive for larvae of this specie, four in the Alboran Sea and the other in the Gulf of Cadiz in (Figure 3-1h).

Larvae of *B. glaciale* were widespread across the Alboran Sea, while they were almost absent from the Atlantic and the Gibraltar Strait regions (Figure 3-1i). *M. punctatum* larvae were widespread across the Alboran Sea and the oceanic Atlantic region, although larval abundances were higher in the Alboran Sea (Figure 3-1j).

Larvae of *E. encrasicolus* were much more abundant in the Gulf than in any other region (Figure 3-1k)

Taxon richness ranged from 1 to 27, with an average of 12.7 ($\pm$5.95 SD). The horizontal distribution of taxon richness showed an irregular pattern although with the lower values recorded in the coastal region (Figure 3-2a). Differences in taxon richness between regions were significant (ANOVA, $F = 8.24$, $p < 0.01$), being higher in the Alboran Sea (SNK test: Atlantic south < Gulf of Cadiz < Alboran north = Alboran south).

Values of larval fish diversity ranged from 0 to 2.68 with a mean of 1.76 ($\pm$0.59 SD. Larval fish diversity showed a pattern of horizontal distribution similar to that of taxon richness (Figure 3-2b). Differences in larval fish diversity between regions were also significant (ANOVA, $F = 14.71$, $p < 0.01$), being higher in the Alboran Sea (SNK test: Atlantic south < Gulf of Cadiz < Alboran north = Alboran south).
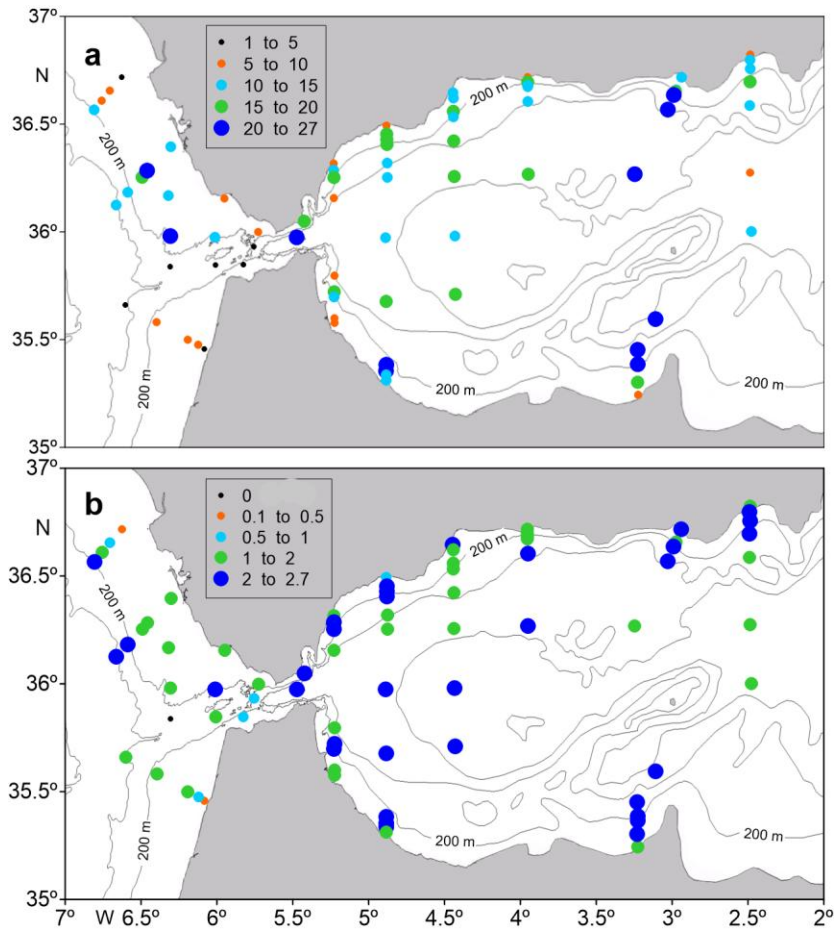
Figure 3-2. Horizontal distribution of: (a) taxon richness and (b) Shannon-Wiener diversity index

3.2. Larval fish assemblages

One-way ANOSIM revealed significant differences in the larval fish community structure between the four regions (R = 0.42, p < 0.01) and the pairwise tests were significant between all pairs of regions (p ≤ 0.01).

Cluster analysis identified two larval fish assemblages (dendograms not included) for the Gulf of Cadiz, Atlantic south and Alboran south. Non-metric multidimensional analysis produced the same results: Gulf of Cadiz (Figure 3-3a), Atlantic south (Figure 3-3b) and Alboran south (Figure 3-3d). However, for the Alboran north, cluster analysis identified a single assemblage and several isolated stations that we considered "outliers", non-metric multidimensional analysis produced the same result (Figure 3-3c). Assemblages were named after the geographical location of the sampling stations they occupied, viz. coastal and outer (Figure 3-3e). The coastal assemblage occupied

very coastal stations in the South Alboran Sean and the South Atlantic regions and was more widespread over the neritic region in the Gulf of Cadiz region (Figure 3-3e).
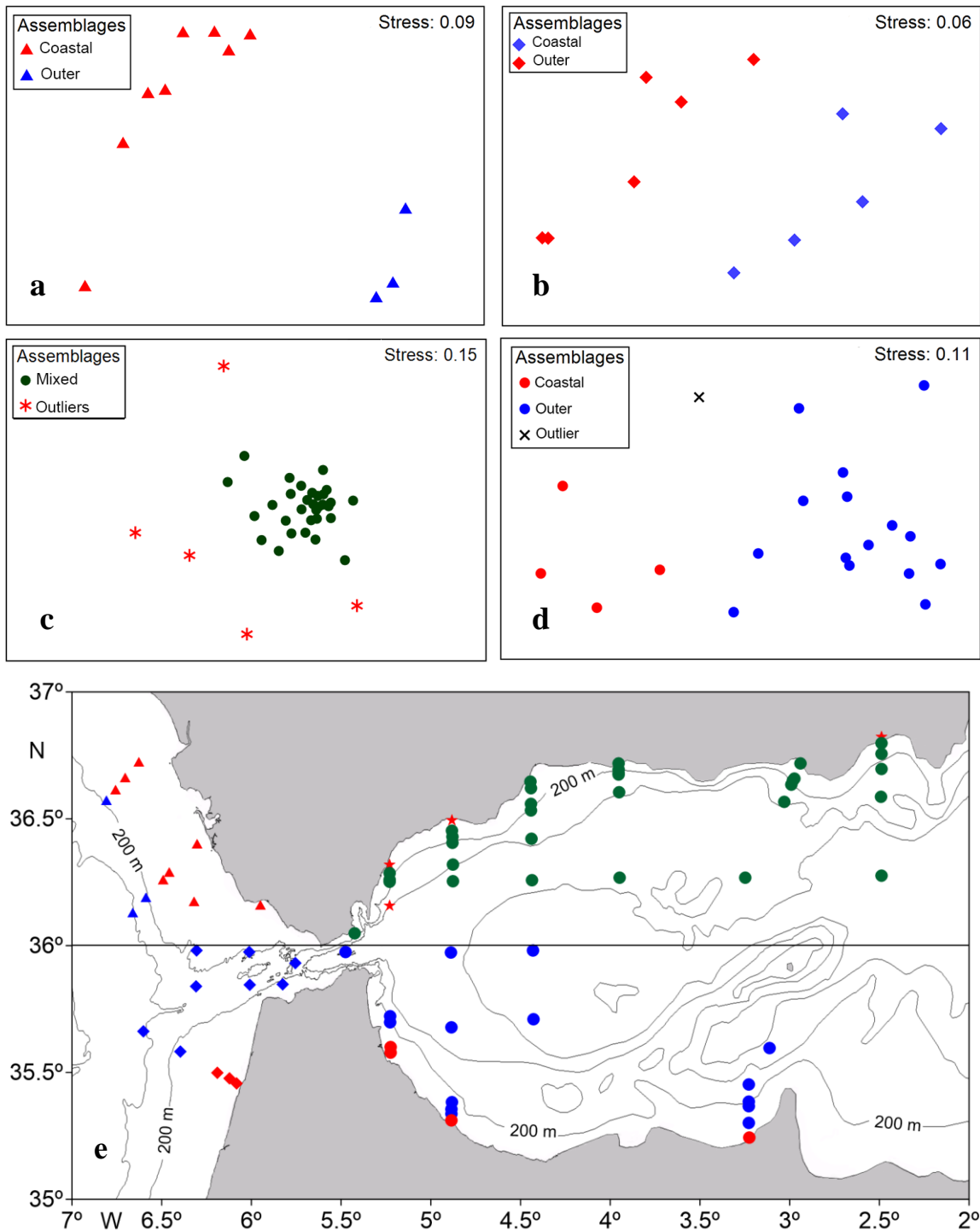

Figure 3-3. Larval fish assemblages defined by cluster analyses and non-metric multidimensional scaling ordination: (a) Gulf of Cadiz, (b) Atlantic south, (c) Alboran north, (d) Alboran south and (e) geographical location of the larval fish assemblages

4. CONCLUSSIONS

This report only gives a relatively accurate idea of the composition and structure of the ichthyoplankton community that inhabits the Alboran Sea and the adjacent Atlantic region, during the early spring because the ichthyoplankton sampling of the neritic and oceanic regions of the area of study was unbalanced. Thus, while the neritic region was oversampled the oceanic region was undersampled.

A total of 16,364 fish eggs and 8,836 fish larvae was captured, and 92 larval fish taxa were identified. The most numerous fish species was the myctophid *Benthosema glaciale*, followed by *Sardina pilchardus* and *Myctophum punctaum*. 45.70% of the fish larvae in 51 taxa belonged to the neritic realm, 53.61% of the larvae in 21 taxa belonged to the oceanic real and 0.69% of the larvae in 10 taxa were of unknown origin.

Fish egg and larval abundances were generally higher in the neritic region of the whole area of study. Differences in fish eggs abundances between regions were not significant. However, larval abundances were lower in the Atlantic south region. Neritic larval abundances were higher in the neritic region, although neritic larvae showed relatively high abundances in the oceanic region of the Alboran Sea. The sea surface circulation in the Alboran Sea could explain this fact. These larvae would be trapped and transported into de oceanic region by the Alboran gyres. Oceanic larvae showed higher abundances in the Alboran Sea, even in coastal stations. This could be related with the narrowness of the shelf region in the Alboran Sea.

S. pilchardus was the second most abundant larval fish species. However, larval abundances were lower for the other two species objective of the TRANSBORAN project. In the case of *Merluccius merluccius*, this could be explained by the fact that the outer shelf and upper slope regions, where this species reproduce, were undersampled. In the case of *Pagellus bogaraveo,* our experience is that this species is scarce in the ichthyoplankton samples.

The structuring of the larval fish community into two assemblages, a coastal and an outer assemblage is common to many other regions. The absence of this structuring in the Alboran north region could be explained by the narrowness of the shelf and by the fact that upwelling events in this region are relatively frequent. Upwelling events would

favour the mixing of neritic and oceanic larvae, by transporting oceanic larvae into the neritic region by the under onshore current associated with upwelling.

Taking into consideration the hydrography of the area of study, the vertical distribution of fish larvae, the swimming capacity of fish larvae, with maxima swimming speeds recorded of about 30 cm^{-1}, the connection between fish populations located in the Atlantic region and the Alboran Sea could only be unidirectional, from the Atlantic Ocean towards the Alboran Sea. More precisely, considering the sea surface circulation in the Atlantic region, these larvae would come from the Gulf of Cadiz and would be transported by the Atlantic jet that enters the Alboran Sea.

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