

## A SECTION-SAMPLING DESIGN TO ASSESS ZOOPLANKTON DISTRIBUTION IN A HIGHLY COMPLEX HYDROGRAPHIC REGION (SW ATLANTIC OCEAN, 34-41°S): INSIGHTS FOR A NEW TIME SERIES?

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### ABSTRACT

Regular fish stock assessment cruises could provide a proper data platform to sample zooplankton. It is essential, however, that adequate sampling designs should be developed for each area so that zooplankton features may be accurately described with minimum sampling effort. On the Northern Argentine Continental Shelf (NACS, 34-41°S), a sectioned-sampling design (18 samples distributed in 4 sections) associated with *E. anchoita* stock estimation cruises was implemented to provide a rapid and reliable survey of zooplankton distribution in relation to the physical environment. The results obtained were similar to those registered in previous studies based on exhaustive sampling. We suggest that a new zooplankton time series covering this broad area be established, based on this sampling design, to contribute to the knowledge of the variability of zooplankton populations and their relation to fishery resources.

### RESUMO

As campanhas de avaliação de recursos pesqueiros podem fornecer uma adequada base de dados para o monitoramento do zooplâncton. No entanto, o desenvolvimento de um esquema de amostragem apropriado constitui uma tarefa difícil, quando se deseja descrever as características do zooplâncton, com um mínimo de esforço amostral. No setor norte da Plataforma Continental Argentina (NACS, 34° - 41°S), se projetou um desenho amostral em seções (18 amostras distribuídas em 4 seções), associadas à campanha de avaliação dos recursos pesqueiros de *E. anchoita*, visando conseguir uma estimativa rápida e confiável da distribuição do zooplâncton. Os resultados obtidos foram semelhantes aos registrados em estudos prévios, baseados na análise de um grande número amostral. Sugere-se o estabelecimento de uma nova série temporal de dados que envolva uma área amostral alargada e um desenho amostral restrito, visando contribuir para o conhecimento da variação das populações zooplanctônicas e sua relação com os recursos pesqueiros.

Descriptors: Copepods, Cladocerans, Northern Argentine Continental Shelf, *E. anchoita* Assessment Cruises.

Descritores: Cópepodos, Cladóceros, Plataforma Continental Argentina Norte, Avaliação dos Recursos Pesqueiros de *E. anchoita*.

### INTRODUCTION

The increasing importance of improving our knowledge of zooplankton variability on interannual and longer time scales, providing useful information about climate-ecosystem interactions, is well recognized (MACKAS; BEAUGRAND, 2010 and references therein). In this regard, there are biological and anthropogenic sources of variation that limit the

ability to accurately predict ecosystem dynamics, which further highlights the need for adequate temporal and spatial resolution to characterize variability in zooplankton populations (VALDÉS et al., 2007). Many questions related to fisheries research, for example, remain unanswered due to the lack of zooplankton data available on an appropriate spatial scale, generating a gap between the two lines of research (IRIGOIEN et al., 2009).

The establishment of a network of time series stations for repeated physical, biological and chemical measurements would be the appropriate method for ecosystem surveillance and would contribute to the implementation of an ecosystem approach to marine resource management (VALDÉS et al., 2007).

In this sense, it has recently been demonstrated that regular fish stock assessment cruises can provide a proper platform to sample zooplankton (IRIGOIEN et al., 2009). However, for each region, the development of adequate sampling designs associated with these cruises is an essential task for the accurate description of zooplankton features, with minimum sampling effort.

The importance of incorporating zooplankton as one of the environmental factors that may affect not only the reproductive and growth processes of fishes, but also their seasonal migration patterns, has been recognized by the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP) and included as one of its scientific goals.

The Northern Argentine Continental Shelf (NACS, 34–43 °S) coastal region is a nutrient and biota source for the continental shelf of eastern South America (LUCAS et al. 2005 and references therein). Two estuarine systems, the Río de la Plata (RDP) and El Rincón (ER), are the major features in this region. The former is one of the most highly productive estuarine environments of the continent, sustaining valuable artisanal and coastal fisheries in Argentina and Uruguay (ACHA et al., 2008). Southwards, between 39 and 41°S, the ER system comes under the influence of the rivers Colorado and Negro, housing intense reproductive and feeding activities of economically important fishes, such as *Micropogonias furnieri* and *Scomber japonicus*, respectively (LASTA, 1998; PERROTA et al., 2003).

As a whole, NACS constitutes the main spring spawning and nursery area of *Engraulis anchoita* (SÁNCHEZ; CIECHOMSKI, 1995). Both estuaries and the adjacent coastal zone provide anchovy larvae, juveniles and adults with abundant planktonic food and adequate temperatures to satisfy their metabolic requirements (MARTOS et al., 2005; PADOVANI et al., 2011; PÁJARO, 2002).

Many studies focused on the mesozooplankton community of this area have demonstrated that changes in physical conditions affect the composition, size structure and abundance of zooplanktonic communities. Some of these studies have been based on an exhaustive analysis of samples difficult to sustain over time (MARRARI et al., 2004; VIÑAS et al., 2002), whereas others have not covered the totality of the area (BERASATEGUI et al., 2006; FERNÁNDEZ ARÁOZ et al., 1994; RAMIREZ; SANTOS, 1994). Nevertheless, in all of

them, copepods and cladocerans were the dominant and most widely distributed groups.

Both groups are known to constitute significant prey items for pelagic fish during their different ontogenetic stages (PADOVANI et al., 2011; PÁJARO, 2002; VIÑAS; RAMIREZ 1996). Therefore, knowing their community structure as well as the variation in their distribution patterns remains a key element, since changes in their abundance and composition might influence fish recruitment (e.g. BEAUGRAND et al., 2003).

In the present study a restricted section-sampling design, coupled to *E. anchoita* spring assessment cruises, was implemented between 34°S and 41°S in order to provide a rapid and reliable survey of copepod and cladoceran distribution. With the intention of establishing a new, permanent zooplankton time-series, the performance of the proposed sampling design was evaluated by comparison with that of previous findings (BERASATEGUI et al., 2006; MARRARI et al., 2004; VIÑAS et al., 2002).

## MATERIAL AND METHODS

### Main Hydrographical Features of the Study Area

The major hydrographic feature of this area is the RDP. This is the second largest South American basin, characterized by a strong vertical stratification modified by local coastal inputs, temperate seasonal cycles and prevailing winds (ACHA et al., 2008; GUERRERO; PIOLA, 1997; LUCAS et al., 2005). The estuarine waters present a seasonal distribution pattern over the adjacent shelf: during the spring-summer period the low salinity signal is forced southwards and eastwards from the Argentinian coast. Conversely, during autumn and winter the river plume extends northeastwards along the Uruguayan coast (GUERRERO et al., 1997).

Between 39°S and 41°S the ER estuarine system is characterized by vertical homogeneity due to tidal forcing. A north-south oriented coastal estuarine front separates diluted waters stemming from the Negro and Colorado rivers from shelf waters with a relative salinity maximum (GUERRERO et al., 1998; LUCAS et al., 2005).

The shelf area between these two estuarine systems is occupied by mid-continental shelf waters (LUCAS et al., 2005).

### Oceanographic Data, Zooplankton Sample Collection and Laboratory Analysis

Oceanographic data and zooplankton samples were obtained during a spring cruise carried

out from 2- 13 November 2002 onboard the R/V “Eduardo Holmberg”, as part of the *E. anchoita* Assessment Project of INIDEP. Oceanographic data were obtained at 88 stations with a conductivity-temperature-depth system (CTD, Sea bird 19).

Zooplankton samples (18) were obtained in four sections (S1 to S4) distributed from 34°S to 41°S (Fig. 1). These sections were established according to the hydrographical conditions: S1 and S2 were located in relation to the RDP runoff, commonly southwards during this season. S4 was located in the ER area, while S3 was located in an area influenced mainly by shelf waters (LUCAS et al., 2005; MARTOS et al., 2005), with a sporadic influence of RDP and ER waters. The sections' positions also aimed to cover the extension of *E. anchoita* massive spawning, which occurs during spring in coastal waters (depth < 75 m) (SÁNCHEZ; CIECHOMSKI, 1995).

Samples were taken by performing oblique tows (towing time: 2 minutes; towing rate: 20m min<sup>-1</sup>) in the whole water column using a small bongo net (18 cm mouth; 220 and 67 µm mesh sizes) equipped with a digital flowmeter. The samples were preserved in 4% formaldehyde-seawater solution.

Copepods and cladocerans were analyzed from samples obtained with 220 µm mesh, with the exception of *Oithona nana* and *Microsetella norvegica*, which were studied from the 67 µm mesh size samples. This procedure was adopted since these species are greatly underestimated with a 220 µm mesh size (DI MAURO et al., 2009). Specimens were identified to species level and enumerated under a compound microscope. For this purpose, sub-sampling into aliquots was undertaken in order to analyze at least 100 adult copepods; abundance was expressed as individuals per m<sup>3</sup>.

#### Data analysis

To identify the different water masses occurring in the study area, the surface salinity ranges suggested by Guerrero; Piola (1997) and Lucas et al. (2005) were adopted: (1) Low Salinity Coastal Waters (LSCW): 0–33.3, (2) High Salinity Coastal Waters (HSCW): 33.7–34.2, (3) Mid-Shelf Waters (MSW): 33.4–33.6/33.7.

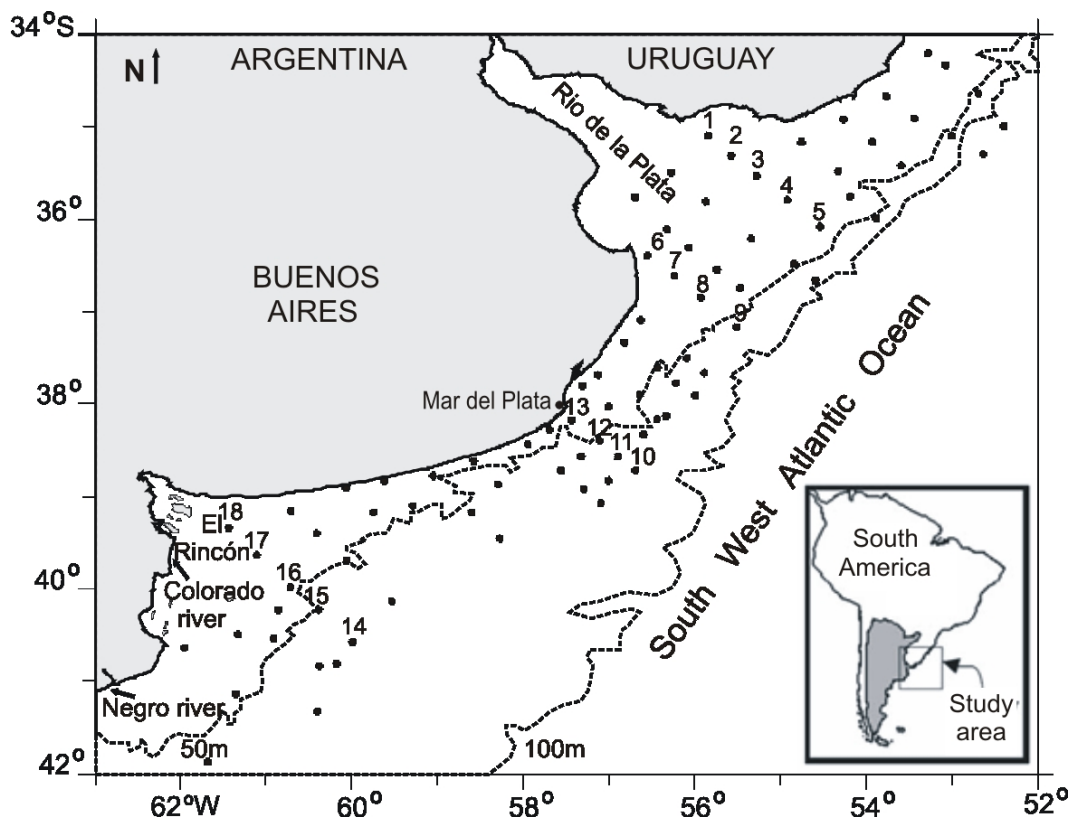


Fig. 1. Map of the study area showing oceanographic (●) and zooplankton (1 to 18) stations.

Water column stratification was estimated from stability parameter  $\Phi$  (SIMPSON, 1981), considering a critical  $40 \text{ Jm}^{-3}$  value to separate mixed from stratified waters (MARTOS; SÁNCHEZ, 1997). Contours of temperature, salinity and stratification were produced from gridded data using kriging method, utilizing Surfer version 8.0.

The copepod and cladoceran community structure was examined by multivariate techniques using the PRIMER v5 software package (CLARKE; WARWICK, 1994). Rare species (present in < 15 % of the samples) were excluded from the analysis.

Biogeographical patterns were investigated using cluster analysis. Previously, all data were transformed using the  $\log_{10}(x+1)$  function to allow the less abundant species to exert some influence on the calculation of similarities (CLARKE; WARWICK, 1994). Stations were classified into assemblages using group average similarities. Similarity level was adjusted to obviously meaningful groupings rather than forcing clusters to a fixed level (HUNT et al., 2002). Moreover, the similarity matrix was ordinated using non-metric multidimensional scaling (NMDS) in a two-axis ordination (CLARKE; WARWICK, 1994).

The contribution percentage of each species to intra-group similarity was determined using the similarity percentages (SIMPER) procedure.

Hydrographic conditions (temperature, salinity and stratification) were used to characterize the station assemblages.

## RESULTS

### Environmental Conditions of the study Area

Salinity distribution range in surface waters revealed the coexistence of LSCW, HSCW and MSW waters. RDP runoff extended southwards (Fig. 2a) and the frontal zone, which included stations from S1 and S2, attained  $37^{\circ}\text{S}$ . The relative salinity minimum (9.0) corresponded to the stations (1 and 2) located in the outer sector of RDP. In the ER, salinities of 33-33.2 were registered along the Buenos Aires coast at  $39^{\circ}\text{S}$ , and also at station 13 (S3). Between  $39^{\circ}\text{S}$  and  $41^{\circ}\text{S}$  (S4) the estuarine frontal system ran parallel to the coastline. Eastward of this front (stations 15 and 16) a relative salinity maximum (34.0), corresponding to HSCW, was registered (Fig. 2a). Outside this relative salinity maximum, values of 33.5 were recorded, showing the presence of MSW waters. Throughout the study area, the bottom salinity distribution pattern was relatively similar to that described for the surface. Salinity gradients were found at RDP and ER, but were less pronounced at both places than those observed at the surface. Values of 24.5 and 33.8 occurred in stations close to RDP and ER (Fig. 2b).

Surface temperature ranged between 12 and  $18^{\circ}\text{C}$ . Maximum values occurred at RDP, while the maximum thermal gradient was registered between  $37^{\circ}$  and  $38^{\circ}30'\text{S}$  (Fig. 2c). Bottom distribution of temperature followed the same pattern recorded for the surface. Values varied between 7 and  $15^{\circ}\text{C}$ , with a gradual decrease towards the slope (Fig. 2d). The warmer waters were restricted to RP and ER (Fig. 2d).

Analysis of the water column vertical structure showed that the limit between stratified and homogeneous waters ( $\Phi_{40}$ ) south of  $36^{\circ}\text{S}$  followed approximately the 50m isobath. Close to the RDP estuary the values were higher, indicating a marked vertical stratification (Fig. 2e).

### Species Composition

A total of 16 copepod and 5 cladoceran species were identified (Table 1). Among copepods, the highest abundances were of *O. nana*, followed by *P. crassirostris* and *P. parvus*. On the other hand, *O. atlantica* showed minimum values. Among the cladocerans, *Pleopsis polyphemoides* and *Podon leuckartii* were the most and the least abundant, respectively (Table 1).

### Faunistic Areas

Three stations' groups were identified by cluster analysis at a 60% similarity level (Fig. 3a). Station 10 differed significantly in species abundances and was omitted from these groups (Table 1). The grouping defined by cluster analysis was also evident in the NMDS ordination plot (stress value= 0.13) (Fig. 3b). Spatial distribution of such groups led to the formation of three faunistic areas: (1) estuarine (ES), (2) coastal (CT) and (3) shelf (SH).

The ES group encompassed stations 1, 2, 3, 6, 7 and 8 located close to the RDP (Fig. 4). This sector had depths lower than 22m and the mean temperature varied between 17.02 (surface) and 14.78 (bottom), while mean salinity was between 24.29 (surface) and 29.83 (bottom), suggesting a marked influence of RDP waters (Table 2).

The CT group extended throughout the area analyzed: from  $36^{\circ}$  to  $40^{\circ}30'\text{S}$  and from the coastal stations out to the 50m isobath (stations 4, 5, 12, 13, 15, 16, 17 and 18) (Fig. 5). Mean temperature values were between 14.39 (surface) and 11.6 (bottom); mean salinity was between 32.96 (surface) and 33.43 (bottom) (Table 2).

The SH group included stations 9, 11 and 14, located between  $37^{\circ}$  and  $41^{\circ}\text{S}$  at depths greater than 50m (Fig. 5). Mean temperature values in this area were between 12.14 (surface) and  $7.55^{\circ}\text{C}$  (bottom), and salinities were typical of MSW (33.46-33.56) (Fig. 2a).

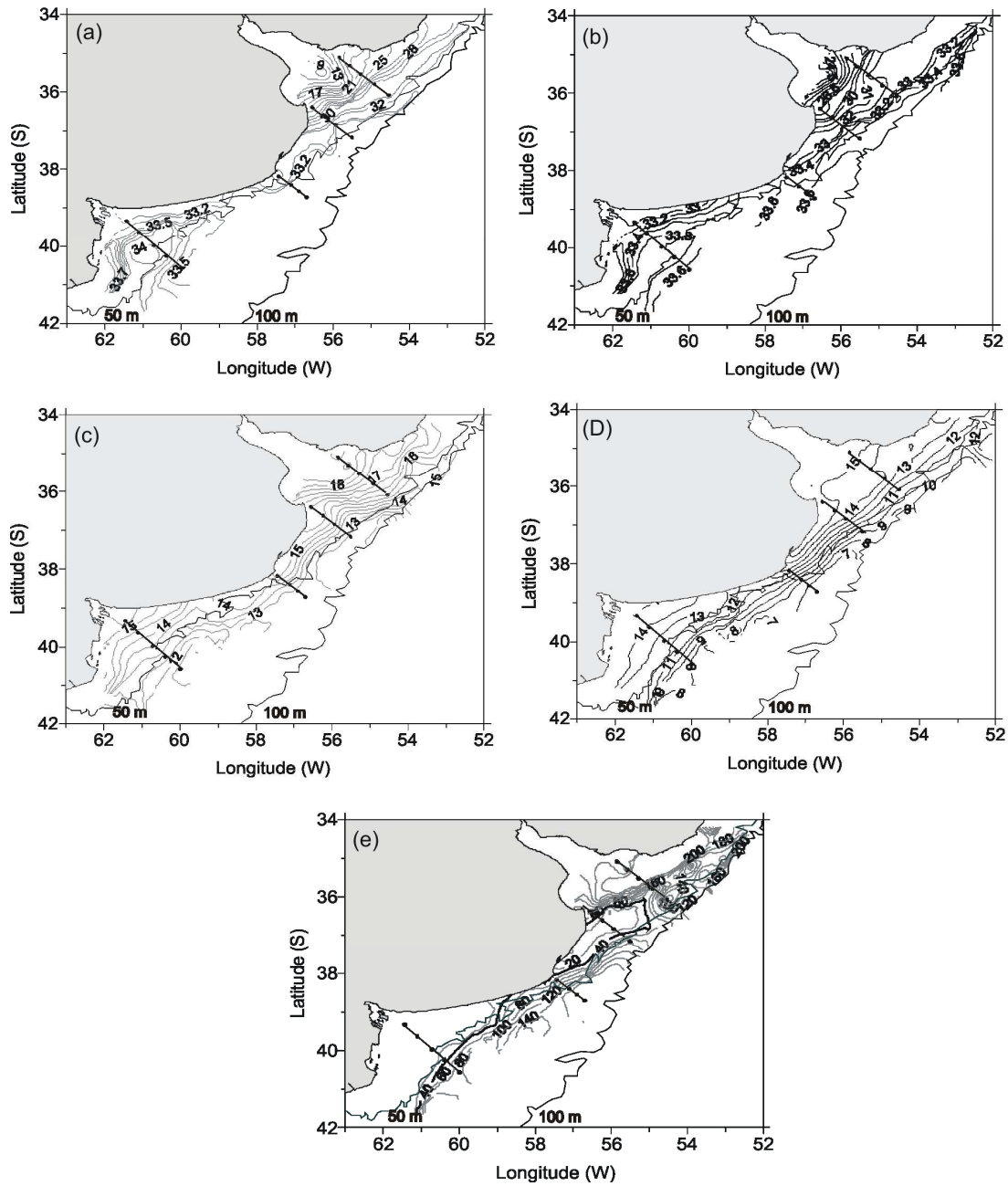


Fig. 2. Horizontal surface and bottom temperature (a, b) and salinity (c, d), Simpson parameter horizontal distribution (e). In bold: Simpson parameter  $\Phi_{40}$ .

It was concluded, by means of SIMPER analysis, that: *A. tonsa*, *C. amazonicus*, *P. crassirostris* and *E. acutifrons* contributed with 49.65 % to the average similarity of the ES group. *O. nana*, *O. similis* (syn. *O. helgolandica*), *P. tergestina*, *E. nordmanni*, *P. intermedius* and *P. polyphemoides* were distinct CT

species contributing with 77% to the average similarity of the group, while *C. carinatus*, *D. forcipatus*, *C. brachiatus* and *C. australis* characterized SH (62.44% average similarity within the group) (Table 2).

Table 1. Mean abundance (individuals  $m^{-3}$ ) standard deviation of copepod and cladoceran species in each group; total abundance and frequency of occurrence in the samples analyzed. Asterisks indicate species that were excluded from the similarity matrix. Estuarine (ES); coastal (CT) and shelf (SH) areas. External station (EX).

Taxon	ES	CT	SH	EX	Total (frequency occurrence)	Frequency of occurrence (%)
<b>Copepods</b>						
<i>Centropages brachiatus</i>	--	34.12±53.35	421.33±535.37	--	1537 (12/18)	66.66
<i>Ctenocalanus vanus</i>	92.16±45	238.75±150.76	300±94.61	122	3485 (18/18)	100
<i>Paracalanus parvus</i>	217±172.18	616.75±867.49	299.3359.39	--	7134 (17/18)	94.44
<i>Parvocalanus crassirostris</i>	1118.35±1308.01	76.34±179.64	14.62±20.68	--	7364.79 (9/18)	50
<i>Corycaeus amazonicus</i>	48.83±42.55	--	13.33±18.85	--	333 (7/18)	38.88
<i>Calanoides carinatus</i>	--	66.37±99.42	419.66±497.52	44	1834 (8/18)	44.44
<i>Calanus australis</i>	5.5±13.47	4.87±13.78	137.33±127.76	--	484 (5/18)	27.77
<i>C. similimus</i>	7.83±19.18	15.25±29.66	81.33±100.53	--	413 (4/18)	22.22
<i>Acartia tonsa</i>	157±111.11	1.37±3.88	37±52.32	--	1064 (8/18)	44.44
<i>Drepanopus forcipatus</i>	5.66±13.88	7.75±14.38	79.33±27.62	--	334 (5/18)	27.77
<i>Clausocalanus brevipes</i>	30.83±36.83	30.5±44.18	101.66±71.89	44	778 (12/18)	66.66
<i>Oithona nana</i>	1862.42±869.30	3318.92±2396.41	1.33±1.88	--	37729.97 (18/18)	100
<i>O. similis</i>	4.83±11.83	260±367.46	4.66±3.68	50	2173 (10/18)	55.55
<i>O. atlantica</i> *	--	4.14±11.71	21.29±21.96	--	97.02 (2/18)	11.11
<i>Euterpina acutifrons</i>	51.83±35.82	23.37±61.78	13.33±18.85	--	538 (9/18)	50
<i>Microsetella norvegica</i>	61.62±50.15	37.35±41.32	33.48±12.28	64.07	833.06 (15/18)	83.33
<b>Cladocerans</b>						
<i>Pseudoevadne tergestina</i>	21.83±20.46	218.25±270.95	--	--	1877 (11/18)	61.11
<i>Evadne nordmanni</i>	48±50.78	578.5±690.81	--	--	4916 (12/18)	66.66
<i>Podon intermedius</i>	--	367±458.67	--	--	2936 (8/18)	44.44
<i>P. leukarti</i> *	5.10±12.50	32.59±79.71	--	--	291.4 (1/18)	5.55
<i>Pleopsis polyphemoides</i>	361.66±381.34	1812.75±2728.78	13.66±19.32	--	16713 (13/18)	72.22

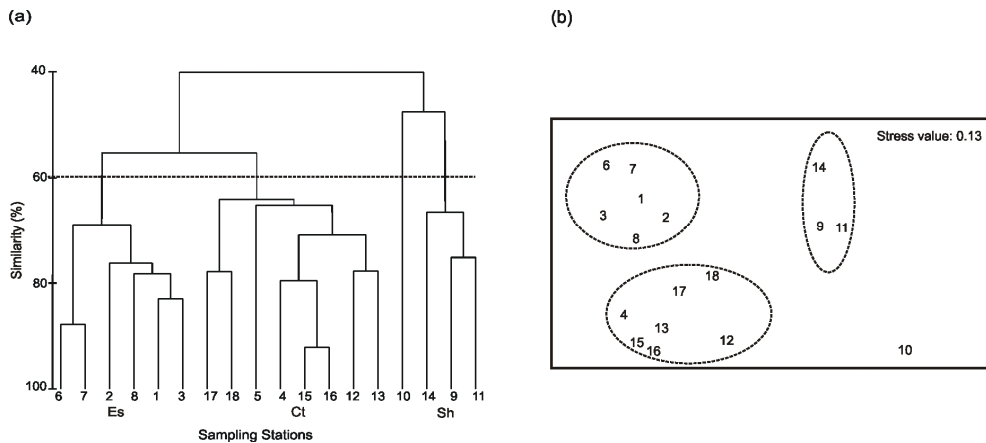


Fig. 3. Groups of samples obtained from similarity matrix based on copepods and cladocerans abundance data. Represented as: (a) Dendrogram. Station groups are indicated. (b) NMDS (stress = 0.13). Station groups are indicated in agreement with groups from dendrogram. Samples are indicated by the station numbers.

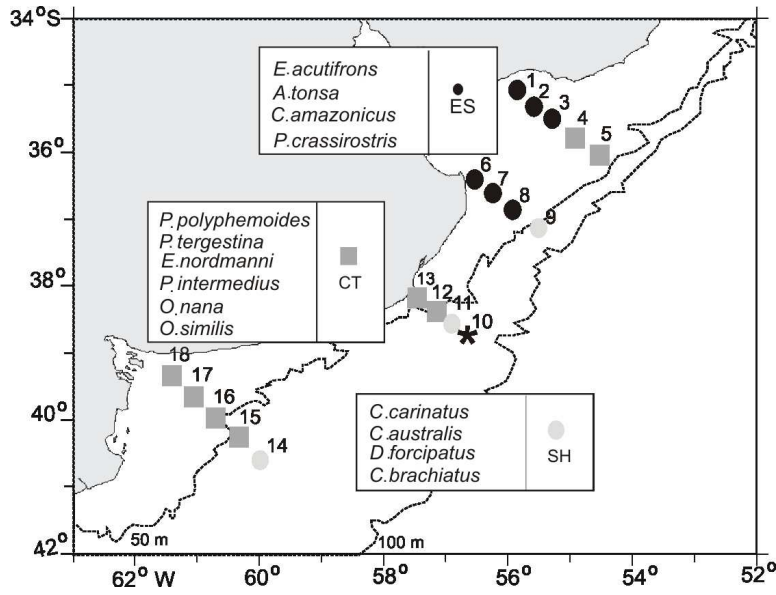


Fig. 4. Spatial distribution of the faunistic areas. Representative copepod and cladoceran species of each area. Estuarine (ES); coastal (Ct) and shelf (Sh) areas, samples are also indicated by the station numbers.

Table 2. Physical parameters values and representative species (from SIMPER) of each assemblage. Estuarine (ES), coastal (CT) and shelf (SH) areas.

Station groups	Mean surface/bottom salinity (range)	Mean surface/bottom temperature (range)	Representative species
ES	24.29 (17.64-33.2)/ 29.83 (27.21-33.2)	17.02 (14.73-19.21)/ 14.78 (13.89-15.4)	<i>A. tonsa</i> , <i>E. acutifrons</i> , <i>C. amazonicus</i> , <i>P. crassirostris</i>
CT	32.96 (30.98-33.96)/ 33.43 (31.43-33.98)	14.39 (12.84-16.7)/ 11.6 (6.83-15.01)	<i>P. polyphemoides</i> , <i>P. tergestina</i> , <i>P. intermedius</i> , <i>E. nordmanni</i> , <i>O. similis</i> , <i>O. nana</i>
SH	33.46 (33.43-33.48)/ 33.56 (33.5-33.68)	12.14 (11.31-12.81)/ 7.55 (6.45-8.65)	<i>C. carinatus</i> , <i>D. forcipatus</i> , <i>C. brachiatus</i> , <i>C. australis</i> , <i>C. simillimus</i>

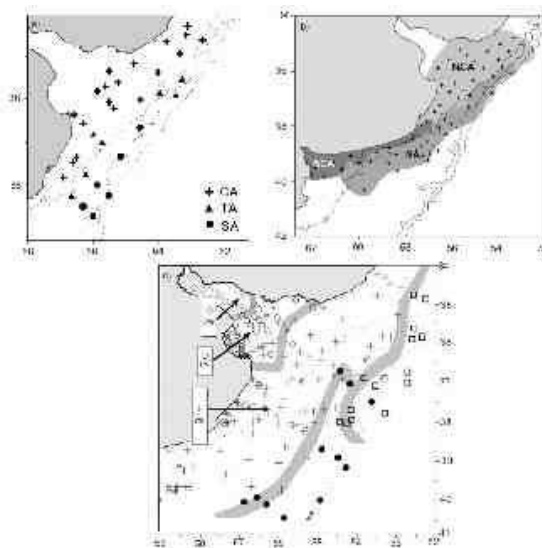


Fig. 5. Spatial distribution of the faunistic areas in previous studies. (a) Viñas et al. 2002; (b) Marrari et al. 2004; (c) Berasategui et al. 2006. Estuarine area (ES); coastal area (CA, CS); north coastal area (NCA); south coastal area (SCA); transitional area (TA) and shelf area (SA).



## DISCUSSION

The present study proposes a new, adequate and sustainable zooplankton time series coupled to *E. anchoita* spring assessment cruises.

Even though the Río de la Plata estuarine regime and salinity distribution play important roles in structuring the northern sector of NACS, temperature controls the seasonal stratification over a large part of the region south of 37°S (LUCAS et al., 2005 and references therein). During spring, seasonal warming of the sea surface results in two different hydrographic systems: 1) a shallower coastal system with a vertically homogeneous water column throughout the year and 2) a deeper shelf system exhibiting vertical stratification in spring through autumn. Both systems are separated by a seasonal front (CARRETO et al., 1995). The presence of these two systems is a recurrent feature over NACS (CARRETO et al., 1995; MARRARI et al., 2004; VIÑAS et al., 2002).

The stations' groups, distinguished by hierarchical classification, defined three distinct faunistic areas that were closely related to characteristic water masses. In a general way, both the species composition and the formation of the estuarine, coastal and shelf areas agrees closely with the results of previous studies undertaken in the area (for a graphical view see fig. 5), in spite the fact that those studies were performed with different samplers and meshes (BERASATEGUI et al., 2006; MARRARI et al., 2004; VIÑAS et al., 2002).

The occurrence of an estuarine faunistic area agrees with the findings of Berasategui et al. (2006) who also reported the presence of *A. tonsa* and *P. crassirostris* as distinctive species of this area. Marrari et al. (2004) also found a faunistic area associated with the Río de la Plata estuary, including *Corycaeus* spp. and *A. tonsa*, coinciding with our results. On the other hand, Viñas et al. (2002) did not report an area directly associated with the estuary, probably because during their cruise, the Río de la Plata run-off was considerably reduced. This fact increased the volume of colder and more saline shelf waters in this sector.

The formation of a coastal faunistic area was a recurrent feature in all the above-mentioned studies, despite changing hydrographic conditions due to the variability of the strong water masses. This faunistic area is mainly characterized by vertically homogeneous waters, produced by wind mixing and tides, throughout the year (CARRETO et al., 1995; MARTOS; PICCOLO, 1988). This system is the nitrate-poorest with high, relatively constant phosphate concentrations throughout the year; however, regenerative processes take place along the water column and in the sediments (CARRETO et al., 2008 and references therein). The regular occurrence of small copepod species and cladocerans is distinctive of

various coastal systems (e.g. IRIGOIEN et al., 2009; RUNGE, 1988). The implementation of different strategies to maximize reproduction and survival (TURNER, 2004) and the ability to feed on particles other than phytoplankton (CASTELLANI et al., 2008; GONZALEZ et al., 2000), contribute to the highest small-sized copepod abundances in this system. With regard to cladocerans, populations are anchored in near-shore habitats because their resting eggs must be laid in continental shelf areas to hatch (EGLOFF et al., 1997; SOMMER; STIBOR, 2002). The cladoceran distributions observed in this study were also in agreement with the general pattern described by Viñas et al. (2007).

The occurrence of stratified waters in the shelf area corroborates the findings of Viñas et al. (2002) and Marrari et al. (2004). The shelf system is stratified during spring and autumn and is also characterized by two chlorophyll *a* maxima (CARRETO et al., 1995). This area consistently presented species similar to those found by the above authors. Conversely, Berasategui et al. (2006) did not differentiate between a coastal and a shelf area, possibly because their analyses were based on qualitative data. Subtle changes in abundance across regions could indicate transition zones (fronts) as well as functional differences in ecosystems. The copepod species present in this system are medium and large-sized, free spawners, mainly herbivores, and can migrate to deep water for diapause due to the large amounts of accumulated lipids (OHMAN; TOWNSEND, 1998; LEE et al., 2006).

Despite some subtle differences, the section-sampling design implemented in this study allowed for the recognition of faunistic areas similar to those established in other studies performed in the area based on a higher number of samples. This implies that it could be applied in future zooplankton studies as a reliable sampling design for this highly productive region. The optimized zooplankton sampling design used in the present study should be extended to other regions in order to sustain and contribute to a global network of zooplankton ecology analysis coupled with fisheries research, similar to fish stock assessment cruises as performed by IRIGOIEN et al. (2009) in the Bay of Biscay.

Mesozooplankton seasonal time series are ongoing in many regions (PERRI et al., 2004 Table I), including the EPEA station in the Argentine Sea (e.g. CAPITANIO et al., 2008; VIÑAS et al., 2007). However, time series covering a broad area, similar to the Radiales project (VALDES et al., 2002), are less frequent worldwide and absent from the Argentine Sea. The development of a time series in this area would be of great interest, especially if it were accompanied by the application of new automatic methods for zooplankton abundance and biomass



assessment such as ZooImage, currently being used in this region (DI MAURO et al, 2011).

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#### REFERENCES

- ACHA, M.; MIANZAN, H.; GUERRERO, R.; CARRETO, J.; GIBERTO, D.; MONTOYA, N.; CARIGNAN, M. An overview of physical and ecological processes in the Río de la Plata Estuary. **Cont. Shelf Res.**, v. 28, p. 1579-1588, 2008.
- BERASATEGUI, A.; MENU MARQUE, S.; GÓMEZ ERACHE, M.; RAMÍREZ, F.; MIANZAN, H.; ACHA, E. Copepod assemblages in a highly complex hydrographic region. **Estuar. Coast. Shelf Sci.**, v. 66, p. 483-492, 2006.
- BEAUGRAND, G.; BRANDER, K.; LINDLEY, J.; SOUISSI, S.; REID, P. Plankton effect on cod recruitment in the North Sea. **Nature**. v. 426, p. 661-664, 2003.
- CAPITANIO, F.; CURELOVICH J.; TRESGUERRES M.; NEGRI, R.; VIÑAS M. D.; ESNAL, G. Seasonal cycle of appendicularians at a coastal station (38°28', 57°41' W) of the South Atlantic Ocean. **Bull. Mar. Sci.**, v. 82, n. 2, p. 171-184, 2008.
- CARRETO, J.; LUTZ, V.; CARIGNAN, M.; CUCCHI COLLEONI, A.; DE MARCO, S. Hydrography and chlorophyll a in a transect from the coast to the shelf-break in the Argentinean Sea. **Cont. Shelf Res.** v. 15, n. 2-3, p.315-336,1995.
- CARRETO, J.; MONTOYA, N.; AKSELMAN, R.; CARIGNAN, M.; SILVA, R.; CUCCHI COLLEONI, A. Algal pigment patterns and phytoplankton assemblages in different water masses of the Río de la Plata maritime front. **Cont. Shelf Res.**, v. 28, p. 1589-1606, 2008.
- CASTELLANI, C.; IRIGOIEN, X.; MAYOR, D.; HARRIS, R.; WILSON, D. Feeding of *Calanus finmarchicus* and *Oithona similis* on the microplankton assemblage in the Irminger Sea, North Atlantic. **J. Plankton Res.**, v. 30, n. 10, p. 1095-1116, 2008.
- CLARKE, K.; WARWICK, R. **Change in marine communities: An approach to statistical analysis and interpretation.** Plymouth: Natural Environment Research Council, Plymouth Marine Laboratory, 1994.
- DI MAURO, R.; CAPITANIO, F.; VIÑAS, M. Capture efficiency for small dominant mesozooplankters (Copepoda, Appendicularia) off Buenos Aires province (34°S-41°S), Argentina, using two plankton mesh sizes. **Braz. J. Oceanogr.** v. 57, n. 3, p 205-214,2009.
- DI MAURO, R.; CEPEDA, G.; CAPITANIO, F.; VIÑAS, M. Using ZooImage automated system for the estimation of biovolume of copepods from the northern Argentine Sea. **J. Sea Res.** n. 66, p.69-75, 2011.
- EGLOFF, D.; FOFONOFF, P.; ONBÉ, T. Reproductive Biology of marine cladocerans. **Adv. Mar. Biol.**, v. 31, p. 79-167,1997.
- FERNANDEZ ARÁOZ, N.; SANTOS, B.; RAMÍREZ, F. Análisis ecológico de la distribución de los copépodos planctónicos de una campaña de primavera, en la zona común de pesca. **Frente marít.**, Mar del Plata, v.15 (A), p. 133-140, 1994.
- GONZÁLEZ, H.; SOBARZO, M.; FIGUEROA, D.; NÓTHIG, E. Composition, biomass and potential grazing impact of the crustacean and pelagic tunicates in the northern Humboldt Current area off Chile: differences between El Niño and non-Niño years. **Mar. Ecol. Prog. Ser.**, v. 195, p. 210-220, 2000.
- GUERRERO, R.; PIOLA, A. Masas de agua en la Plataforma Continental. In: BOSCHI, E. (Ed.). **El Mar Argentino y sus recursos pesqueros**, 1. Mar del Plata: INIDEP, 1997. p. 107-118.
- GUERRERO, R.; ACHA, M.; FRAMIÑAN, M.; LASTA, C. Physical oceanography of the Río de la Plata Estuary, Argentina. **Cont. Shelf Res.**, v.17, p.7, p. 727-742, 1998.
- HUNT, B.; PAKHOMOV, E.; MCQUAID, C. Community structure of mesozooplankton in the Antarctic polar frontal zone in the vicinity of the Prince Edward Islands (Southern Ocean): small-scale distribution patterns in relation to physical parameters. **Deep-Sea Res. (2 Top. Stud. Oceanogr.)**, v. 49, p. 3307-3325, 2002.
- IRIGOIEN, X.; FERNANDES, J.; GROSJEAN, P. Spring zooplankton distribution in the Bay of Biscay from 1998 to 2006 in relation with Anchovy recruitment. **J. Plankton Res.**, v.31, p. 1-17, 2009.
- LASTA, C. Resultados de una campaña de evaluación de recursos demersales costeros de la provincia de Buenos Aires y del litoral uruguayo. Noviembre, 1994. **Inf. Téc. Oficial**, INIDEP, Mar del Plata, n. 21, 1998.
- LEE, R.; HAGEN, W.; KATTNER, G. Lipid storage in marine zooplankton. **Mar. Ecol. Prog. Ser.** v. 307, p. 273-306, 2006.
- LUCAS, A.; GUERRERO, R.; MIANZAN, H. ; ACHA, E.; LASTA, A. Coastal oceanographic regimes of the northern Anchovy Continental Shelf (34-43°S). **Estuar. Coast. Shelf Sci.**, v. 65, n. 3, p. 405-420, 2005.
- MACKAS, D.; BEAUGRAND, G. Comparisons of zooplankton time series. **J. Mar. Syst.** v. 79, p. 286-304, 2010.
- MARRARI, M.; VIÑAS, M.; MARTOS, P.; HERNÁNDEZ, D. Spatial patterns of mesozooplankton distribution in the Southwestern Atlantic Ocean (34°-41°S) during austral spring: relationship with the hydrographic conditions. **ICES J. Mar. Sci.**, v. 61, p.667-679, 2004.
- MARTOS, P.; PICCOLO, M. Hydrography of the Argentine Continental Shelf between 38° and 42°S. **Cont. Shelf Res.**, v. 8, n. 9, p 1033-1056, 1988.
- MARTOS, P.; SÁNCHEZ, R. Caracterización oceanográfica de regiones frontales en la plataforma patagónica en relación con áreas de desove y cría de anchoíta (*Engraulis anchoíta*). In: COLOQUIO ARGENTINO DE OCEANOGRAFÍA. IAPSO-IADO (CONICET), Bahía Blanca, 4-5 September, 1997. **Abstracts...**p. 30, 1997.

- MARTOS, P.; HANSEN, J.; NEGRI, R.; MADIROLAS, A. Factores oceanográficos relacionados con la abundancia relativa de anchoíta sobre la plataforma bonaerense (34-41°S) durante la primavera. **Revta. Invest. Des. Pesq. INIDEP, Mar del Plata**, v. 17, p. 5-33, 2005.
- OHMAN, M.; TOWNSEND, A. Egg strings in *Euchirella pseudopluchra* (Aetideidae) and comments on the relation between egg size and body size in planktonic marine copepods. **J. Mar. Sys.**, v. 15, p. 61-69, 1998.
- PADOVANI, L.; VIÑAS, M.; PÁJARO, M. Importance of the Río de la Plata estuarine front (southwestern Atlantic Ocean) in the feeding ecology of Argentine anchovy, *Engraulis anchoita* (Clupeiformes, Clupeidae). **Lajar.**, v. 39, p. 205-213, 2011.
- PÁJARO, M. Alimentación de la anchoíta argentina (*Engraulis anchoita* Hubbs y Marini, 1935) (Pisces: Clupeiformes) durante la época reproductiva. **Rev. Invest. Des. Pesq.**, v. 15, p. 111-125, 2002.
- PERRY, R.; BATCHELDER, H.; MACKAS, D.; CHIBA, S.; DURBIN, E.; GREVE, W.; VERHEYE, H. Identifying global synchronies in marine zooplankton populations: issues and opportunities. **ICES J. Mar. Sci.**, v. 61, p. 445-456, 2004.
- PERROTA, R.; VIÑAS, M.; MADIROLAS, A.; RETA, R.; AKSELMAN, R.; CASTRO MACHADO, F.; GARCARENA, D.; MACCHI, P.; MORIONDO DANOVARO, P.; LLANOS, V.; URTEAGA, J. La caballa (*Scomber japonicus*) y las condiciones ambientales en el área "El Rincón" (39°-40°S) del Mar Argentino. Septiembre, 2000. **Inf. Téc. Oficial, INIDEP, Mar del Plata**, n. 54, 2003.
- RAMÍREZ, F.; SANTOS, B. Análisis del zooplancton de la plataforma bonaerense en relación con algunas variables ambientales: Campañas "Transección" de 1987. **Frente Marít.** v. 15(A), p. 141-156, 1994.
- RUNGE, J. Should we expect a relationship between primary production and fisheries? The role of copepod dynamics as filter of trophic variability. **Hydrobiologia**. v. 167/168, p. 61-71, 1988.
- SÁNCHEZ, R.; CIECHOMSKI, J. Spawning and nursery grounds of pelagic fish species in the sea-shelf off Argentina and adjacent areas. **Sci. Mar.**, v. 59, p. 455-478, 1995.
- SIMPSON, J. The shelf-sea fronts: implications of their existence and behavior. **Philos. T. R. Soc. A**, v. 302, p. 531-546, 1981.
- SOMMER, U.; STIBOR, H. Copepoda-Cladocera-Tunicata: the role of three major mesozooplankton groups in pelagic food webs. **Ecol. Res.**, v. 17, p.161-174, 2002.
- TURNER, J. T. The importance of small planktonic copepods and their roles in pelagic marine food webs. **Zool. Stud.**, v. 43, n. 2, p. 255-266, 2004.
- VALDÉS, L.; LAVÍN, A. Dynamics and human impact in the Bay of Biscay: An ecological perspective. In: **Large marine ecosystems of the North Atlantic: Changing states and sustainability**. Amsterdam: Elsevier Science, 2002. p. 293-320.
- VALDÉS, L., LÓPEZ-URRUTIA, A., CABAL, J., ALVAREZ-OSSORIO, M., BODE, A.; MIRANDA, A.; CANANAS, M.; HUSKIN I.; ANADÓN R.; ALVAREZ-MARQUEZ, F.; LLOPE, M.; RODRIGUEZ, N. A decade of sampling in the Bay of Biscay: What are the zooplankton time series telling us? **Prog. Oceanogr.**, v. 74, p. 98-114, 2007.
- VIÑAS, M.; RAMÍREZ, F. Gut analysis of firstfeeding anchovy larvae from the Patagonian spawning areas in relation to food availability. **Arch. Fish. mar. Res.**, v. 43, n.3, p. 231-256, 1996.
- VIÑAS, M. D.; NEGRI, R. M.; RAMÍREZ, F. C.; HERNÁNDEZ D. Zooplankton assemblages and hydrography in the spawning area of anchovy (*Engraulis anchoita*) off Río de la Plata estuary (Argentina-Uruguay). **Mar. Freshwat. Res.**, v. 53, p. 1031-1043, 2002.
- VIÑAS, M.; RAMÍREZ, F.; SANTOS, B.; MARRARI, M. Spatial and temporal distribution patterns of Cladocera in the Argentine Sea. **Hydrobiologia**. v. 594, p. 59-68, 2007.

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