2013-05-10

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# Continental Shelf Research

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A B S T R A C T

The present work investigates the composition of larval fish assemblages in the area under the influence of the Brazil Current (BC) off the Southeastern Brazilian Bight. Ichthyoplankton was sampled during two oceanographic cruises (November–December/1997 – spring; May/2001 – autumn) with bongo nets oblique tows. Seasonal variation and a coastal-ocean pattern in the distribution of larval fish was observed and was influenced by the dynamics of the water masses, Coastal Water (CW), Tropical Water (TW) and South Atlantic Central Water (SACW), the last two of which were transported by the BC. During spring, the shelf assemblage was dominated by larvae of small pelagic fishes, such as *Sardinella brasiliensis, Engraulis anchoita* and *Trachurus lathami*, and was associated with the enrichment of shallow water by the SACW upwelling. In autumn, the abundance of coastal species larvae was reduced, and the shelf assemblage was dominated by *Bregmaceros cantori*. A transitional assemblage occurred during the spring, and comprised mesopelagic and coastal species. In both seasons, the oceanic assemblage was dominated by the mesopelagic families, Myctophidae, Sternopthychidae and Phosichthyidae. The oceanographic conditions also demonstrated clear differences between the northern and southern subareas, particularly in the shelf zone. This was especially the case during autumn when a latitudinal gradient in larval fish assemblages became more pronounced.

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## 1. Introduction

The Southeastern Brazilian Bight (SBB), located between 23° and 28°S, is largely influenced by the occurrence of mesoscale eddies from the Brazil Current (BC) and seasonal upwelling (Silveira et al., 2000). The BC flows southward along the continental slope near the shelf edge, where vertical current shear, bottom topography and strong change of coastal orientation near 23°S contribute to the development of meandering and eddies (Campos et al., 1995, Castelao et al., 2004). The cyclonic eddies of BC may promote upwelling in the shelf break along the SBB, as well as favor the movement of the upwelling frontal zone toward the inshore area (Campos et al.,1995, 2000). The position of the bottom thermal front changes seasonally and is closer to the coast during summer and farther offshore during winter. Additionally, depending on the strength of the South Atlantic Central Water (SACW) intrusion, coastal upwelling may also occur (Castro and Miranda, 1998).

Physical processes, in all scales, can affect the distribution and abundance of animal populations in the sea (Harrison and Parsons, 2001), especially the plankton community. The occurrence of upwelling is known to drive the ichthyoplankton assemblages in the eastern boundary coastal systems (Olivar and Shelton, 1993; Landaeta et al., 2008) and in the SBB (Katsuragawa et al., 2006), although it is generally considered weaker than the previous systems. The intrusion of the SACW toward the coast in the bottom layer is a hydrographic feature that enhances regional primary productivity and consequently, the fisheries (Brandini, 1990; Gasalla and Rossi-Wongtschowski, 2004). Studies have shown the tendency of the peak spawning period for some small pelagic fish species, as sardine and rough scad, during the spring and summer, when the intrusion of SACW over the continental shelf becomes more frequent (Matsuura et al., 1992; Katsuragawa et al., 2006).

The mesoscale meanders and eddies may transport fish larvae from one area to another, such as from the shelf to the ocean and vice-versa, which influences the composition and abundance of larval fish assemblages (Wroblewski and Cheney, 1984; Fleirl and Wroblewski, 1985; Myers and Drinkwater, 1989; Franco et al., 2006). Despite the importance of these features, their influence on ichthyoplankton in the Brazilian coast is poorly studied. However, for the southern region, approximately 31°S, Franco et al. (2006) previously observed that larval fish are advected with tropical offshore waters toward the inner shelf by an anticyclonic eddy.

To improve the understanding of larval fish distribution, the present study compares the spatial changes in larval fish assemblages

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in SBB under the influence of spring and autumn oceanographic conditions.

## 2. Material and methods

Biological and hydrographic data were obtained during two oceanographic cruises (November–December/1997 – spring; May/ 2001 – autumn) carried out with the R/V "Prof. W. Besnard" off the Southeastern Brazilian Bight, from cape Frio (23°S) to the cape of Santa Marta Grande (29°S). The samples are stored at the ColBIO – IOUSP (Biological Collection "Prof. Edmundo F. Nonato" – Oceanographic Institute, São Paulo University). Each survey comprised 15 across-shelf transects with a total of 47 stations in the spring cruise and 46 stations in autumn cruise (Fig. 1). Ichthyoplankton was collected with bongo nets according to Smith and Richardson (1977). The maximum sampling depth of the tows was limited to 5 m above the bottom at shallow stations and to the upper 210 m of the water column at offshore stations. Flow meters in the net mouths measured the volumes of water sampled to estimate the levels of larval abundance. Only samples of 333 μm mesh nets were analyzed. All samples were fixed in a buffered, 4% formaldehyde–seawater solution.

A CTD (conductivity–temperature depth profiler) cast provided hydrographic data for each station, and temperature–salinity diagrams (T–S) provided the identification of the water masses (Emílsson, 1961). The maps of horizontal distribution of temperature and salinity was created with 81–91 rows and 100 columns grid size, using the Kriging method of the Surfer software.

Maps of the program, "Simple Ocean Data Assimilation – SODA" (version 2.2.4), were analyzed. This is a collaborative project that has been ongoing since the 1990s, and has the goal of providing an improved estimate of the ocean state that is based on observations and numerical simulations. Presently, it covers the period, 1871–2008, with several improvements since its first version (Carton and Giese, 2008). This oceanic reanalysis data set consists of monthly means of gridded state variables for the global ocean with a resolution of approximately $0.25° \times 0.4°$ horizontally and 40 levels vertically. It provides several oceanic fields, including sea surface height, temperature, salinity and currents, and is based on the meteorological data produced by reanalysis from the European Center for Medium-Range Weather Forecasts (ECMRWF). The maps of the mean values of the meteorological and oceanographic data in the Southeastern Brazilian Bight were selected and were compared to those based on the samplings in this region, at the depths of 25 m (near to the average depth of TW, 20 m) and 317 m (near to the average depth of SACW, 300 m).

In the laboratory, the fish larvae were identified to the lowest possible taxon based on several guides, including Fahay (1983), Moser et al. (1984), Leis and Trnski (1989) and Moser (1996).

The occurrence frequency of larvae (FO%) was calculated based on Guille (1970), and the abundance of fish larvae (larvae m$^{-2}$) was estimated according to Tanaka (1973). The volume of filtered water (m³) was estimated by the expression, $V$=a.n.c, where $a$=bongo net mouth area; $n$=flow meter rotation number; and $c$=calibration index of each flow meter. Community structure indicators, including Shannon–Wiener and Simpson diversity indexes and equitability, were calculated by BioEstat (Ayres et al., 2007) using the base 10 of logarithms.

Based on previous oceanographic studies (Miranda and Katsuragawa, 1991; Mahiques et al., 2004), the area was divided in two subareas as follows: the northern part, from Cape Frio to São Sebastião Island, and the southern part, from São Sebastião Island to the Cape of Santa Marta Grande. The area was also subdivided in the three following zones based on bathymetry: (a) the shelf zone, for stations near 100 m depth; (b) the transition zone, for stations between 100 and 500 m depth; and (c) the
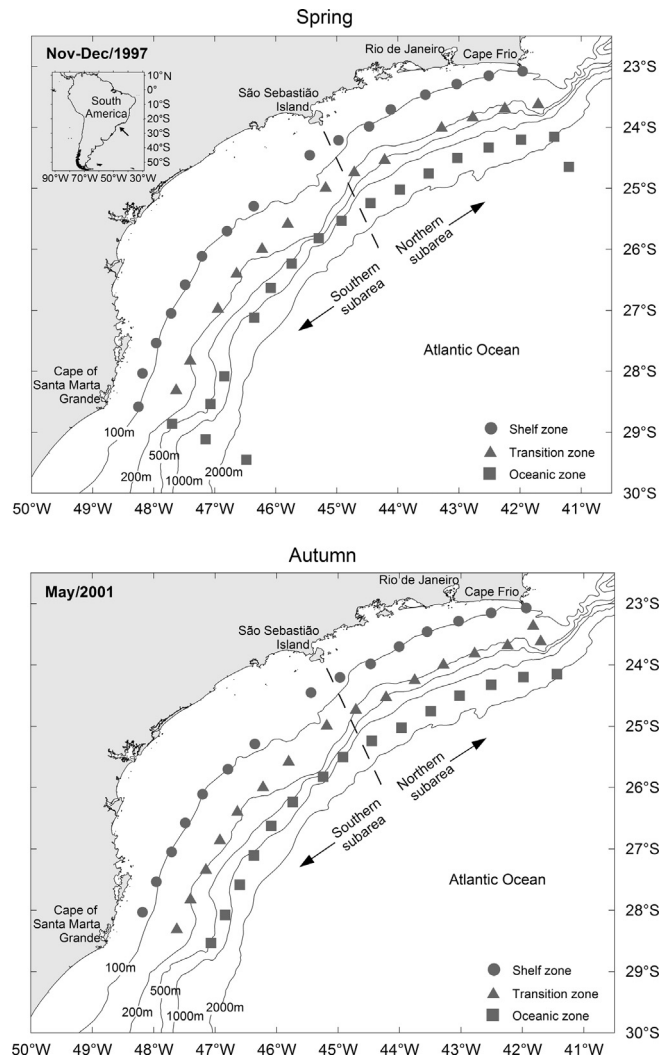


**Fig. 1.** Study area showing the oceanographic stations in the Southeastern Brazilian Bight during the spring (November–December/ 1997) and autumn (May/2001).

oceanic zone, for stations located along the shelf break and the slope area and $>500$ m depth (Fig. 1).

One-way analysis of similarity (ANOSIM) (Clarke, 1993) was used to test whether the larval fish composition differed significantly between the shelf, transition and oceanic stations, using the PRIMER software. This analysis compares the average rank similarities within the pre-defined groups of samples with the average similarity between groups. *R*-values close to 1 indicate a strong separation between the groups, while an *R*-value of 0 indicates no differences between the groups. Prior to analysis, the larval abundances were $\log(x+1)$ transformed to reduce the weighting of dominant species, and the similarity matrices used were based on the Bray–Curtis similarity index. The similarity percentage routine (SIMPER) was applied to the data to identify the species characteristic of each larval fish assemblage.

Detrended correspondence analysis (DCA) was performed, and showed lengths of gradients $>3$ (spring=4.803; autumn=4.038) that indicate an unimodal trend (ter Braak, 1994). Based on the DCA results, canonical correspondence analysis (CCA) using CANOCO 4.5 was employed to investigate the relationships between larval fish and their environment (ter Braak and Verdonschot, 1995). Larval abundances were $\log(x+1)$ transformed to reduce the weighting of dominant species. Taxa with a frequency of occurrence of less than 10% were eliminated, and rare taxa were down weighted prior to analysis. Five environmental variables, temperature and salinity at

25 m depth, zooplankton biovolume, station depth and subarea, were represented. The temperature (°C), salinity, zooplankton biovolume (ml m$^{-3}$) and station depth (m) were measured directly as continuous variables. Subareas were coded as the nominal variables, north and south, for which a value of 1 signified the appropriate subarea. The Monte Carlo permutation test (9999 unrestricted permutations) was used for forward stepwise selection of variables ($p < 0.05$). Statistical significance of the first four axes and of the sum of all constrained eigenvalues of the CCA model were also tested.

## 3. Results

### 3.1. Monthly distributions of properties

#### 3.1.1. Mean monthly distributions of winds, currents, sea surface heights and temperatures

Figs. 2 and 3 present the mean monthly vectors of surface wind stress and currents at 25 m and 317 m, and distributions of sea surface height and temperature at 25 m and 317 m, in November



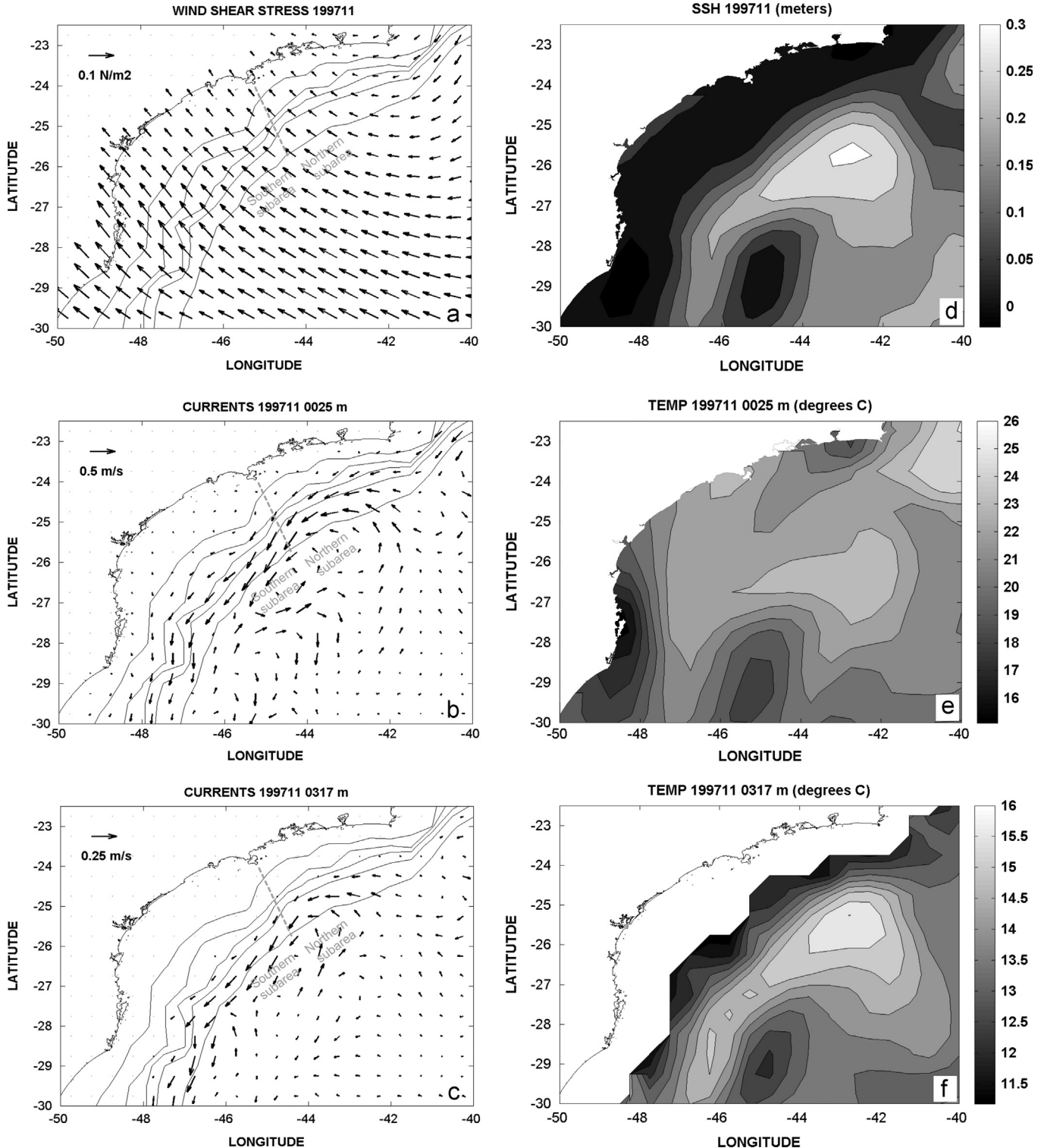**Fig. 2.** Monthly mean vectors of surface wind stress (a), currents at 25 m (b) and 317 m (c), and monthly mean distributions of sea surface height (d) and temperature at 25 m (e) and 317 m (f), in November 1997, as computed by the SODA project.
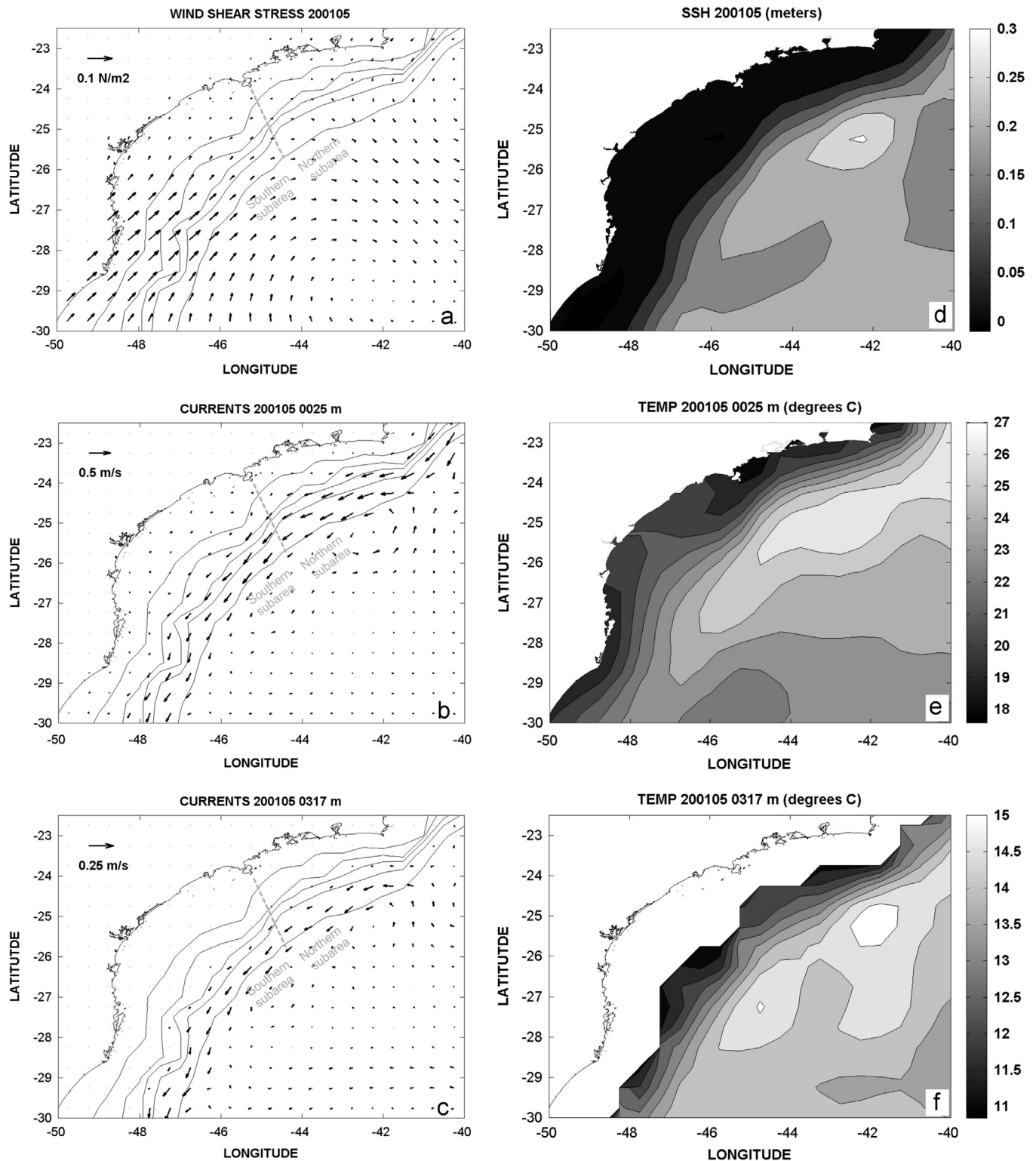
**Fig. 3.** Monthly mean vectors of surface wind stress (a), currents at 25 m (b) and 317 m (c), and monthly mean distributions of sea surface height (d) and temperature at 25 m (e) and 317 m (f), in May 2001, as computed by the SODA project.

1997 and May 2001, respectively, as given by SODA Project. In November 1997, the wind stress was from NE north to 23°S and from E-SE south to 23°S (typical of the summer season) (Fig. 2a). The currents at 25 m present the BC with several eddies and re-circulations, especially between 24°S and 29°S of SBB (Fig. 2b). At 317 m, only at latitudes below 24°S there is an organized flow of SACW towards the south, with weak re-circulation cells (Fig. 2c).

Two main eddies detected in the currents maps at 25 m depth (Fig. 2b), centered on 25.5°S 43°W and 28.5°S 45°W, are also detected in the distributions of sea surface heights (Fig. 2d) and temperatures at 25 m (Fig. 2e), around their extreme values; the weakening of the eddies at 317 m is observed on both currents map (Fig. 2c) and temperature distribution (Fig. 2f). Conversely, in May 2001, the wind stress had features of the winter season and

was from SW in the shelf south to 26°S (Fig. 3a), due to the influence of cold fronts, and was highly variable in the remaining part of the SSB. Consequently, the BC was weakened towards the south, and so were its eddies. Similar observations are made for the SACW flow (Fig. 3b, c). In autumn, only one main eddy is seen in the currents maps at 25 m depth (Fig. 3b), centered on 25°S 42.5°W, and it is also present in the distributions of sea surface heights (Fig. 3d) and temperatures at 25 m (Fig. 3e), around its extreme values, being weaker in the respective maps of currents and temperature at 317 m (Fig. 3c and f).

### 3.1.2. Measurements of temperature and salinity

During spring, the temperature at the 15 m layer ranged from 17.7 °C to 25.4 °C. The horizontal distribution pattern (Fig. 4a) showed that almost the whole area was occupied by waters warmer than 22 °C. However, temperatures $< 22$ °C were also observed along the northern shelf zone, and a nucleus of $< 18$ °C was observed off Rio de Janeiro. The minimum value observed at the northern was 17.7 °C, and 21.4 °C at the southern. The thermal structure of autumn (Fig. 4b) differed from the spring, presenting a slight increase in the values of the minimum temperature. A range from 20 °C to 26.8 °C was observed. A large tongue of water warmer than 26 °C was also observed offshore of the northern area (Fig. 4b).

In general, the vertical structure of the water column was stratified in both seasons (Fig. 5) and was characterized by a warmer layer at the surface that was separated from the colder water at the bottom ($< 18$ °C) by a variable thermocline. The position of the thermocline changed especially at the continental shelf. In the spring it was shallower (20–60 m) (Fig. 5a) and, during the autumn, it was under 60 m in the northern subarea (Fig. 5b). The mixed layer occupied the entire water column on the southern continental shelf during autumn (Fig. 5b).

During spring, the salinity at the 15 m layer ranged from 35.0 to 37.3. Overall, salinity values higher than 36 predominated in the oceanic zone of northern subarea, whereas most of the southern subarea was characterized by salinity lower than 36 (Fig. 4c). A filament of salinity $< 35$ was observed in the coastal zone approximately from Santos to Florianópolis (Fig. 4c). The salinity in the southern subarea was lower than in the northern subarea, and a gradient on-offshore was evident, with lower salinity values along the shelf zone and higher values along the oceanic zone. In the autumn, the haline structure observed for the entire area was very similar to that observed in spring, but with lower minimum (33.7) and slightly higher maximum (37.5) (Fig. 4d). Salinity was higher in the northern than in the southern subarea. A large extension of the northern part was occupied by waters of salinity $> 37.0$. On the other hand, the southern part was characterized by the presence of waters of salinity $< 35.5$. In terms of the distance from the coast, the waters of the shelf zone presented lower salinity values than the transition and oceanic zones (Fig. 4d).

### 3.1.3. Water masses

The T–S diagrams showed the presence of three water masses in the study area, Coastal Water (CW), Tropical Water (TW) and South Atlantic Central Water (SACW). The distribution of the T–S pairs also indicated mixing processes between them (Figs. 6 and 7).

The interaction between the TW and SACW kept the same pattern in both seasons in the northern and the southern subareas (Figs. 6 and 7). On the other hand, the influence of CW seemed to be higher in the southern subarea, due to the presence of waters with low salinity ($< 34$).

High variations in the T–S pairs distribution were observed with increasing distance from the coast (Figs. 6 and 7). The

influence of TW was lower in the composition of the water masses of the shallower zone, mainly at the southern subarea, and became progressively greater toward the transition and oceanic zones. The mixing of CW and SACW that was observed in the shallower zone also occurred in the southern transition zone, but with less intensity. The contribution of SACW was low in the shallower zone, but increased toward the oceanic zone.

### 3.2. Taxonomic composition

Overall 15,184 fish larvae, representing 188 taxonomic groups, were collected in the study area. This included 6984 larvae (144 taxa) collected during the spring cruise and 8195 larvae (130 taxa) collected during the autumn cruise (Table 1). Of the total larvae collected, unidentified or damaged specimens accounted for approximately 11% in spring and 25% in autumn. The mean abundance of larvae was 107.49 larvae m$^{-2}$ (sd = 79.96) in the spring and 84.63 larvae m$^{-2}$ (sd = 71.20) in autumn.

The number of species identified in the total area was 98 during the spring and 89 in autumn (Table 2). The highest values of richness were observed in the transition zone in spring and in the transition and oceanic zones in autumn. A gradient of increasing diversity values from the shelf toward the ocean, was also detected (Table 2).

The presence and abundance of the most abundant species in the spring and autumn, both in the northern and southern subareas, are summarized in Fig. 8. During spring, the shelf zone was dominated by small pelagic species, especially *Engraulis anchoita* (27.30 larvae m$^{-2}$; sd = 45.71) and *Sardinella brasiliensis* (11.42 larvae m$^{-2}$; sd = 24.85), although *Maurolicus stehmanni,* a bathypelagic species, and *Trachurus lathami,* a benthopelagic one, were also conspicuous in the north shelf zone. At the transition zone, *M. stehmanni* was the most abundant species (17.07 larvae m$^{-2}$; sd = 20.95), followed by *Myctophum affine* at the northern subarea and *S. brasiliensis*, *E. anchoita* and *Bregmaceros cantori* at the southern subarea. In the oceanic zone, bathypelagic species were the most abundant and were dominated by *M. stehmanni,* in the north and *Cyclothone sp.* in the south.

During autumn, the abundance of pelagic species in the shelf decreased. The abundance of *E. anchoita* was reduced to 4.55 larvae m$^{-2}$ (sd = 9.80), while the mesopelagic *B. cantori* (18.87 larvae m$^{-2}$; sd = 14.27) became dominant in this zone. The transition and oceanic zones were dominated by meso-bathypelagic species, with *M. stehmanni* being the most abundant species (17.07 larvae m$^{-2}$; sd = 27.38; 15.83 larvae m$^{-2}$ sd = 29.04, respectively). A clear increase in the abundance of a reef-associated Scaridae *sp.*1 was observed in the offshore area (Fig. 8).

### 3.3. Assemblage analysis

The ANOSIM test showed significant differences in the larval fish composition among the shelf, transition and oceanic zones ($p < 0.05$) with clear group distinctions during spring (Global $R = 0.544$) and autumn (Global $R = 0.535$). However, the difference between the oceanic and transition groups was much less evident in the spring ($R = 0.380$), compared to autumn ($R = 0.119$). Although the northern and southern subareas were similar in both cruises ($R < 0.2$), the differences between these two groups were still significant ($p < 0.05$). According to SIMPER analysis (Table 3), during spring, *E. anchoita*, *B. cantori*, *T. lathami*, *S. brasiliensis* and *Saurida caribbea* accounted for most of the similarity ($> 70\%$) for the shelf group, *M. stehmanni*, *Diaphus sp.*, *Auxis sp.*, *M. affine* and *E. anchoita* for the transitional group and *Cyclothone sp.*, *M. stehmanni*, *Diaphus sp.*, *Lepidophanes guentheri* and *Vinciguerria nimbaria* for the oceanic group. In autumn, *B. cantori* accounted for most of the similarity for the shelf group
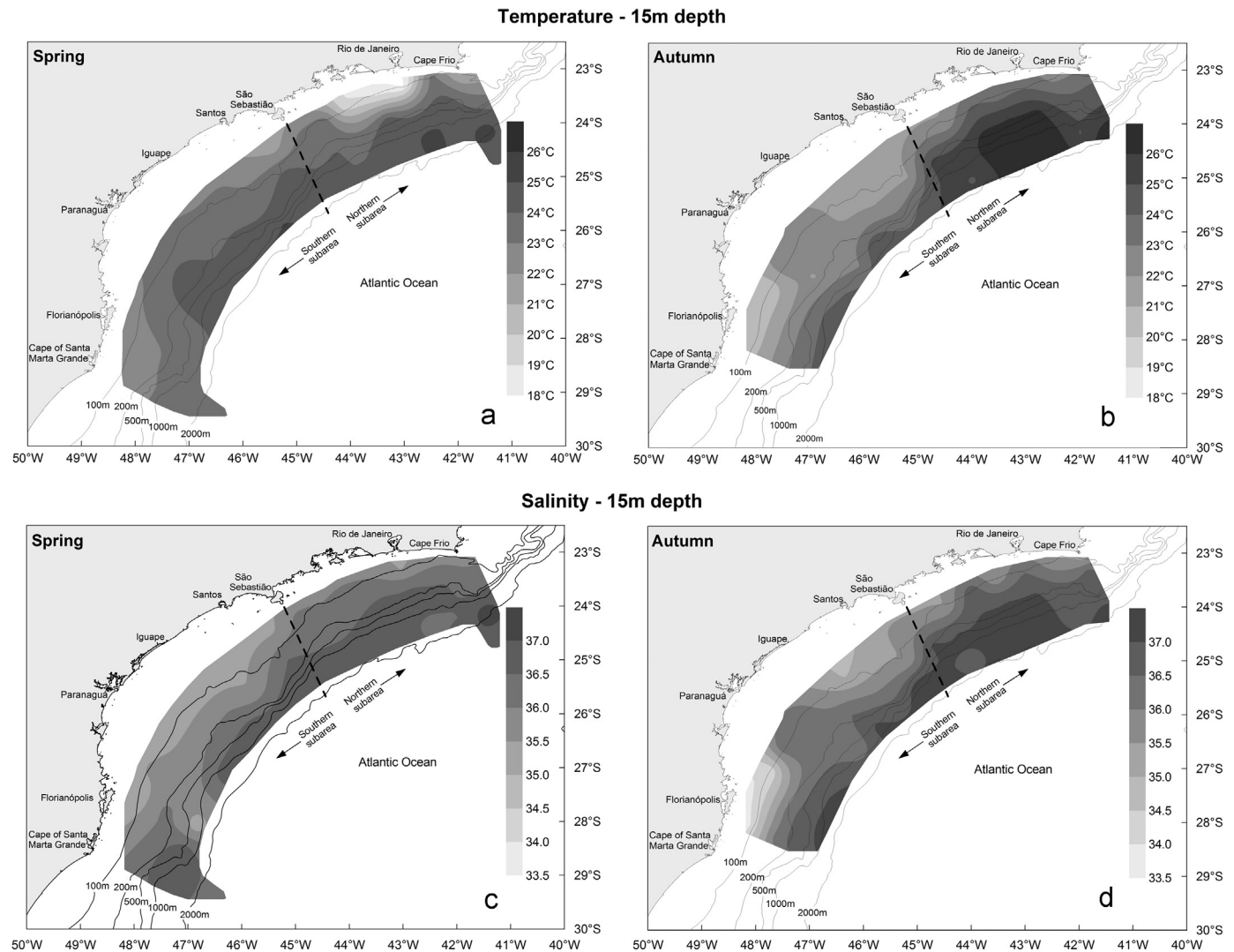
## Temperature - 15m depth



**Fig. 4.** Horizontal sections of temperature (a, b) and salinity (c, d) at 15 m depth, off the Southeastern Brazilian Bight, during spring (November–December/1997) and autumn (May/ 2001).

( > 60%), while *B. atlanticus*, *Diaphus sp.*, *M. stehmanni* and *Pollichthys mauli* represented over 50% of the similarity in the formation of the transition and oceanic groups.

The Monte Carlo test showed significant associations between species abundance and environmental variables (Table 4). Temperature, salinity and northern–southern subareas were significant in both seasons, while station depth were only significant in the spring. Zooplankton biovolume were not significant in any season.

CCA explained more than 29% of the variation in species matrix for spring and 26% in autumn. The results were interpreted considering only the first and second axes, as they explained most of the species data and cumulatively accounted for 81.2% and 88.9% of the species-environment relation variance in spring and autumn, respectively (Table 4). The species were distributed along a clear gradient of salinity and temperature, from shelf, which had lower temperatures and salinity values, to oceanic, which had higher temperatures and salinity values (Fig. 9), in both seasons. Such species as *E. anchoita*, *S. brasiliensis, Paralichthys sp.* and *Lophius gastrophysus* were placed at the right of the diagram, related with to the shallower stations and lower values of temperatures and salinity. Most mictophids and other mesopelagic fishes were placed at the left of the diagram and were related to the deepest stations and higher values of salinity and temperature.

Station depth was important only during spring, reinforcing the shelf-oceanic gradient in this season. The influence of subareas north and south was stronger in autumn than in spring and was depicted along axis 2 of CCA plots (Fig. 9).

## 4. Discussion

The circulation patterns and water masses observed in the study area were similar to previous descriptions for the SSB (Campos et al., 2000, Castelao and Barth, 2006, Castro et al., 2006). The influence of CW on the composition of water masses was lower than TW and SACW, reflecting the characteristic of the study area, which primarily included the shelf break and continental slope, and excluded the continental shelf region shallower than 100 m. The differences in water mass distribution between the seasons was caused by the differences in wind stress and BC meanders and eddies (Campos et al., 2000; Castelao and Barth, 2006), which are mesoscale phenomena with tens of kilometers in radius that extend vertically to 500 m depth (Castro et al., 2006). During spring, the TW contribution to the shelf was low because the predominant NE winds limits the TW intrusion into the shelf, as is usually observed in the summer (Campos et al., 2000;
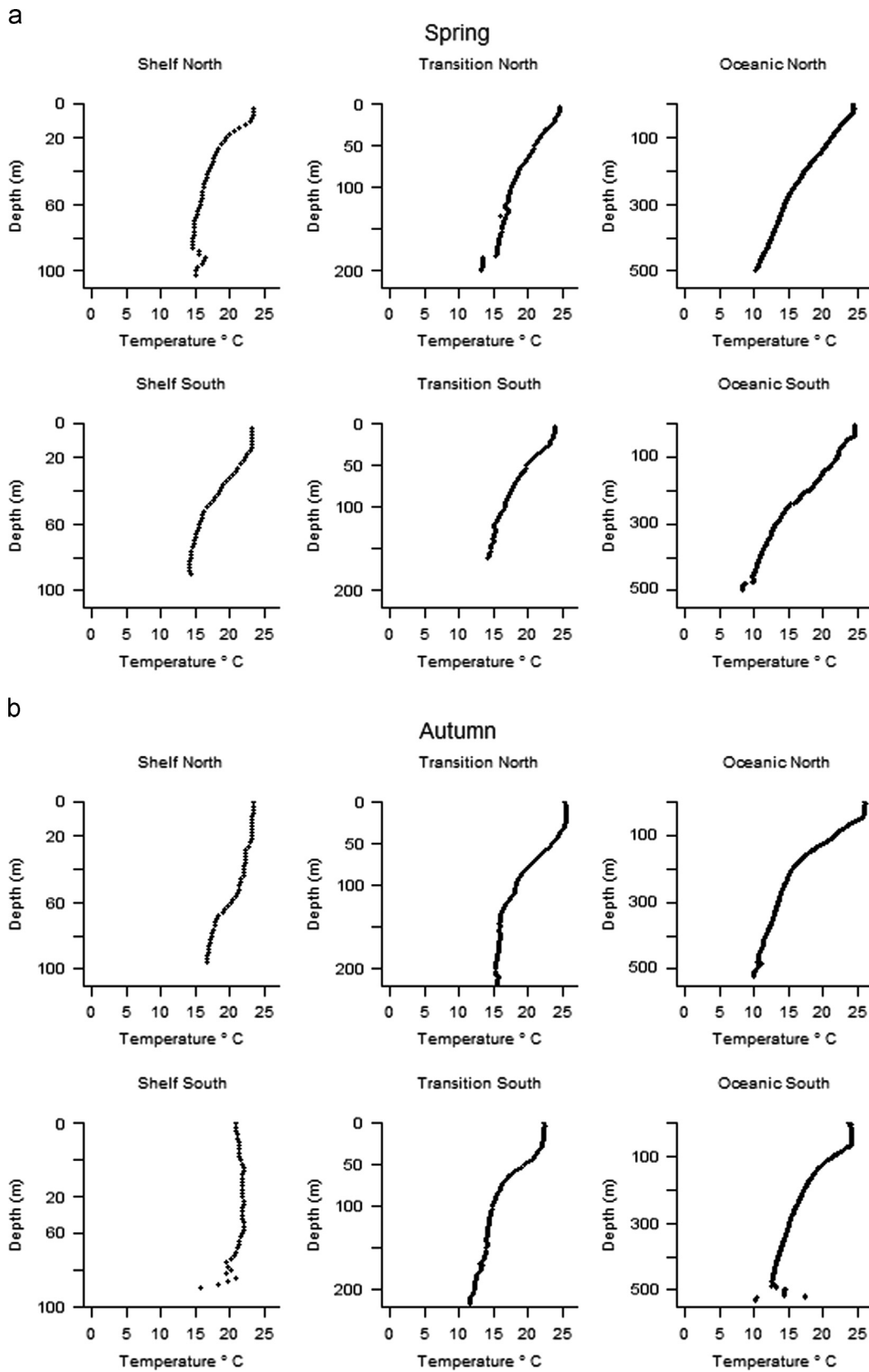
**Fig. 5.** Vertical profiles of mean temperature, during spring (November–December/1997) and autumn (May/2001), off the Southeastern Brazilian Bight.

Castelao and Barth, 2006). Furthermore, the cyclonic meanders of the BC at the shelf break and slope induce upward motions, bringing the SACW to shallower depths, where it is influenced by the wind and penetrates all the way to the coast (Castelao et al.,

2004). Although the eddies of BC are common on the mid- and outer shelf throughout the year (Kampel et al., 2000), during autumn, a reversal of the wind direction usually occurs and is more favorable to the TW subsidence and spread towards the shelf
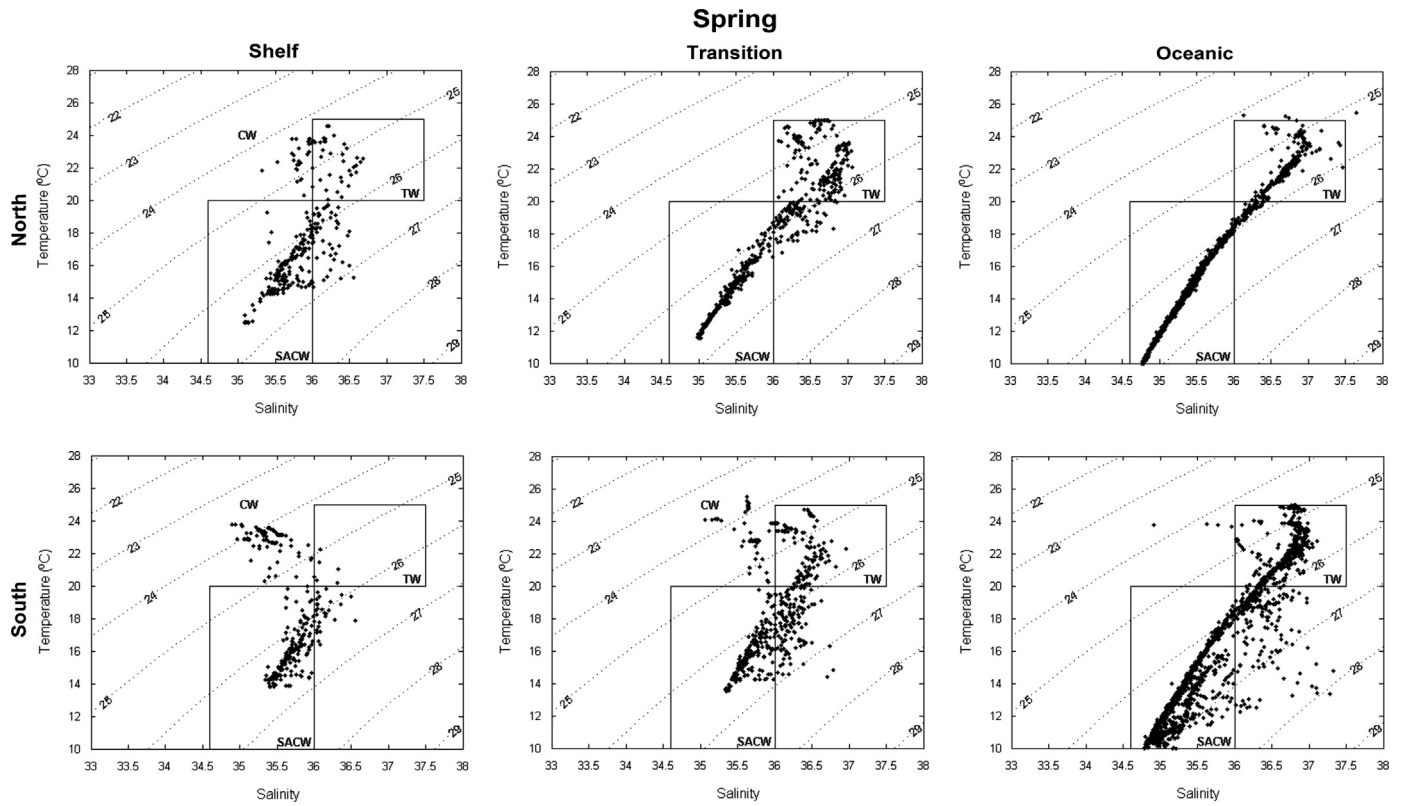
## Spring



**Fig. 6.** T–S diagram contoured in $\sigma_t$ values regarding the shelf (a, d), transition (b, e) and oceanic (c, f) zones from the northern and southern subareas off the Southeastern Brazilian Bight during spring (November–December/1997).
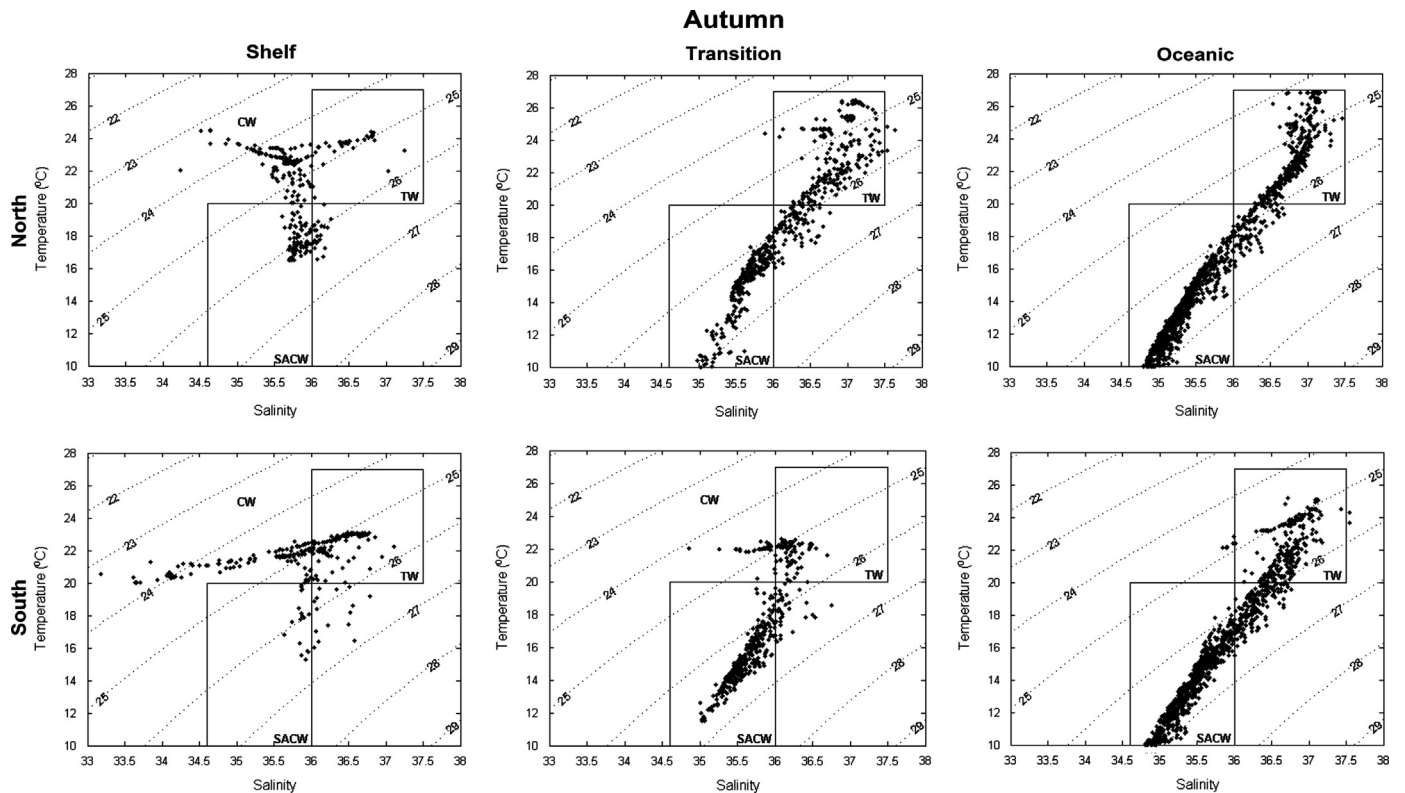
## Autumn



**Fig. 7.** T–S diagram contoured in $\sigma_t$ values regarding the shelf (a, d), transition (b, e) and oceanic (c, f) zones from the northern and southern subareas off the Southeastern Brazilian Bight during autumn (May/2001).

(Castelao and Barth, 2006). It also enhances the contribution of TW to the shelf zone, while the SACW retreats to near the shelf break (Campos et al., 2000).

The positions of meanders and eddy-like features in SODA maps of currents, sea surface height and temperature (Figs. 2 and 3) are not exactly coincident neither with those in the temperature maps

**Table 1**
Taxonomic composition, frequency of occurrence (FO%) and mean abundance of larval fish (larvae m$^{-2}$) off the Southeastern Brazilian Bight, during spring (November–December/1997) and autumn (May/2001).

| | Taxa | Spring | | | Autumn | | |
|---|---|---|---|---|---|---|---|
| | | FO | Mean | sd | FO | Mean | sd |
| Muraenidae | *Gymnothorax ocellatus* | 2.1 | 0.01 | 0.09 | – | – | – |
| Muraenidae | Other Muraenidae | 6.4 | 0.05 | 0.18 | 4.35 | 0.02 | 0.09 |
| Synaphobranchidae | Synaphobranchidae | – | – | – | 4.35 | 0.03 | 0.12 |
| Ophichthidae | *Ophichthus gomesi* | 4.3 | 0.11 | 0.57 | 4.35 | 0.04 | 0.20 |
| Ophichthidae | Other Ophichthidae | 10.6 | 0.09 | 0.29 | 15.22 | 0.22 | 0.73 |
| Congridae | Congridae | 19.1 | 0.21 | 0.51 | 52.17 | 0.54 | 0.65 |
| Nettastomatidae | *Hoplunnis sp.* | 2.1 | 0.02 | 0.10 | 10.87 | 0.07 | 0.24 |
| Nettastomatidae | *Hoplunnis tenuis* | – | – | – | 2.17 | 0.03 | 0.18 |
| Nettastomatidae | *Saurenchelys sp.* | – | – | – | 13.04 | 0.15 | 0.43 |
| Nettastomatidae | Other Nettastomatidae | – | – | – | 2.17 | 0.01 | 0.09 |
| Engraulidae | *Engraulis anchoita* | 40.4 | 10.18 | 29.20 | 26.09 | 1.61 | 5.86 |
| Clupeidae | *Harengula jaguana* | 6.4 | 0.15 | 0.79 | 6.52 | 0.04 | 0.18 |
| Clupeidae | *Sardinella brasiliensis* | 25.5 | 4.96 | 16.44 | 2.17 | 0.07 | 0.45 |
| Argentinidae | *Argentina striata* | 21.3 | 0.25 | 0.61 | 6.52 | 0.07 | 0.26 |
| Sternopthychidae | *Maurolicus stehmanni* | 57.4 | 13.46 | 25.83 | 52.17 | 22.86 | 41.75 |
| Sternopthychidae | *Argyropelecus sp.* | – | – | – | 2.17 | 0.01 | 0.09 |
| Sternopthychidae | Other Sternopthychidae | 10.6 | 0.16 | 0.53 | 15.22 | 0.58 | 2.55 |
| Gonostomatidae | *Cyclothone sp.* | 51.1 | 4.75 | 7.52 | 4.35 | 0.04 | 0.20 |
| Gonostomatidae | *Gonostoma elongatum* | 2.1 | 0.04 | 0.24 | 4.35 | 0.08 | 0.42 |
| Gonostomatidae | *Gonostoma sp.* | 2.1 | 0.01 | 0.10 | 4.35 | 0.10 | 0.50 |
| Gonostomatidae | Other Gonostomatidae | 14.9 | 0.18 | 0.50 | 6.52 | 0.03 | 0.11 |
| Phosichthydae | *Ichthyococcus ovatus* | 2.1 | 0.01 | 0.07 | – | – | – |
| Phosichthydae | *Pollichthys mauli* | 31.9 | 1.48 | 3.89 | 47.83 | 2.47 | 3.88 |
| Phosichthydae | *Vinciguerria nimbaria* | 23.4 | 1.95 | 4.91 | 36.96 | 1.09 | 2.78 |
| Phosichthydae | Other Phosichthyidae | 17.0 | 0.79 | 2.36 | 26.09 | 1.49 | 2.66 |
| Stomiidae | *Aristostomias sp.* | 4.3 | 0.03 | 0.16 | – | – | – |
| Stomiidae | *Eustomias sp.* | 2.1 | 0.02 | 0.10 | 4.35 | 0.02 | 0.11 |
| Stomiidae | *Idiacanthus sp.* | – | – | – | 2.17 | 0.01 | 0.09 |
| Stomiidae | *Stomias sp.* | 12.8 | 0.14 | 0.44 | 10.87 | 0.13 | 0.47 |
| Stomiidae | Other Stomiidae | – | – | – | 10.87 | 0.04 | 0.21 |
| Scopelarchidae | *Scopelarchoides danae* | 4.3 | 0.02 | 0.12 | – | – | – |
| Scopelarchidae | *Scopelarchus sp.* | – | – | – | 8.70 | 0.12 | 0.47 |
| Chlorophthalmidae | *Chlorophthalmus agassizi* | – | – | – | 4.35 | 0.07 | 0.41 |
| Notosudidae | *Scopelosaurus sp.* | – | – | – | 4.35 | 0.10 | 0.54 |
| Evermannellidae | *Coccorella atlantica* | 2.1 | 0.02 | 0.11 | 6.52 | 0.11 | 0.48 |
| Synodontidae | *Saurida caribbea* | 36.2 | 0.97 | 1.79 | 15.22 | 0.36 | 1.24 |
| Synodontidae | *Synodus synodus* | – | – | – | 6.52 | 0.04 | 0.14 |
| Synodontidae | *Trachinocephalus myops* | 2.1 | 0.01 | 0.07 | 15.22 | 0.13 | 0.33 |
| Synodontidae | other Synodontidae | – | – | – | 6.52 | 0.03 | 0.13 |
| Paralepididae | *Lestidiops jayakari* | 10.6 | 0.12 | 0.39 | – | – | – |
| Paralepididae | *Lestidiops affinis* | 10.6 | 0.26 | 1.06 | – | – | – |
| Paralepididae | *Lestidium atlanticum* | – | – | – | 26.09 | 0.35 | 0.82 |
| Paralepididae | *Lestrolepis intermedia* | – | – | – | 4.35 | 0.05 | 0.30 |
| Paralepididae | *Lestrolepis sp.* | 6.4 | 0.05 | 0.18 | 17.39 | 0.82 | 2.08 |
| Paralepididae | *Macroparalepis sp.* | – | – | – | 8.70 | 0.10 | 0.33 |
| Paralepididae | *Paralepis atlantica* | 2.1 | 0.01 | 0.07 | – | – | – |
| Paralepididae | *Stemonosudis sp.* | 6.4 | 0.07 | 0.14 | 19.57 | 0.85 | 3.32 |
| Paralepididae | *Sudis atrox* | 6.4 | 0.06 | 0.26 | 2.17 | 0.04 | 0.25 |
| Paralepididae | *Uncisudis advena* | 8.5 | 0.05 | 0.16 | 4.35 | 0.03 | 0.16 |
| Paralepididae | other Paralepididae | 12.8 | 0.16 | 0.43 | 8.70 | 0.26 | 1.30 |
| Myctophidae | *Benthosema suborbitale* | 12.8 | 0.15 | 0.43 | 10.87 | 0.09 | 0.28 |
| Myctophidae | *Bolinichthys spp.* | 4.3 | 0.04 | 0.19 | 2.17 | 0.03 | 0.17 |
| Myctophidae | *Diaphus spp.* | 53.2 | 5.11 | 8.95 | 63.04 | 4.64 | 7.12 |
| Myctophidae | *Hygophum bruuni* | 12.8 | 0.14 | 0.45 | – | – | – |
| Myctophidae | *Hygophum hygomii* | 14.9 | 0.32 | 1.13 | 36.96 | 1.33 | 2.98 |
| Myctophidae | *Hygophum reinhardtii* | 6.4 | 0.31 | 1.52 | 6.52 | 0.08 | 0.41 |
| Myctophidae | *Hygophum spp.* | 14.9 | 0.33 | 0.92 | – | – | – |
| Myctophidae | *Lampadena luminosa* | – | – | – | 4.35 | 0.17 | 1.05 |
| Myctophidae | *Lampanyctus spp.* | 17.0 | 0.20 | 0.51 | 32.61 | 0.74 | 1.56 |
| Myctophidae | *Lepdophanes guentheri* | 27.7 | 2.81 | 7.52 | 36.96 | 3.07 | 8.10 |
| Myctophidae | *Lepdophanes sp.* | 2.1 | 0.28 | 1.91 | – | – | – |
| Myctophidae | *Lobianchia gemellarii* | 10.6 | 0.23 | 0.78 | 2.17 | 0.01 | 0.08 |
| Myctophidae | *Myctophum affine* | 46.8 | 2.80 | 7.68 | 39.13 | 1.21 | 2.96 |
| Myctophidae | *Myctophum obtusirostre* | 2.1 | 0.03 | 0.23 | 13.04 | 0.13 | 0.36 |
| Myctophidae | *Myctophum selenops* | 17.0 | 0.65 | 2.19 | 6.52 | 0.12 | 0.45 |
| Myctophidae | *Myctophum spp.* | 8.5 | 0.43 | 2.37 | 4.35 | 0.11 | 0.67 |
| Myctophidae | *Notolychnus valdiviae* | 19.1 | 0.40 | 1.14 | – | – | – |
| Myctophidae | *Symbolophorus sp.* | 4.3 | 0.12 | 0.68 | 2.17 | 0.02 | 0.13 |
| Myctophidae | Other Myctophidae | 61.7 | 31.01 | 39.11 | 69.57 | 14.74 | 19.06 |
| Lamprididae | *Lampris guttatus* | 2.1 | 0.02 | 0.12 | – | – | – |
| Lamprididae | Other Lamprididae | 2.1 | 0.24 | 1.61 | – | – | – |
| Carapidae | Carapidae | 6.4 | 0.05 | 0.20 | 13.04 | 0.14 | 0.39 |

**Table 1** (continued)

| | Taxa | Spring | | | Autumn | | |
|---|---|---|---|---|---|---|---|
| | | FO | Mean | sd | FO | Mean | sd |
| Ophidiidae | Ophidiidae sp.1 | 21.3 | 0.43 | 1.36 | 2.17 | 0.01 | 0.07 |
| Ophidiidae | Ophidiidae sp.2 | 17.0 | 0.44 | 1.99 | 2.17 | 0.01 | 0.06 |
| Ophidiidae | Ophidiidae sp.3 | 2.1 | 0.01 | 0.10 | – | – | – |
| Ophidiidae | Ophidiidae sp.4 | – | – | – | 2.17 | 0.01 | 0.08 |
| Ophidiidae | *Lepophidium sp.* | – | – | – | 2.17 | 0.03 | 0.21 |
| Ophidiidae | other Ophidiidae | 8.5 | 0.07 | 0.23 | 2.17 | 0.02 | 0.12 |
| Macrouridae | Macrouridae sp.1 | 2.1 | 0.03 | 0.18 | 2.17 | 0.02 | 0.10 |
| Macrouridae | Macrouridae sp.2 | 4.3 | 0.06 | 0.30 | – | – | – |
| Macrouridae | Macrouridae sp.3 | 2.1 | 0.01 | 0.10 | – | – | – |
| Macrouridae | Macrouridae sp.4 | – | – | – | 4.35 | 0.04 | 0.21 |
| Macrouridae | Other Macrouridae | – | – | – | 2.17 | 0.02 | 0.11 |
| Phycidae | *Urophycis sp.* | 2.1 | 0.02 | 0.14 | 26.09 | 1.02 | 2.49 |
| Bregmacerotidae | *Bregmaceros atlanticus* | 29.8 | 0.60 | 1.13 | 47.83 | 3.27 | 6.25 |
| Bregmacerotidae | *Bregmaceros cantori* | 29.8 | 2.10 | 5.06 | 54.35 | 7.11 | 14.27 |
| Merlucciidae | *Merluccius hubbsi* | 19.1 | 0.20 | 0.52 | – | – | – |
| Moridae | Moridae | – | – | – | 2.17 | 0.02 | 0.10 |
| Lophiidae | *Lophyus gastrophysus* | 12.8 | 0.13 | 0.36 | – | – | – |
| Antennariidae | Antennariidae | – | – | – | 4.35 | 0.04 | 0.22 |
| Mugilidae | Mugilidae | 4.3 | 0.03 | 0.13 | 15.22 | 0.21 | 0.60 |
| Exocoetidae | *Cypcelurus sp.* | 6.4 | 0.06 | 0.23 | – | – | – |
| Exocoetidae | Other Exocoetidae | – | – | – | 2.17 | 0.01 | 0.08 |
| Melamphaidae | *Melamphaes sp.* | 2.1 | 0.01 | 0.07 | 6.52 | 0.04 | 0.17 |
| Holocentridae | Holocentridae | 2.1 | 0.01 | 0.10 | – | – | – |
| Zeidae | *Zenopsis conchifer* | 2.1 | 0.02 | 0.10 | – | – | – |
| Caproidae | *Antigonia capros* | 2.1 | 0.01 | 0.09 | 15.22 | 0.25 | 0.87 |
| Aulostomidae | Aulostomidae | 2.1 | 0.01 | 0.08 | – | – | – |
| Fistulariidae | Fistularidae | 2.1 | 0.02 | 0.11 | – | – | – |
| Syngnathidae | Syngnathidae | – | – | – | 4.35 | 0.03 | 0.15 |
| Scorpaenidae | Scorpaenidae sp.1 | 10.6 | 0.31 | 1.00 | 15.22 | 0.11 | 0.30 |
| Scorpaenidae | Scorpaenidae sp.2 | – | – | – | 19.57 | 0.19 | 0.40 |
| Scorpaenidae | Scorpaenidae sp.3 | 2.1 | 0.02 | 0.13 | – | – | – |
| Scorpaenidae | other Scorpaenidae | 4.3 | 0.12 | 0.74 | 15.22 | 0.16 | 0.49 |
| Triglidae | *Bellator sp.* | 2.1 | 0.02 | 0.17 | – | – | – |
| Triglidae | other Triglidae | 12.8 | 0.39 | 1.35 | 6.52 | 0.04 | 0.13 |
| Acropomatidae | *Synagrops spinosus* | 12.8 | 0.35 | 1.06 | 19.57 | 0.38 | 1.01 |
| Acropomatidae | Other Acropomatidae | – | – | – | 4.35 | 0.04 | 0.21 |
| Serranidae | Serraninae | 14.9 | 0.21 | 0.70 | 17.39 | 0.29 | 0.84 |
| Serranidae | Anthinae | 12.8 | 0.81 | 3.08 | 6.52 | 0.07 | 0.26 |
| Serranidae | Epinephelinae | 2.1 | 0.01 | 0.08 | – | – | – |
| Serranidae | Grammistinae | 2.1 | 0.01 | 0.09 | – | – | – |
| Serranidae | Other Serranidae | 2.1 | 0.02 | 0.12 | 2.17 | 0.08 | 0.56 |
| Priacanthidae | *Priacanthus sp.* | 2.1 | 0.01 | 0.07 | 2.17 | 0.06 | 0.41 |
| Malacanthidae | *Caulolatilus sp.* | 2.1 | 0.02 | 0.10 | – | – | – |
| Pomatomidae | *Pomatomus saltatrix* | 2.1 | 0.01 | 0.09 | – | – | – |
| Echeneidae | Echeneidae | – | – | – | 15.22 | 0.17 | 0.54 |
| Coryphaenidae | *Coryphaena hipurus* | 19.1 | 0.15 | 0.34 | 8.70 | 0.05 | 0.18 |
| Coryphaenidae | Other Coryphaenidae | 2.1 | 0.03 | 0.24 | – | – | – |
| Carangidae | *Chloroschombrus crysurus* | 4.3 | 0.04 | 0.18 | – | – | – |
| Carangidae | *Decapterus punctatus* | 4.3 | 0.03 | 0.14 | – | – | – |
| Carangidae | *Naucrates ductor* | – | – | – | 6.52 | 0.04 | 0.16 |
| Carangidae | *Selene setapinnis* | 2.1 | 0.01 | 0.07 | – | – | – |
| Carangidae | *Trachurus lathami* | 40.4 | 2.00 | 5.19 | 4.35 | 0.02 | 0.09 |
| Carangidae | other Carangidae | 10.6 | 0.27 | 0.87 | – | – | – |
| Gerreidae | *Eucinostomus sp.* | 2.1 | 0.03 | 0.23 | – | – | – |
| Gerreidae | Other Gerreidae | 2.1 | 0.15 | 1.03 | 4.35 | 0.05 | 0.30 |
| Sparidae | *Archosargus rhomboidalis* | 2.1 | 0.01 | 0.08 | – | – | – |
| Sciaenidae | Sciaenidae | 8.5 | 0.21 | 0.73 | 4.35 | 0.47 | 3.10 |
| Mullidae | Mulus argentinae | 12.8 | 0.25 | 0.99 | – | – | – |
| Mullidae | Other Mullidae | 19.1 | 0.26 | 0.72 | 13.04 | 0.16 | 0.58 |
| Labridae | Labridae sp.1 | – | – | – | 6.52 | 0.09 | 0.41 |
| Labridae | Labridae sp.2 | – | – | – | 2.17 | 0.01 | 0.06 |
| Labridae | Labridae sp.3 | 2.1 | 0.02 | 0.15 | 2.17 | 0.03 | 0.18 |
| Scaridae | Scaridae sp.1 | 10.6 | 0.07 | 0.20 | 36.96 | 3.41 | 12.47 |
| Scaridae | Other Scaridae | 2.1 | 0.02 | 0.11 | 2.17 | 0.02 | 0.10 |
| Chiasmodontidae | *Chiasmodon sp.* | 2.1 | 0.02 | 0.16 | 10.87 | 0.13 | 0.54 |
| Chiasmodontidae | *Kali sp.* | 6.4 | 0.07 | 0.33 | – | – | – |
| Chiasmodontidae | Other Chiasmodontidae | 2.1 | 0.02 | 0.15 | – | – | – |
| Pinguipedidae | Pinguipididae | 2.1 | 0.07 | 0.51 | – | – | – |
| Percophidae | Percophidae | 2.1 | 0.02 | 0.17 | – | – | – |
| Uranoscopidae | *Astroscopus y-graecum* | 2.1 | 0.02 | 0.15 | – | – | – |
| Blenniidae | Blenniidae | 4.3 | 0.05 | 0.29 | 4.35 | 0.04 | 0.18 |
| Callionymidae | Callionymidae sp.1 | – | – | – | 17.39 | 0.22 | 0.59 |
| Callionymidae | Callionymidae sp.2 | – | – | – | 4.35 | 0.13 | 0.68 |
| Callionymidae | Other Callionymidae | 2.1 | 0.01 | 0.09 | 6.52 | 0.05 | 0.18 |

**Table 1** (*continued*)

| Taxa | | Spring | | | Autumn | | |
|------|--|--------|--|--|--------|--|--|
| | | FO | Mean | sd | FO | Mean | sd |
| Gobiidae | Gobiidae sp.1 | 4.3 | 0.05 | 0.29 | 10.87 | 0.07 | 0.20 |
| Gobiidae | Gobiidae sp.2 | – | – | – | 2.17 | 0.03 | 0.18 |
| Gobiidae | Gobiidae sp.3 | 2.1 | 0.02 | 0.15 | 8.70 | 0.11 | 0.39 |
| Gobiidae | Gobiidae sp.4 | – | – | – | 6.52 | 0.11 | 0.48 |
| Gobiidae | Gobiidae sp.5 | 2.1 | 0.04 | 0.28 | 4.35 | 0.03 | 0.13 |
| Gobiidae | Other Gobiidae | 8.5 | 0.06 | 0.19 | 8.70 | 0.07 | 0.26 |
| Microdesmidae | Microdesmidae | – | – | – | 2.17 | 0.01 | 0.08 |
| Luvaridae | Luvaridae | 2.1 | 0.01 | 0.08 | – | – | – |
| Acanthuridae | Acanthuridae | 2.1 | 0.02 | 0.13 | – | – | – |
| Sphyraenidae | Sphyraenidae | 2.1 | 0.03 | 0.24 | – | – | – |
| Scombrolabracidae | Scombrolabracidae | – | – | – | 2.17 | 0.02 | 0.10 |
| Gempylidae | Other Gempylidae | 6.4 | 0.08 | 0.37 | – | – | – |
| Gempylidae | *Thyrsitops lepidopoides* | – | – | – | 2.17 | 0.03 | 0.21 |
| Trichiuridae | *Benthodesmus sp.* | 2.1 | 0.01 | 0.09 | 26.09 | 0.61 | 1.40 |
| Trichiuridae | *Lepidopus sp.1* | 6.4 | 0.05 | 0.19 | 10.87 | 0.20 | 0.93 |
| Trichiuridae | *Lepidopus sp.2* | – | – | – | 4.35 | 0.04 | 0.19 |
| Trichiuridae | *Trichiurus lepturus* | 21.3 | 0.27 | 0.66 | 34.78 | 0.35 | 0.56 |
| Trichiuridae | Other Trichiuridae | – | – | – | 2.17 | 0.01 | 0.09 |
| Scombridae | *Allothunnus sp.* | 4.3 | 0.08 | 0.46 | – | – | – |
| Scombridae | *Auxis thazard* | 4.3 | 0.10 | 0.57 | – | – | – |
| Scombridae | *Auxis spp.* | 38.3 | 4.52 | 12.27 | – | – | – |
| Scombridae | *Thunnus sp.* | 2.1 | 0.29 | 2.02 | – | – | – |
| Scombridae | Other Scombridae | 12.8 | 1.18 | 5.28 | 8.70 | 0.06 | 0.19 |
| Ariommatidae | *Arioma bondi* | 27.7 | 1.25 | 3.39 | – | – | – |
| Ariommatidae | Other Ariommatidae | 4.3 | 0.10 | 0.56 | – | – | – |
| Bothidae | *Bothus ocellatus* | 19.1 | 0.42 | 1.60 | 43.48 | 0.98 | 1.82 |
| Bothidae | *Monolene spp.* | 14.9 | 0.21 | 0.55 | 4.35 | 0.02 | 0.10 |
| Paralichthyidae | *Citharichthys sp.* | – | – | – | 2.17 | 0.02 | 0.12 |
| Paralichthyidae | *Etropus sp.* | 17.0 | 0.97 | 3.35 | 19.57 | 0.78 | 3.07 |
| Paralichthyidae | *Paralichthys sp.* | 14.9 | 0.20 | 0.62 | – | – | – |
| Paralichthyidae | *Syacium papillosum* | 8.5 | 0.08 | 0.29 | 19.57 | 0.21 | 0.49 |
| Paralichthyidae | Other Paralichthydae | 10.6 | 0.09 | 0.26 | 4.35 | 0.03 | 0.16 |
| Cynoglossidae | *Symphurus ginsburgi* | 2.1 | 0.01 | 0.09 | 6.52 | 0.09 | 0.39 |
| Cynoglossidae | *Symphurus kyaropterygium* | 6.4 | 0.15 | 0.81 | – | – | – |
| Cynoglossidae | *Symphurus tessellatus* | 4.3 | 0.02 | 0.12 | – | – | – |
| Cynoglossidae | *Symphurus trewavasae* | 8.5 | 0.11 | 0.42 | – | – | – |
| Cynoglossidae | Other Cynoglossidae | – | – | – | 6.52 | 0.04 | 0.14 |
| Monacanthidae | *Stephanolepis hispidus* | – | – | – | 2.17 | 0.03 | 0.18 |
| Monacanthidae | *Monacanthus ciliatus* | – | – | – | 2.17 | 0.03 | 0.21 |
| Ostracidae | *Lactophrys sp.* | 2.1 | 0.01 | 0.07 | – | – | – |
| Tetraodontidae | *Lagocephalus sp.* | 6.4 | 0.06 | 0.25 | – | – | – |
| Tetraodontidae | Other Tetraodontidae | – | – | – | 4.35 | 0.04 | 0.20 |

(Fig. 4a and 4b). This is due to the different nature of these data (monthly means and instantaneous observations) and to the methodologies used for SODA computations; for example, currents are computed mainly through numerical models while temperatures are mostly satellite observations blended with buoys measurements. Additionally, the predominant forcing effects, such as wind stress, geostrophy and radiation balance, are different for each variable. However, all the sets of results display similar significant spatial variability.

These mesoscale features are considered an important exchange mechanism between coastal and oceanic waters, as they alter the specific composition of the ichthyoplankton assemblages (Wroblewski and Cheney, 1984; Olivar and Shelton, 1993; Franco et al., 2006). As the swimming ability of larvae is limited, some additional mechanisms, such as meanders and eddies, are necessary to enable them to move long distances (Houde, 2009). The result of the present study suggests that mesopelagic larvae, especially *M. stehmanni,* were transported onto the shelf by an eddy of BC, the periphery of which reached the shelf at the northern area during the spring. Weiss et al. (1988) concluded that *M. stehmanni* spawns at continental slopes in onshore moving water masses to maintain the larvae in a favorable retention area between the oceanic and coastal waters. At the Southern Brazilian Shelf, mesopelagic larvae association with TW (Franco and Muelbert, 2003) and an increase in larval fish abundance around the eddy periphery was reported (Franco et al., 2006).

The coastal-ocean pattern in the larval fish distribution observed in the study area was characterized by the predominance of mesopelagic species in the oceanic waters and of epipelagic species in the shelf. Another feature was the decrease in abundance and increase in diversity towards the ocean. This pattern has previously been described for ichthyoplankton and zooplankton in other areas (Olivar and Shelton, 1993; Lopes et al. 2006; Muhling et al., 2008). During spring, the shelf assemblage was dominated by larvae of small pelagic fishes, such as *S. brasiliensis*, *E. anchoita* and *T. lathami.* Small pelagic coastal fishes intensely spawn during the spring and summer (Katsuragawa and Matsuura, 1992; Matsuura, 1998; Katsuragawa and Ekau, 2003, Moraes et al., 2012). The coastal system is connected to the SACW upwelling, which enriches the shallow waters near the coast, enhances planktonic production and varies seasonally (Lopes et al., 2006). Coastal upwelling can occur at any time of the year; however, it is more intense and frequent during the summer (Castelao and Barth, 2006). Many species of epipelagic and demersal fish that occupy the continental shelf are adapted to this situation, and show higher spawning intensity and thus, higher larval abundance, during these intense upwelling periods (Katsuragawa et al., 1993). *Sardinella brasiliensis*, for example, depends on the accumulation of food in the deep chlorophyll maximum layers, which occurs in association with the

**Table 2**
Ecological community indexes off the Southeastern Brazilian Bight, during spring (November–December/1997) and autumn (May/2001) in the total area, shelf (S), transition (T) and oceanic (O) zones.

| Area | Total | Spring | | | Total | Autumn | | |
|---|---|---|---|---|---|---|---|---|
| | | S | T | O | | S | T | O |
| Number of species | 98 | 47 | 64 | 64 | 89 | 39 | 71 | 58 |
| Shannon–Wiener index | 1.309 | 1.003 | 1.123 | 1.205 | 1.179 | 0.801 | 0.973 | 1.158 |
| Equitability | 0.657 | 0.600 | 0.622 | 0.667 | 0.605 | 0.503 | 0.526 | 0.656 |
| Simpson Index | 0.913 | 0.824 | 0.863 | 0.892 | 0.845 | 0.661 | 0.731 | 0.861 |
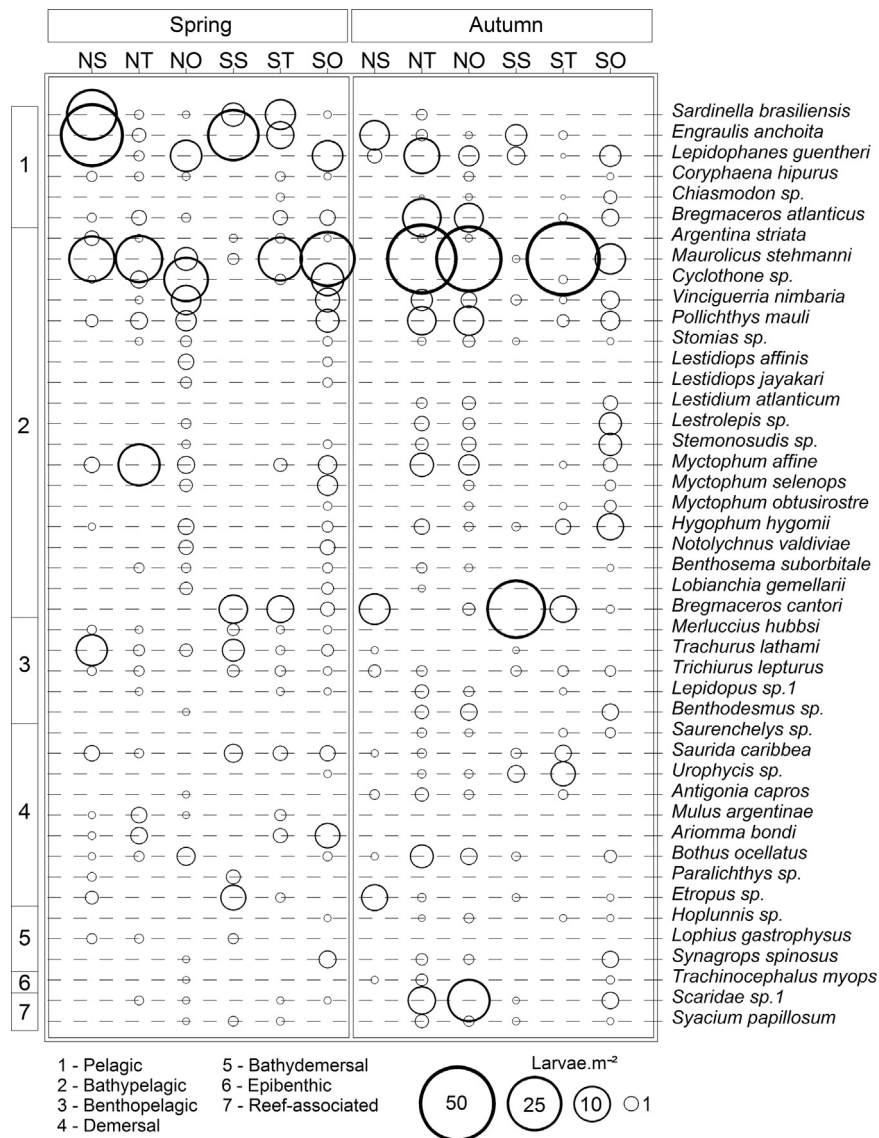


**Fig. 8.** Mean abundance of the most frequent species, classified according to adult position in the water column off the Southeastern Brazilian Bight, during spring (November–December/ 1997) and autumn (May/2001).

nutrient enrichment and water column stability induced by SAWC coastal upwelling (Brandini, 1990; Castro et al., 2006; Moraes et al., 2012; Brandini et al., 2014). In autumn, when hydrographic conditions are similar to the winter, the SACW retreats, and the nutrient input to the continental shelf is directly influenced by fronts and eddies (Gaeta et al., 2006). Therefore, the abundance of coastal species larvae is reduced, and a shelf assemblage with a different composition is formed. This assemblage was dominated by *B. cantori*, which is usually abundant during winter (Matsuura et al., 1993; Namiki et al., 2007), and *Engraulis anchoita*, which shows high levels of larval abundance year-round (Katsuragawa et al., 1993, Matsuura and Kitahara, 1995).

There was also some seasonality within the transitional assemblage, which only occurred during spring. Specifically, it was composed of mesopelagic and coastal species. This assemblage was not observed during autumn because during this season, the abundance of coastal species in the transition zone was very low. Accordingly, mesopelagic species dominated the samples, expanding the oceanic assemblage onto the transition region.

The oceanic assemblage was dominated by the mesopelagic families, Myctophidae, Sternopthychidae and Phosichthyidae, in both seasons. These fishes frequently have protracted spawning seasons or year-round spawning (Gartner, 1993), most likely

**Table 3**
Similarity (%) in taxon contribution for shelf (S), transition (T) and oceanic (O) zones off the Southeastern Brazilian Bight, during spring (November–December/1997) and autumn (May/2001). Higher values (underscored) totaling ~70% of taxa contribution.

| | Spring | | | | Autumn | | |
|---|---|---|---|---|---|---|---|
| | S | T | O | | S | T | O |
| Avarage similarity (%) | 30.47 | 28.64 | 35.07 | Avarage similarity (%) | 36.48 | 33.18 | 37.00 |
| Taxon contribution (%) | | | | Taxon contribution (%) | | | |
| *Engraulis anchoita* | 43.04 | 4.39 | | *Bregmaceros cantori* | 63.22 | 5.01 | |
| *Bregmaceros cantori* | 8.88 | | | *Engraulis anchoita* | 9.56 | | |
| *Trachurus lathami* | 8.50 | | | *Etropus sp.* | 7.52 | | |
| *Sardinella brasiliensis* | 7.82 | | | *Diaphus spp.* | 6.69 | 13.11 | 10.56 |
| *Saurida caribeae* | 5.54 | 2.10 | | *Trichiurus lepturus* | 4.57 | 1.40 | |
| *Maurolicus stehmanni* | 5.22 | 25.37 | 10.37 | *Maurolicus stehmanni* | | 33.70 | 13.60 |
| *Etropus sp.* | 4.45 | | | *Congridae* | | 10.31 | |
| *Paralichthys sp.* | 2.70 | | | *Pollichthys mauli* | | 6.14 | 12.24 |
| *Ophididae sp.* 1 | 1.94 | | | *Bregmaceros atlanticus* | | 5.76 | 15.23 |
| *Diaphus spp.* | 1.84 | 19.85 | 9.53 | *Urophycis sp.* | | 3.13 | |
| *Argenteus striata* | 1.82 | | | *Scaridae sp.* 1 | | 2.81 | 4.98 |
| *Auxis spp.* | | 12.36 | 1.89 | *Bothus ocellatus* | | 2.35 | 3.48 |
| *Myctophum affine* | | 11.80 | 3.49 | *Hygophum hygomii* | | 2.30 | 4.24 |
| *Cyclothone sp.* | | 4.29 | 34.77 | *Myctophum affine* | | 2.07 | 3.87 |
| *Bregmaceros atlanticus* | | 3.45 | 1.52 | *Lepdophanes guentheri* | | 2.05 | 3.04 |
| *Ariomma bondi* | | 2.39 | 2.06 | *Benthodesmus sp* | | | 4.04 |
| *Monolene spp.* | | 2.11 | | *Vinciguerria nimbaria* | | | 3.86 |
| *Pollichthys mauli* | | 2.09 | 2.49 | *Lampanyctus spp.* | | | 3.53 |
| *Lepidophanes guentheri* | | | 9.14 | *Lestrolepis sp.* | | | 2.98 |
| *Vinciguerria nimbaria* | | | 6.90 | *Lestidium atlanticum* | | | 2.69 |
| *Myctophum selenops* | | | 3.55 | Scorpaenidae *sp.* 2 | | | 1.98 |
| *Notolichnus spp.* | | | 2.19 | | | | |
| Congridae | | | 1.51 | | | | |
| *Synagrops spinosus* | | | 1.43 | | | | |

**Table 4**
Summary of CCA performed on larval fish abundance, relating species with environmental variables off the Southeastern Brazilian Bight, during spring (November–December/1997) and autumn (May/2001). Underscores values are the highest correlation values for each variable.

| | Spring | | | | | Autumn | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Axes | | | | Total inertia | Axes | | | | Total inertia |
| | 1 | 2 | 3 | 4 | | 1 | 2 | 3 | 4 | |
| Eigenvalues: | 0.591 | 0.167 | 0.111 | 0.064 | 3.174 | 0.456 | 0.175 | 0.079 | 0.325 | 2.726 |
| Species–environment correlations | 0.951 | 0.765 | 0.782 | 0.732 | | 0.896 | 0.83 | 0.748 | 0 | |
| Cumulative percentage variance | | | | | | | | | | |
| of species data | 18.6 | 23.9 | 27.4 | 29.4 | | 16.7 | 23.1 | 26.0 | 38.0 | |
| of species–environment relation | 63.4 | 81.2 | 93.1 | 100 | | 64.3 | 88.9 | 100 | 0 | |
| Sum of all eigenvalues | | | | | 3.174 | | | | | 2.726 |
| Sum of all canonical eigenvalues | | | | | 0.933 | | | | | 0.71 |
| North | −0.1888 | 0.0967 | 0.6698 | 0.3358 | | −0.2514 | −0.7964 | 0.022 | 0 | |
| South | 0.1888 | −0.0967 | −0.6698 | −0.3358 | | 0.2514 | 0.7964 | −0.022 | 0 | |
| Temperature 15 m | −0.6522 | −0.4188 | −0.3262 | 0.1733 | | −0.7466 | −0.3994 | −0.2045 | 0 | |
| Salinity 15 m | −0.8981 | −0.1023 | 0.1166 | −0.1919 | | −0.8903 | −0.0522 | 0.0731 | 0 | |
| Depth | −0.793 | 0.3373 | −0.1147 | 0.2186 | | | | | | |

because the oceanographic conditions of the oceanic region are more stable than the coastal areas (Doyle et al., 1993; Lopes et al., 2006). Furthermore, Brandini (1990) found high productive areas near the continental slope during winter and summer, which was associated with the shelf break upwelling of SACW and enhanced by BC eddies. A parallel case has been observed in South Carolina (USA), where a high level of biological activity during winter time was due to the nutrient input from the Gulf Stream (Deibel, 1985).

With regards to the oceanographic conditions, there were clear differences between the north subarea, extending from Cape Frio to São Sebastião Island, and the south subarea, extending from São Sebastião Island to Cape of Santa Marta Grande, particularly in the shelf zone, as observed by Miranda and Katsuragawa (1991). This difference was most clear in autumn, when the zone of maxima values of temperature do not reach the southern part of the shelf due to the

weakening of BC induced by the cold fronts. It is probable that the topographic of southern part is associated with wind stress, BC meanders and the La Plata River outflow, which may contribute to differentiate this area from the northern part. The distribution of larval fish seems to have followed these oceanographic patterns, as depicted by CCA analysis. During both seasons, the distribution of larval fish showed a costal-ocean gradient. However, during autumn, a latitudinal gradient become more pronounced. Those differences have also been observed in other regions. For instance, in the Benguela region, a north–south difference in larval fish distribution was also observed and was found to depend on the strength of the upwelling system (Olivar, 1990).

The results of the present work indicate the importance of the Brazil Current to the dynamics of water masses and the horizontal ichthyoplankton distribution along the SSB. It was clear that larval
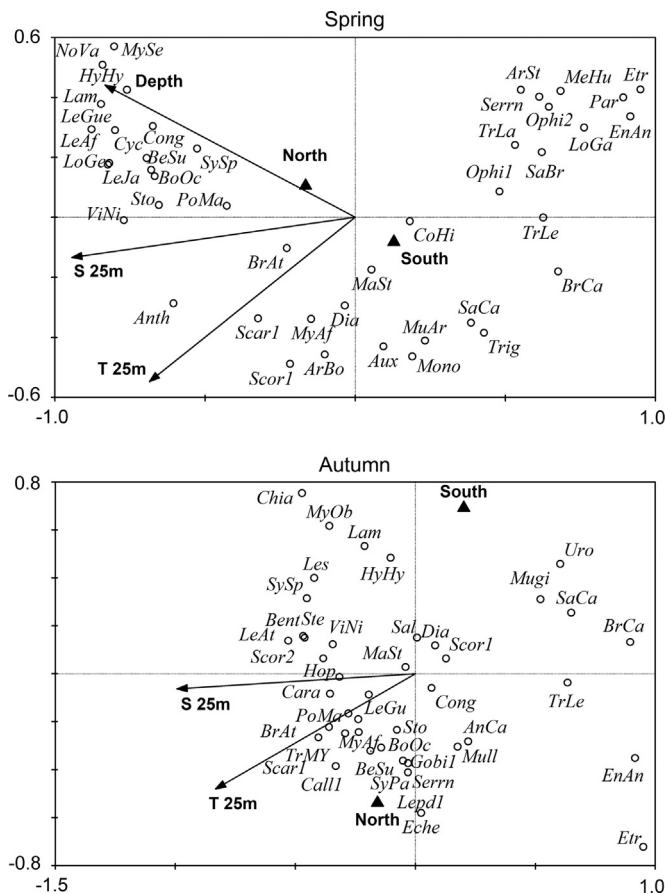
**Fig. 9.** CCA ordination diagram with taxa and environmental variables (arrows) off the Southeastern Brazilian Bight, during spring (November–December/1997) and autumn (May/ 2001). Taxa code: AnCa=*A. capro*, Anth=Anthinae, ArBo=*A. bondi*, ArSt=*A. striata*, Aux=*Auxis spp.*, Bent= *Benthodesmus sp.*, BeSu=*B. suborbitale*, BoOc=*B. ocellatus*, BrAt=*B. atlanticus*, BrCa=*B. cantori*, Call1= Callionymidae sp.1, Cara=Carapidae, Chia=*Chiasmodon sp.*, CoHi=*C. hipurus*, Cong=Congridae, Cyc=*Cyclothone sp.*, Dia=*Diaphus spp.*, Eche=Echeneidae, EnAn=*E. anchoita*, Etr=*Etropus sp.*, Gobi1=Gobiidae sp.1, Hop=*Hoplunnis sp.*, HyHy=*H. hygomii*, Lam=*Lampanyctus spp.*, LeAf=*L. affinis*, LeAt=*L. atlanticum*, LeGu=*L. guentheri*, LeJa=*L. jayakari*, Lepd1=*Lepidopus sp.1*, Les=*Lestrolepis sp.*, LoGa=*L. gastrophysus*, LoGe=*L. gemellarii*, MaSt=*M. stehmanni*, MeHu=*M. hubbsi*, Mono=*Monolene spp.*, MuAr=*M. argentinae*, Mugi=Mugilidae, Mull=Mullidae, MyAf=*M. affine*, MyOb=*M. obtusirostre*, MySe=*M. selenops*, NoVa=*N. valdiviae*, Ophi1=Ophidiidae sp.1, Ophi2=Ophidiidae sp.2, Par=*Paralichthys sp.*, PoMa=*P. mauli*, SaBr=*S. brasiliensis*, SaCa= *S. caribbea*, Sal=*Saurenchelys sp.*, Scar1=Scaridae sp.1, Scor1=Scorpaenidae sp.1, Scor2=Scorpaenidae sp.2, Serrn=Serraninae, Ste=*Stemonosudis sp.*, Sto=*Stomias sp.*, SyPa=*S. papillosum*, SySp=*S. spinosus*, Trig=Triglidae, TrLa=*T. lathami*, TrLe=*T. lepturus*, TrMY=*T. myops*, Uro=*Urophycis sp.*, ViNi=*V. nimbaria*.

fish distribution and composition is temporally and spatially influenced by different oceanographic conditions. The oceanic assemblage, dominated by ecologically important mesopelagic families and associated with the warmer and oligotrophic TW, was similar in both seasons. On the other hand, the shelf and transitional assemblages may change significantly, depending on the extension of the CW and SACW influence on the area. The transitional assemblage, that was present during the spring, did not remain during the autumn. This event probably followed the variation of oceanographic conditions as a result of the retreat of SACW, favoring the expansion of the oceanic assemblage toward the coast. As coastal assemblage contains species of economic importance, issues such as spawning grounds and the vertical distribution of larvae can influence the variability of recruitment. Studies should be conducted in order to understand how the transport of these larvae affects the availability of exploited stocks.

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