Potential zooplankton preys (Copepoda and Appendicularia) for *Engraulis anchoita* in relation to early larval and spawning distributions in the Patagonian frontal system (SW Atlantic Ocean)

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SUMMARY: We investigated the spatial distribution of the abundance, biomass and size of zooplankton (nauplii, calanoids, cyclopoids and appendicularians) in relation to the distribution of first-feeding larvae and eggs of *Engraulis anchoita* across the frontal system of Peninsula Valdés. Twelve samples of zooplankton and ichthyoplankton were taken with small Bongo (67 µm) and Pairovet (200 µm) nets during the spring of 2004 along two transects. The total abundance of zooplankton and the chlorophyll *a* concentration were higher in homogeneous waters, while total biomasses were higher in stratified waters. Temperature was negatively correlated with biological variables and was the main factor affecting the zooplankton distribution. In both transects, abundance peaks of first-feeding larvae were detected at coastal stations along with the smallest fraction of zooplankton (<500 µm), while the largest fraction was dominant at the external stations, coinciding with the highest egg abundance. The physical structure of this front generates different levels of food availability for first-feeding larvae. Calanoids (southern transect) and cyclopoids (northern transect) are predominant followed by nauplii and appendicularians. The biomass of zooplankton preys contributes to the carbon transfer to the upper trophic levels and is probably important for the survival and growth of anchovy larvae in this frontal system.

Keywords: southwestern Atlantic Ocean, North Patagonian frontal system, copepods, appendicularians, zooplankton-anchovy linkage.

RESUMEN: Se investigó la distribución espacial de la abundancia, biomasa y tallas del zooplancton (nauplii, calanoides, ciclopoideos y appendicularias) en relación con la distribución de las larvas en estadio de primera alimentación y los huevos de *Engraulis anchoita* en el sistema frontal de Península Valdés. Se tomaron 12 muestras de zooplancton e ictioplancton durante la primavera de 2004 a lo largo de dos transectos, mediante una red Minibongo (67 µm) y una Pairovet (200 µm) respectivamente. La abundancia total del zooplancton y la concentración de clorofila fue mayor en aguas homogéneas, mientras que la biomasa fue mayor en aguas estratificadas. La temperatura se correlacionó negativamente con las variables biológicas siendo ésta el principal factor que afectó la distribución del zooplancton. En las estaciones costeras de ambos transectos, se encontró la mayor abundancia de larvas en coincidencia con la fracción más pequeña de zooplancton (<500 µm), mientras que la fracción más grande fue dominante en las estaciones externas, en coincidencia con la mayor abundancia de huevos. La estructura física de este frente genera diferente disponibilidad de alimento para las larvas siendo los calanoides (transecto sur) y los ciclopoideos (transecto norte) predominantes, seguidos por nauplii y appendicularias. La biomasa de dicho alimento zooplanctónico podría contribuir a la transferencia de carbono a los niveles tróficos superiores y esto sería importante para la supervivencia y crecimiento de la anchoita en este sistema frontal.

Palabras clave: océano Atlántico sudoccidental, sistema frontal norpatagónico, copépodos, appendicularias, relación zooplancton-anchova.
INTRODUCTION

Copepods are considered the most abundant mesozooplankton group in many pelagic environments (Kiørboe 1998), and along with appendicularians, they are the most important secondary producers (Gorsky and Fenaux 1998, Hopcroft and Roff 1998, Sato et al. 2008). Both groups play an important role as consumers of both the phytoplankton and microbial components of food webs. Moreover, they are also preyed on by several pelagic ichthyoplankters (Berggren et al. 1988, Deibel and Lee 1992, Flood et al. 1992; Stibor et al. 2004, Castro et al. 2010). Fish reproduction is linked to plankton production cycles, and larvae, juveniles and adults generally coincide with peaks in zooplankton biomass (Kiørboe 1991, Bollens et al. 1992, Hunter and Alheit 1995, Cushing et al. 1996). Various factors affect the survival of young fish, and predation and starvation are the main sources of mortality. Hjort (1914) suggested that larval survival might be affected by lack of food during the early stages of external feeding. Various copepod stages are the main component of the diet of many pelagic fish during their ontogenetic development (Last 1980). Therefore, the availability of prey for fish larvae will partially depend on the transfer rate of primary producers through copepods.

In frontal areas, biological production may be intensified (Mann and Lazier 1993). The circulation in frontal systems is usually associated with a density difference between two water masses that generates a convergence at the surface or bottom boundary and makes the front an abrupt transition (Larger 1993). The most conspicuous feature in the Patagonian coastal area is the development during spring and summer of a tidal front that extends from 42° to 45°S, north from Peninsula Valdés to Camarones Bay. Its middle position is oriented NE-SW, closely following the isobaths of 75-80 m (Sabatini and Martos 2002). High tidal dissipation rates generate strong vertical mixing in near shore waters that can homogenize the entire water column. Wind stress on the surface layer also contributes to forming and maintaining the homogeneity of the front. This feature, combined with the stratification of shelf waters induced by seasonal surface warming, results in the highly mixed coastal waters being separated from the stratified offshore waters. This structure is maintained until autumn when stratification breaks down (Carreto et al. 1986, Glorioso 1987, Acha et al. 2004).

Several authors have studied the horizontal and vertical distributions of zooplankton in this front (e.g. Santos and Ramirez 1995, Capitanio and Ensal 1998, Sabatini and Martos 2002). They highlight the high productivity of this system, which supports several commercial target species, such as hake, mackerel and anchovy, among others (Sánchez et al. 1997, Beazzi 2000). Anchovy (*Engraulis anchoita*) is the main pelagic species in the Argentine Sea and its range extends from southern Brazil (22°S) to Patagonia (48°S). South of 34°S, at least two populations of *E. anchoita* occur separately at approximately 41°S: the northern population and the southern population (Patagonian stock) (Hansen et al. 1984). The Patagonian stock spawns during late spring and summer in association with tidal frontal systems, and the spawning area varies between 39063 and 78440 km². Whether there are anchovy eggs off Patagonia depends on the formation of these systems, and eggs can reach densities from 425 to 1023 eggs m⁻² y⁻¹ (Sánchez and Ciechomski 1995, Pájaro et al. 2009a). However, the annual anchovy larval density, mostly first-feeding larvae, ranges from 84 to 833 larvae m⁻² (Pájaro et al. 2009b). Anchovy is a zooplanktivorous species throughout its life cycle, and therefore its population could play an important role in shaping pelagic food webs (Pájaro 1998). Viñas and Ramirez (1996) and Capitanio et al. (1997) studied the stomach contents of first feeding larvae of Patagonian anchovy, and found that appendicularians, nauplii, copepod eggs and small copepods such as Paracalanus parvus, Oithona spp, Microsetella norvegica and Euterpinia acutifrons were the main food items. Although the spatial distribution of *E. anchoita* populations in the external area of Rio de la Plata estuary has been associated with the densities of small zooplankters, such as copepods, cladocerans and appendicularians (Viñas et al. 2002, Marrari et al. 2004, Capitanio et al. 2005), there are still very few studies on the Patagonian anchovy. We investigated the spatial distribution of the abundance, size spectra and biomass of dominant zooplankton (nauplii, cladocerans, cyclopoids and appendicularians) in relation to the distribution of anchovy first-feeding larvae and spawners (determined according to egg distributions) in the Peninsula Valdés tidal front. We tested the hypothesis that the zooplankton distribution is influenced by temperature and we analyzed the distribution patterns of some of the potential food preys available for *E. anchoita* in the homogeneous and stratified waters of this front.

MATERIALS AND METHODS

Twelve zooplankton samples were taken during the spring (December) of 2004 along two transects (Fig. 1a) by the Instituto Nacional de Investigación y Desarrollo Pesquero, Argentina. The zooplankton samples were collected with a small Bongo net with a 0.2 m diameter (67 µm) operated at 1 to 1.2 m s⁻¹. A Paivoret net with a mouth diameter of 0.225 m and 220 µm mesh size was used for the anchovy larvae. Small Bongo and Paivoret nets were operated from the bottom to the surface with vertical and oblique tows respectively. A mechanical flowmeter (Hydrobios) was used to measure the volume of filtered water and all samples were fixed on board with 2% formaldehyde. In the frontal area (41°-45°S) vertical continuous conductivity-temperature-depth (CTD) profiles were recorded with a Searbide 19. In order to quantify the stratification at the front, the f parameter of stability (Simpson, 1981) in J m⁻³ was used as a measure of the energy needed to mix the water column. The parameter
is defined as follows: \( \Phi = g \cdot h \cdot \int (\rho - \rho_0) \cdot Z \cdot dz \) where \( g \) is the acceleration of gravity, \( h \) is the total depth, \( \rho \) is the density of sea water, \( \rho_0 \) is the average density of the water column and \( z \) is the depth. These calculations were made with MatLab Software, and a critical value of 40 J m\(^{-3}\) was used to separate mixed and stratified waters according to Martos and Sánchez (1997). Temperature profiles were analyzed at each station of the two transects. The surface chlorophyll \( a \) concentration was estimated from satellite images corresponding to the sampling dates (14 to 17 December 2004), provided by ANTARES and processed according to Buono and Cucchi Colleoni (2009). The appendicularians and copepods (calanoids, cyclopoids and nauplii) present in all plankton samples were separated in the laboratory using a stereoscopic microscope. In addition, those samples that had more than 200 specimens were fractionated. Anchovy eggs and first-feeding larvae were also identified and counted under a binocular-dissecting microscope. Density was calculated for each group and determined for all stations and species by microscopic inspection of subsamples. Between 30 and 50 organisms of each group were measured using an ocular micrometer in order to analyze the size structure of the different groups in each zooplankton sample. Using these sizes, the biomass (\( \mu g \) C m\(^{-3}\)) of each individual was estimated using the relationships described in Sabatini and Kiørboe (1994), Capitanio et al. (2008) and Jasper et al. (2009), and then extrapolated to the biomass of each group.

Georeferenced maps showing the position of the front, and temperature profiles were drawn using the Golden Software’s Surfer program 8.0. The abundances for each group (cyclopoids, calanoids, nauplii and appendicularians) were compared in the two transects with a Mann-Whitney nonparametric test. A principal component analysis (PCA) was applied to establish the relationship between biological (total zooplankton, nauplii, cyclopoids, calanoids and appendicularians densities), and standardized environmental (temperature and Simpson index) variables. Statistica 6.0 and InfoStat packages were used for data analysis.

RESULTS

Relationships between zooplankton (copepods and appendicularians) and the environment

The stratified and homogeneous waters of the front were separated according to a critical value of 40 J m\(^{-3}\), taking into account the distribution of the Simpson index (Fig. 1a). In the northern transect, only the coastal station (station 716) was homogeneous (<40 J m\(^{-3}\)), and the surface signal of the front was detected at 26 km from the coast with a gradient of 0.25°C/10 km. In contrast, the bottom signal was located at 140 km from the coast (stations 712 and 711) with a gradient of 0.75°C/10 km. In the southern transect, two coastal stations (stations 683 and 684) were homogeneous and both the surface and the bottom signals of the front were recorded at a distance of 70 km, with a gradient of 0.29°C/10 km and 0.54°C/10 km respectively. The temperature of homogeneous waters varied between 13°C and 14°C for both transects, while in stratified waters the temperature varied from 16.5 to 7.5°C and from 16.5 to 11°C (surface to bottom layers) in the northern and southern transects respectively (Fig. 1b, c). The maximum surface (satellite) chlorophyll \( a \) concentrations (3.5-5.0 mg m\(^{-3}\)) were found in homogeneous and transitional waters, mainly in the southern transect. However, stratified waters showed consider-
ably lower values, 1.5 mg m\(^{-3}\) and 0.3 mg m\(^{-3}\) for the southern and northern transects respectively (Fig. 2).

The distribution of calanoids, cyclopoids, nauplii and appendicularians was analyzed in relation to the frontal area. We found two species of cyclopoids, *Oithona helgolandica* and *Oithona nana*, and several calanoid species, *Acartia tonsa*, *Calanoides carinatus*, *Paracalanus parvus*, *Ctenocalanus vanus*, *Centropages brachiatus* and *Drepanopus forcipatus*. Moreover, *Oithona spp.*, *C. carinatus*, *C. vanus*, *A. tonsa* and *P. parvus* were present at every station (homogeneous and stratified) in both transects, while *D. forcipatus* and *C. brachiauaitus* were present only at stratified stations. *Oikopleura dioica* was the only appendicularian species registered. The densities calculated for copepods and appendicularians are shown in Figure 3. The abundances of cyclopoids and calanoids differ between transects (Mann-Whitney test, U=5 and U=6 respectively, p<0.05), and cyclopoids are more abundant (2622 ind. m\(^{-3}\)) in the northern transect and calanoids (3554 ind. m\(^{-3}\)) in the southern transect. No differences in abundances between transects were observed for nauplii (Mann-Whitney test, U=9, p>0.05), which reached densities of 1358 ind. m\(^{-3}\). The highest densities of *O. dioica* appendicularians were recorded in the southern transect with values between 400 and 526 ind. m\(^{-3}\) (Mann-Whitney test, U=5, p<0.05).

The principal component analysis showed that components 1 and 2 explained 48.5% and 30.8% of the total variability respectively (Fig. 4). The Simpson index, temperature, total zooplankton and nauplii densities were mainly correlated with the first component. Both environmental variables were inversely correlated with the biological variables as higher zooplankton and nauplii abundances were found in homogeneous waters where a lower Simpson index and temperature were detected. Cyclopoids and appendicularians showed an
inverse relationship and were mainly associated with component 2 (Table 1).

**Table 1.** Results of the PCA analysis, eigenvectors (Evc), eigenvalues, percent of the variance explained by the original data set ($r^2$), and correlation ($r$) of the original variables with the first two principal components.

<table>
<thead>
<tr>
<th>Variable</th>
<th>PC1</th>
<th>Evc</th>
<th>PC2</th>
<th>Evc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>-0.80</td>
<td>-0.43</td>
<td>-0.30</td>
<td>-0.20</td>
</tr>
<tr>
<td>Nauplii</td>
<td>0.71</td>
<td>0.39</td>
<td>0.23</td>
<td>0.16</td>
</tr>
<tr>
<td>Calanoids</td>
<td>0.71</td>
<td>0.38</td>
<td>-0.66</td>
<td>-0.45</td>
</tr>
<tr>
<td>Cyclopoids</td>
<td>0.13</td>
<td>0.07</td>
<td>0.89</td>
<td>0.61</td>
</tr>
<tr>
<td>Appendicularians</td>
<td>0.44</td>
<td>0.24</td>
<td>-0.76</td>
<td>-0.52</td>
</tr>
<tr>
<td>Total zooplankton</td>
<td>0.94</td>
<td>0.51</td>
<td>-0.07</td>
<td>-0.05</td>
</tr>
<tr>
<td>Simpson’s stability</td>
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<td>-0.44</td>
<td>-0.44</td>
<td>-0.30</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>3.39</td>
<td></td>
<td>2.16</td>
<td></td>
</tr>
<tr>
<td>$r^2$</td>
<td>48.5</td>
<td></td>
<td>30.8</td>
<td></td>
</tr>
</tbody>
</table>

**Small-sized zooplankters as potential prey of E. anchoita in the frontal system**

*Engraulis anchoita* larval abundance was highest at coastal stations (stations 714, 713 and 684), mainly in the southern transect (max. 6000 larvae/10 m$^2$), in contrast to egg abundance, which was higher at the outside stations (station 711 and 689) of both transects (max. 50000 eggs/10 m$^2$) (Fig. 5). The standard lengths of first-feeding larvae ranged from 2.6 mm to 9 mm, and the largest larvae were found in the southern transect. Zooplankton sizes in the different stations were also analyzed (Fig. 6). The smallest sizes (mainly <500 µm) were predominant in homogenous coastal waters, while larger organisms (>500 µm) dominated in the external stratified waters. Nauplii ranged from 50 to 500 µm and were larger in the southern transect. The largest calanoids were found mainly at the external stations and the largest appendicularians, *O. dioica* (>1000 µm), were found at the coastal stations of the southern transect. In the northern transect the sizes of this last species were much smaller. The cyclopoids were predominant in the northern transect, and small individuals under 500 µm prevailed at coastal stations. In general, it was observed that the dominance of the smallest sizes of zooplankton at the coastal stations coincided with the highest larval abundances, while the dominance of the largest fractions at outside stations coincided with the highest egg abundances. In terms of biomass (Fig. 7), the main carbon contributions were found at the external stations (stations 711 and 689) of the northern and southern transects (12384 µg C m$^{-3}$ and 40777 µg C m$^{-3}$ respectively). The largest values corresponded to calanoids (40000 µg C m$^{-3}$).
followed by cyclopoids (2550 µg C m\(^{-3}\)), appendicularians (750 µg C m\(^{-3}\)) and nauplii (350 µg C m\(^{-3}\)). At stations 716, 714 and 710 of the northern transect, cyclopoid biomasses were two times higher than calanoid biomasses. In general, cyclopoid, nauplii and *O. dioica* appendicularian biomasses were higher in homogeneous coastal waters, while calanoid biomasses were higher in the external stratified waters.

**DISCUSSION**

The physical structure of the North Patagonian frontal system shows latitudinal differences that may be related to changes in the relative importance of meteorological forces, such as tides and winds. The marked thermal gradient observed along the two transects, both in distance from the shore and depth,
resulted in different zooplankton compositions and distribution patterns. Cyclopoids were dominant (ca. 70%, with few exceptions) in the northern transect and calanoids (average 80%) were dominant in the southern transect. *P. parvus* and *C. vanus* were dominant in homogeneous waters and *D. forcipatus* and *C. branchiatus* in stratified waters. It is known that cyclopoids are associated with microbial production processes (Franz and Gonzalez 1995, Nielsen and Sabatini 1996), which could explain the observed dominance of cyclopoids over calanoids because a low chlorophyll *a* concentration was found in the northern transect. The same pattern of the latitudinal distribution of zooplankton was observed in the spring of 1995 and 1998 (Sabatini and Martos 2002). However, in relation to stratification and water mixing, higher densities were found in stratified waters in 1995, and in homogeneous waters in 1998, which could be related to the physical conditions of the front (the temperature was higher in 1998 throughout the entire frontal system compared to 1995). In our study, the surface temperature in homogeneous waters of the northern transect was similar to that of 1998 and higher than that of 1995. However, when the stratified waters were compared, the temperature observed was higher than in 1995 and 1998, and there was a very pronounced thermocline (AT = 9°C). As the southern transect in Sabatini and Martos (2002) was located further south, we did not compare it with our southern transect. In addition, in our study, temperature was negatively correlated with all biological variables, and the differences in zooplankton abundances in homogeneous and stratified waters corresponded to fluctuations in their physical structure. Temperature was the main factor affecting the zooplankton distribution. The abundance and biomass of calanoids and cyclopoids were significantly higher than those of appendicularians, mainly in homogeneous and transitional waters. There were higher densities of copepods and *O. dioica* appendicularians in the transitional waters of the front, coinciding with lower chlorophyll *a* concentration (Viñas and Ramirez 1996, Capitanio and Esnal 1998). Although both the biomass and abundance of copepods were higher than those of appendicularians, the latter had significantly higher production rates (Sato et al. 2008, Jaspers et al. 2009). While several experimental studies have shown an indirect interaction between calanoids and appendicularians, no studies have been carried out on the interactions between cyclopoids and appendicularians. In the coastal waters of the Japan Sea and Baltic Sea, blooms of *O. dioica* occur after the calanoid abundances decline or whenever they are low (Behrends 1996, Nakamura 1998, Sommer et al. 2000, 2003, Stibor et al. 2004). In addition, Tönnesson et al. (2005) suggested that there is predation pressure by calanoids on appendicularian eggs, which would thus influence their population dynamics. Moreover, in our southern transect, the largest calanoids were observed with the smallest *O. dioica* appendicularians at the external stations, while the smallest calanoids were found with the largest *O. dioica* appendicularians at the coastal stations. However, the negative relationship between the total abundance of cyclopoids (mainly small *Oithona* spp.) and *O. dioica* appendicularian suggests there is competition for food.

The distribution of first-feeding larvae of *E. anchoita* in this frontal system was related to the small sized copepods (mainly <500 µm). The peaks of larvae at coastal stations (mean larval standard length: 4.6 mm, St. 684) coincided with the highest abundances of these small zooplankton sizes, mainly calanoids and cyclopoids. In this front Sabatini and Martos (2002) registered low densities of nauplii in relation to the low fecundity of copepod females found experimentally. During our sampling period (14-17 December), nauplii densities were also low (they reached 1358 ind. m⁻³ only at St. 685 of the southern transect), which indicates that the study was probably conducted out of the reproductive period of most copepods or that their fecundity was low. In terms of the carbon contribution of these four groups to the mixed waters of the front, 60% and 50% of the total biomasses corresponded to cyclopoids and calanoids in the northern and southern transects respectively. Moreover, Diaz et al. (2009) found highly propitious nutritional conditions for the anchovy larvae collected in this frontal system, including the first-feeding larvae. Viñas and Ramirez (1996) analyzed the stomach contents of anchovy larvae (2.5 to 5.5 mm standard length), and found that nauplii, eggs and small copepods (<500 µm) were the main food items. In our study, the small copepods *P. parvus* and *Oithona* spp. were registered at all plankton stations of the front, and were thus available as the main food source for anchovy larvae. The diets of other clupeid larvae, such as *Sardinella aurita*, are based on different copepod stages, and a higher preference for nauplii in larvae <8 mm has been detected (Morote et al. 2008). In addition, Morote et al. (2010) observed prey selectivity in the feeding ecology of *E. encrasicolus* larvae (2.7 to 14.5 mm), which begin feeding on prey items >150 µm length. On the Algerian coast, copepods are found in 98% of the stomach contents of adults of this species, and during its first year of life, anchovy feed almost exclusively on copepods (mainly small and medium sized preys). As the anchovy grow, copepods are gradually substituted by large crustaceans, such as decapods and amphipods (Bacha and Amara 2009).

It is known that before the spring-summer spawning season, schools of the Patagonian stock of *E. anchoita* feed on the larger zooplankton available in deep shelf waters and then migrate to coastal areas, such as the frontal system of Peninsula Valdés, to reproduce (Pájaro 1998). Wind mixing, and its associated turbulence, influence plankton populations in different ways, with either beneficial or detrimental consequences depending on their role within pelagic food webs. In particular, homogeneous waters enhance encounter rates between zooplankton preys and ichthyo plankton predators (Rothschild and Osborn 1988). The complex ecological
interactions among the vast numbers of zooplankton organisms can result in positive, negative or random relationships, which can be related to physical and biological environmental conditions. Moreover, these relationships are not fixed over time and can vary according to the type of interactions between organisms. In this study, we detected a positive relationship between the small zooplankton fraction and the first-feeding larvae of E. anchoita. According to Sanvicente-Añorve et al. (2006), this type of relationship may be due to the absence or low abundance of the main predators of the ichthyoplankton, and the high food availability for fish larvae; however, in this study no data on predators of anchovy larvae were available.

In the Patagonian area, the onset of anchovy spawning and the distribution of anchovy eggs depend on the formation of tidal frontal systems. Sánchez et al. (1996) observed larger concentrations of eggs in the transition and stratified waters, which was also observed in our study. The high densities of anchovy eggs at external stations in coincidence with larger calanoids (>1000 µm) could be indicative of the presence of spawning groups of anchovies feeding on them. Furthermore, the higher biomass (mainly calanoids) in these stratified waters would contribute to the carbon transfer to the upper trophic levels and anchovy adults would be benefited. During winter, Castro et al. (2009, 2010) reported that variations in the biochemical composition of Engraulis ringens eggs in the upwelling system off the Chile coast were beneficial for young larvae. These authors found a negative relationship between egg size and food availability for larvae: smaller-sized copepods (presumably more prone to being captured by the youngest larvae) were most abundant when eggs were smaller because larvae would not need much lipid reserves to survive due to the abundance of small food sources in the sea. In other areas, such as on the Catalan coast (NW Mediterranean), high larval densities of both E. encrasicolus and Sardinella aurita suggest that the high abundance of zooplankton in surface layers forms a favourable habitat for the nutrition and survival of these larvae. Accordingly, high correlations between both larvae and the trophic variables (i.e. sea surface fluorescence) were detected (Olivar et al. 2010). In our study, in the Peninsula Valdés front, similar results were found because high chlorophyll a concentrations were recorded together with high abundances of small zooplankton and larvae in the homogenous waters. Although other fish larvae (e.g. Merluccius hubbsi) are usually spawned on the Patagonian coast (Macchi et al. 2007), no interaction between larvae of the different species is possible due to their different temporal distribution patterns.

It is therefore evident that frontal zones play a key role in ecological processes of the ocean (Acha et al. 2004), allowing an exceptionally large primary production (Carreto et al. 1986), offering adequate feeding and reproductive habitats for planktivorous species and acting as retention areas for larvae. In the Peninsula Valdés frontal system, homogeneous and transitional waters constitute a suitable environment for the small fraction of zooplankton, and the abundances of these prey foods would be important for the survival and growth of first-feeding larvae. Therefore, more studies on the links between zooplankton and anchovy are still necessary.

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