

SPATIAL DISTRIBUTION OF JUVENILE FISH SPECIES IN NURSERY GROUNDS OF A TROPICAL COASTAL AREA OF THE SOUTH-WESTERN ATLANTIC

Victor E. L. DA SILVA ^{1*}, Elizabeth C. TEIXEIRA ², Vandick S. BATISTA ², and Nidia N. FABRÉ ¹

¹Laboratory of Ecology, Fish and Fisheries, Federal University of Alagoas, Maceió, Brazil

²Laboratory of Conservation and Management of Fishery Resources, Federal University of Alagoas, Maceió, Brazil

Da Silva V.E.L., Teixeira E.C., Batista V.S., Fabr e N.N. 2018. Spatial distribution of juvenile fish species in nursery grounds of a tropical coastal area of the south-western Atlantic. *Acta Ichthyol. Piscat.* 48 (1): 9–18.

Background. Assessing patterns in habitat utilization and changes in the composition of biont assemblages is a key tool for efficient ecosystem conservation planning and management. Nevertheless, habitat use patterns by juvenile fish still need more comprehension. Therefore, the presently reported study investigated relations between the type of nursery ground and the structure of juvenile fish assemblages in a tropical coastal area of the south-western Atlantic.

Materials and methods. From December 2009 to November 2010, we conducted monthly sampling of ichthyofauna in two habitat types (mangrove and sandy beach) used as nursery grounds by juvenile fish of the south-western Atlantic. Species richness and abundance were used to identify spatial and temporal patterns in the distribution of fish assemblages throughout habitats' dynamics.

Results. A total of 845 fishes representing 16 families and 34 species were found during the presently reported study: *Albula vulpes* (Linnaeus, 1758); *Atherinella brasiliensis* (Quoy et Gaimard, 1825); *Strongylura marina* (Walbaum, 1792); *Tylosurus acus acus* (Lacep de, 1803); *Caranx crysos* (Mitchill, 1815); *Caranx latus* Agassiz, 1831; *Oligoplites saurus* (Bloch et Schneider, 1801); *Selene setapinnis* (Mitchill, 1815); *Selene vomer* (Linnaeus, 1758); *Centropomus parallelus* Poey, 1860; *Centropomus undecimalis* (Bloch, 1792); *Harengula clupeiola* (Cuvier, 1829); *Opisthonema oglinum* (Lesueur, 1818); *Anchoa tricolor* (Spix et Agassiz, 1829); *Anchovia clupeioides* (Swainson, 1839); *Diapterus auratus* Ranzani, 1842; *Diapterus rhombeus* (Cuvier, 1829); *Eucinostomus argenteus* Baird et Girard, 1855; *Eucinostomus gula* (Quoy et Gaimard, 1824); *Eucinostomus melanopterus* (Bleeker, 1863); *Bathygobius soporator* (Valenciennes, 1837); *Conodon nobilis* (Linnaeus, 1758); *Haemulon plumierii* (Lacep de, 1801); *Haemulopsis corvinaeformis* (Steindachner, 1868); *Hemiramphus brasiliensis* (Linnaeus, 1758); *Lutjanus apodus* (Walbaum, 1792); *Lutjanus griseus* (Linnaeus, 1758); *Lutjanus jocu* (Bloch et Schneider, 1801); *Mugil brevirostris* (Ribeiro, 1915); *Mugil curema* Valenciennes, 1836; *Mugil curvidens* Valenciennes, 1836; *Paralichthys tropicus* Ginsburg, 1933; *Sphyraena barracuda* (Edwards, 1771); *Sphoeroides testudineus* (Linnaeus, 1758). No significant differences in species richness and total abundance were found between habitats and seasons. Nevertheless, our analyses showed that distinct sets of species use these areas. Moreover, we identified a strong relation between the rainfall and the species turnover in both habitats studied.

Conclusion. Diversity of nursery grounds in coastal areas not only increases fish diversity but also plays an important role in the sustaining fish stocks.

Keywords: fish fauna, habitat heterogeneity, mangrove, nursery grounds, sandy beach

INTRODUCTION

Coastal and estuarine habitats play an important role in growth, feeding, and protection of many species (Blaber and Blaber 1980, Barletta et al. 2005, Vasconcelos et al. 2010), especially by serving as nursery grounds for juveniles of marine, freshwater, and estuarine-resident and brackish-water fishes (Beck et al. 2003, Elliott et al. 2007). Though frequently credited for sustaining fish stocks (Beck et al. 2003, Crona and R nnb ck 2007),

these ecosystems, in the global scale, have been impacted by intense habitat degradation processes, mostly caused by human activities (Baptista et al. 2015, Freedman et al. 2016). For instance, the transformation of mangrove areas into shrimp farms along with the shrinking of seagrass coverage due to water quality degradation and increasing beach pollution in tropical regions have been vastly associated with losses of fish diversity and remarkable declines in fishery catches (Arthington et al. 2016). As a

* Correspondence: Victor Emmanuel Lopes da Silva, Universidade Federal de Alagoas, Instituto de Ci ncias Biol gicas e da Sa de, Laborat rio de Ecologia, Peixes e Pesca, Av. Lourival Melo Mota - Tabuleiro do Martins, 57072-900, Alagoas, Brazil, phone: +55 82 9-9843-9768, e-mail: (VELS) lopesdasilvavictor@gmail.com, (ECT) lizzieteixeira@gmail.com, (VSB) vandickbatista@gmail.com, (NNF) nidia.fabre@pq.cnpq.br.

result, natural and anthropogenic impacts on coastal biota have been constantly assessed by ecologists, but some processes still demand more comprehension, such as the reciprocal relations between the species and the local conditions.

Furthermore, our poor understanding of habitat use patterns by juvenile fish makes conservation planning in coastal areas a really challenging task (Barletta et al. 2010). This particular problem can be blamed on numerous studies that treated these areas as a homogeneous environment, disregarding their diversity reflected by different habitat types, such as, mangroves, seagrass beds, sandy beaches, and mudflats (Nagelkerken et al. 2000a, Beck et al. 2003, Minello et al. 2003). Moreover, many field studies in these ecosystems are often carried out in single habitats, because responsible researchers are often discouraged by their structural complexity, making comparisons of fauna composition difficult (Nagelkerken et al. 2000a). This further translates into a lack of reliable information on the ecosystem as a whole. Mangroves, for instance, have traditionally received considerable attention from scientific community due to their distinct features, such as high structural complexity and greater food abundance (Vendel and Chaves 2006, Vilar et al. 2011, Castellanos-Galindo and Krumme 2014). Consequently, other habitats, especially those without vegetation coverage, such as coastal sandy beaches, have been less-intensively investigated (Santos and Nash 1995, Barletta et al. 2010, Rodrigues and Vieira 2013, Lacerda et al. 2014, Blaber and Barletta 2016).

Since different coastal habitats have distinct features (e.g., structural complexity) and dynamics, it is likely that they may vary in their ecological functions as nursery grounds (Beck et al. 2003). Thus, identifying patterns in habitat utilization and changes in the composition of assemblages is extremely necessary for proper conservation planning and management of fishery resources in these environments (Barletta et al. 2010, Blaber and Barletta 2016). In this respect, our study intended to assess patterns in the distribution of juvenile fish assemblages in a coastal area from the south-western Atlantic, considering its availability of nursery grounds and possible relations between species and environmental conditions. Specifically, we used species richness and fish abundance to answer the following questions:

Is the structuring of juvenile fish assemblages in these areas associated with the different types of habitats used as nursery grounds?

Which (and how) environmental conditions affect the spatial distribution of juveniles in these habitats?

MATERIALS AND METHODS

Study area and fish sampling. The study was carried out in the Santo Antônio River estuary (9°24'50"S, 35°30'24"W), located on the north-eastern coast of Brazil, South America (Fig. 1). The fishes were sampled monthly using a monofilament beach seine (15 m wide, 2 m high, and 5-mm mesh size) from December 2009 through November 2010 at four sites located in two different habitat types.

Two sites were situated on the left bank of the estuary, covered with mangrove forest dominated by *Rhizophora mangle*, *Avicennia schaueriana*, and *Laguncularia racemosa*, whereas the other two sites were located in the shallow waters of a sandy beach (mean depth ≤ 1.5 m) adjacent to the estuary mouth. Each site was sampled once per month (a total of 48 samples) for 5 min and only one net type was used to minimize impacts on the existent fauna. Upon capture, all fishes collected were kept on ice. In the laboratory, each individual was identified to species level following regional taxonomic keys (Figueiredo and Menezes 1978, 1980, Menezes and Figueiredo 1980, 1985).

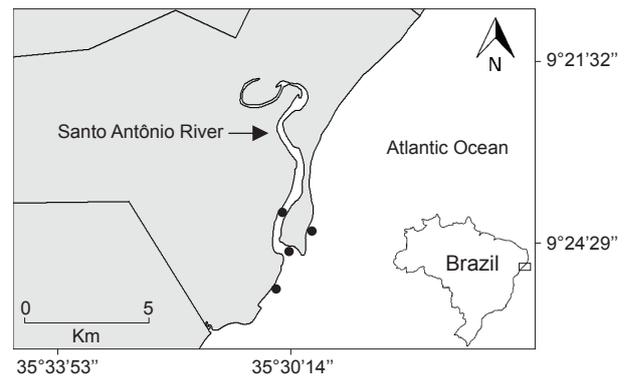


Fig. 1. The Santo Antônio River estuary located on the north-eastern coast of Brazil, indicating the location of sampling sites (●)

During fieldwork, water physicochemical parameters, such as salinity [‰], temperature [°C], and dissolved oxygen [%] were also measured at each site before fish sampling using a Hanna HI 9828 multi-parameter water quality portable meter. Monthly rainfall data [mm] were obtained from the National Institute of Meteorology (INMET), and these data were used to identify seasonal trends. The rainy season was defined as the period from March through August (monthly rainfall 205.4 ± 133.4 mm) and the dry season from September through February (64.5 ± 63.8 mm).

Data analysis. Non-parametric Kruskal–Wallis test was used to identify spatial and seasonal patterns in environmental conditions for both habitats since data did not meet the assumptions of normality and homoscedasticity even after transformations. Variations in species richness and total fish abundance were tested between the mangrove and sandy beach sites, and over time (dry and rainy reason) using two-way analysis of variance (ANOVA). Prior to analysis, data were log-transformed (\ln_{n+1}) to reduce the effect of data aggregation. Normality and homogeneity of datasets were then tested by Shapiro–Wilk and Levene's tests, respectively.

Differences in the composition of fish assemblages among habitats and seasons were assessed by two-way analysis of similarity (ANOSIM) using the Bray–Curtis similarity coefficient (Clarke 1993). To further identify patterns in assemblages, we also performed a non-metric

multidimensional scaling (nMDS) (Anderson and Walsh 2013). Subsequently, species which contributed the most to the total dissimilarity between samples were identified using a similarity percentage analysis (SIMPER).

Furthermore, interactions between species abundance and environmental conditions were investigated by canonical correspondence analysis (CCA). CCA was chosen after we tested the gradient length of species composition by detrended correspondence analysis (DCA) as suggested by ter Braak (1995). Environmental variables were previously tested for collinearity by Pearson's correlations with a threshold of 0.7 (Dormann et al. 2012). The two firsts components' scores and factor loadings of CCA were then plotted to detect general gradients in ecological and environmental descriptors. Additionally, the Monte-Carlo permutation test was used to determine if the correlations found between species and environmental conditions were statically significant. All analyses were performed in the software R statistics with the package 'Vegan' (Oksanen 2016) at a significance level of $P < 0.05$.

The presently reported study has been carried out in accordance with Brazilian regulations (Federal Scientific Fish Sampling Licence 1837810).

RESULTS

The annual precipitation reached 1610 mm and approximately 76% of this total fell during the rainy season (March through August). Water temperature and dissolved oxygen did not differ between habitats and seasons ($P > 0.05$). Salinity was higher and stable during the entire year in the sandy beach ($P > 0.05$), whereas in the mangrove a seasonal trend could be observed ($P < 0.05$).

This trend was characterized by the decreasing of salinity at the end of the dry season, reaching the lowest values during the months with high rainfall rates (Fig. 2).

A total of 845 fishes representing 16 families and 34 species were collected during the study period: *Albula vulpes* (Linnaeus, 1758); *Atherinella brasiliensis* (Quoy et Gaimard, 1825); *Strongylura marina* (Walbaum, 1792); *Tylosurus acus acus* (Lacepède, 1803); *Caranx crysos* (Mitchill, 1815); *Caranx latus* Agassiz, 1831; *Oligoplites saurus* (Bloch et Schneider, 1801); *Selene setapinnis* (Mitchill, 1815); *Selene vomer* (Linnaeus, 1758); *Centropomus parallelus* Poey, 1860; *Centropomus undecimalis* (Bloch, 1792); *Harengula clupeiola* (Cuvier, 1829); *Opisthonema oglinum* (Lesueur, 1818); *Anchoa tricolor* (Spix et Agassiz, 1829); *Anchoa clupeioides* (Swainson, 1839); *Diapterus auratus* Ranzani, 1842; *Diapterus rhombeus* (Cuvier, 1829); *Eucinostomus argenteus* Baird et Girard, 1855; *Eucinostomus gula* (Quoy et Gaimard, 1824); *Eucinostomus melanopterus* (Bleeker, 1863); *Bathygobius soporator* (Valenciennes, 1837); *Conodon nobilis* (Linnaeus, 1758); *Haemulon plumierii* (Lacepède, 1801); *Haemulopsis corvinaeformis* (Steindachner, 1868); *Hemiramphus brasiliensis* (Linnaeus, 1758); *Lutjanus apodus* (Walbaum, 1792); *Lutjanus griseus* (Linnaeus, 1758); *Lutjanus jocu* (Bloch et Schneider, 1801); *Mugil brevisrostris* (Ribeiro, 1915); *Mugil curema* Valenciennes, 1836; *Mugil curvidens* Valenciennes, 1836; *Paralichthys tropicus* Ginsburg, 1933; *Sphyrna barracuda* (Edwards, 1771); *Sphoeroides testudineus* (Linnaeus, 1758) (Table 1). Fish assemblages were mainly comprised of juveniles (73% of total abundance). In terms of number of individuals, the most abundant species in the mangrove were *Atherinella*

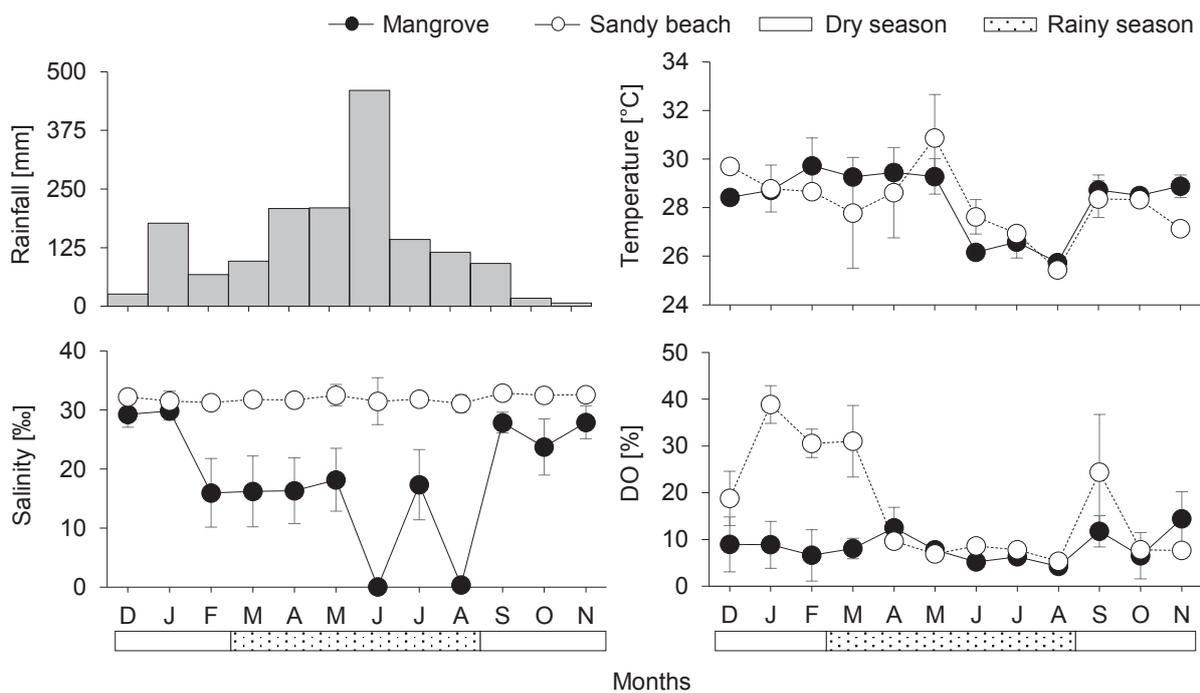


Fig. 2. Rainfall, mean water temperature, salinity, and dissolved oxygen registered in the mangrove and the sandy beach studied at the Santo Antônio River estuary during December 2009 and November 2010

brasiliensis (20.5%), *Mugil curema* (17.8%), *Caranx latus* (12.2%), *Diapterus rhombeus* (Cuvier, 1829) (10.5%), *Eucinostomus melanopterus* (9.9%), and *Anchovia clupeioides* (9.2%), whereas in the sandy beach the most important species in number, besides *A. brasiliensis* (20.9%), *C. latus* (17.9%), and *M. curema* (13.5%), were *Mugil curvidens* (9.5%), *Haemulopsis corvinaeformis* (9.2%), and *Hemiramphus brasiliensis* (8%). Fourteen of these species were exclusively found in mangrove sites, while nine occurred only in the sandy beach area. The eleven species that occurred in both habitats accounted for 70% of total abundance. Even though higher species richness and abundance were registered in some samples from mangrove than from sandy beach (Fig. 3), no significant differences between habitats and among seasons were found (ANOVA, $P > 0.05$), neither an interaction between these two factors could be observed (ANOVA, $P > 0.05$, see Table 2 for the total ANOVA output).

While no significant differences in the structure of assemblages between seasons were found (ANOSIM, $R = 0.16$, $P > 0.05$), fish composition varied significantly between mangrove and sandy beach sites (ANOSIM, $R = 0.1982$, $P < 0.05$) (Fig. 4). According to SIMPER analysis, these differences were partly due to fluctuations in the abundance of common species to both habitats (e.g., *Atherinella brasiliensis* and *Mugil curema*), as well as the exclusive occurrence of a few species in only one habitat, such as

Diapterus rhombeus in the mangrove and *Haemulopsis corvinaeformis* in the sandy beach (Table 3, Fig. 5).

Though some environmental conditions showed a certain degree of correlation (Table 4), none of them presented collinearity ($R > 0.7$), therefore CCA was performed including all four studied variables. The two first axes of CCA explained 65% of total variation in the relation between species and environmental conditions. Considering their vectors length and the Monte Carlo permutation test, rainfall was found to be the most significant factor influencing the distribution and abundance of most species (Fig. 6, $P < 0.05$).

DISCUSSION

Many factors can be associated with temporal and spatial changes in species composition of coastal environments, such as substrate type (Nagelkerken et al. 2000b), fluctuations in environmental conditions—especially, salinity, temperature and dissolved oxygen—(Harrison and Whitfield 2006, Ooi and Chong 2011), and inter- and intraspecific relations (Elliott et al. 2007). However, habitat utilization patterns in nursery grounds are still partly unclear. For example, although mangrove vegetation coverage is often related to the sustaining of future fish populations, providing food and shelter availability for juveniles (Nagelkerken et al. 2001, Beck et al. 2003, Sales et al. 2016), the absence of significant differences in species richness and total fish abundance reported in our study and in some other earlier works (Blaber et al. 1989, Sichum and Tantichodok 2013) shows that non-vegetated areas, such as sandy beaches, are also suitable environments for several species.

Differences in the composition of juvenile fish assemblages from mangrove and sandy beach found in our data indicate that different sets of species use these areas as nursery grounds. Such variability may result from specialization in habitat exploitation by species and by habitat dynamics (Igulu et al. 2014, Ebner et al. 2016). The ability to use different environments within single ecosystems may depend on species trophic level, morphological characteristics, and functional attributes (Matthews et al. 2010, Mouillot et al. 2013, de Andrade et al. 2015). For instance, fish which inhabit a greater variety of habitats typically present distinct physiologic adaptations, intraspecific variability in fish behaviour (Bourke et al. 1997, Silva-Falcão et al. 2012) and greater functional specialization and originality (Sales et al. 2016). Our results support this information as species which were common to both habitats (e.g., *Atherinella brasiliensis* and *Mugil curema*) have been previously reported in literature as presenting high plasticity in their diet (Rueda 2002, Contente et al. 2010) and great tolerance to changes on environmental conditions that are typical of coastal environments (Neves et al. 2006, Albiéri et al. 2010).

Fluctuations of the environmental conditions are closely related to the structure of fish assemblages (Blaber et al. 1989, 2010, Harrison and Whitfield 2006) and habitat selection by species (Porter and Church 1987, Bernardo

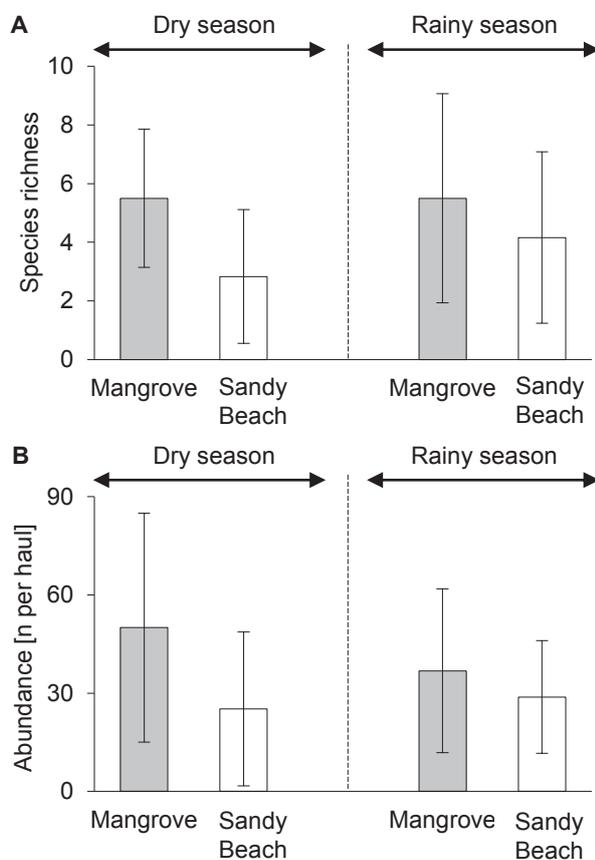


Fig. 3. Variation (mean \pm SD) in the species richness (A) and total fish abundance (B) among habitats and seasons in the Santo Antônio River estuary

et al. 2003). In tropical regions, for instance, variations in dissolved oxygen, salinity, and rainfall often affect fish movements and migration, influencing total density and biomass (Barletta et al. 2005, Gaonkar et al. 2013, Campbell and Rice 2014). In our study, rainfall was found to be the main driver of spatial variability among juvenile fish fauna. In general, over the studied period, changes in rainfall rate

coincided with remarkable changes in species composition in both habitats. However, it is important to notice that rainfall affected their dynamics in different ways.

In the mangrove, the rainfall was negatively correlated with the salinity, creating a seasonal trend in this habitat. Many authors have indicated that the salinity was the main factor structuring fish assemblages in coastal areas

Table 1

Total number of individuals (*n*) and relative abundance in percentage (Ab%) of fish species caught in microhabitats of the Santo Antônio River estuary during December 2009 and November 2010

| Family | Species | Mangrove | | Sandy beach | |
|-----------------|-----------------------------------|----------|------|-------------|------|
| | | <i>n</i> | Ab% | <i>n</i> | Ab% |
| Albulidae | <i>Albula vulpes</i> | — | — | 14 | 4.32 |
| Atherinopsidae | <i>Atherinella brasiliensis</i> | 105 | 20.5 | 68 | 20.9 |
| Belonidae | <i>Strongylura marina</i> | 3 | 0.58 | 2 | 0.61 |
| | <i>Tylosurus acus acus</i> | 1 | 0.19 | — | — |
| Carangidae | <i>Caranx crysos</i> | 5 | 0.98 | 1 | 0.30 |
| | <i>Caranx latus</i> | 63 | 12.3 | 58 | 17.9 |
| | <i>Oligoplites saurus</i> | — | — | 9 | 2.77 |
| | <i>Selene setapinnis</i> | — | — | 1 | 0.30 |
| Centropomidae | <i>Selene vomer</i> | — | — | 1 | 0.30 |
| | <i>Centropomus parallelus</i> | 14 | 2.74 | — | — |
| | <i>Centropomus undecimalis</i> | 7 | 1.37 | — | — |
| Clupeidae | <i>Harengula clupeola</i> | — | — | 15 | 4.62 |
| | <i>Opisthonema oglinum</i> | 1 | 0.19 | — | — |
| Engraulidae | <i>Anchoa tricolor</i> | — | — | 1 | 0.30 |
| | <i>Anchoa clupeoides</i> | 48 | 9.41 | — | — |
| Gerreidae | <i>Diapterus auratus</i> | 2 | 0.39 | — | — |
| | <i>Diapterus rhombeus</i> | 55 | 10.7 | — | — |
| | <i>Eucinostomus argenteus</i> | 2 | 0.39 | 13 | 4.01 |
| | <i>Eucinostomus gula</i> | 1 | 0.19 | — | — |
| Gobiidae | <i>Eucinostomus melanopterus</i> | 52 | 10.1 | 3 | 0.92 |
| | <i>Bathygobius soporator</i> | 4 | 0.78 | — | — |
| Haemulidae | <i>Conodon nobilis</i> | — | — | 1 | 0.30 |
| | <i>Haemulon plumierii</i> | 3 | 0.58 | — | — |
| | <i>Haemulopsis corvinaeformis</i> | — | — | 30 | 9.25 |
| Hemiramphidae | <i>Hemiramphus brasiliensis</i> | 5 | 0.98 | 26 | 8.02 |
| Lutjanidae | <i>Lutjanus apodus</i> | 14 | 2.74 | 1 | 0.30 |
| | <i>Lutjanus griseus</i> | 3 | 0.58 | — | — |
| | <i>Lutjanus jocu</i> | 2 | 0.39 | — | — |
| Mugilidae | <i>Mugil brevirostris</i> | 1 | 0.19 | — | — |
| | <i>Mugil curema</i> | 93 | 18.2 | 44 | 13.5 |
| | <i>Mugil curvidens</i> | 14 | 2.74 | 31 | 9.56 |
| Paralichthyidae | <i>Paralichthys tropicus</i> | 1 | 0.19 | — | — |
| Sphyraenidae | <i>Sphyraena barracuda</i> | — | — | 1 | 0.30 |
| Tetraodontidae | <i>Sphoeroides testudineus</i> | 11 | 2.15 | 4 | 1.23 |

Table 2

Two-way ANOVA results for species richness and total abundance of studied fish assemblages

| Factor | Species richness | | | | Total abundance | | | |
|-------------|------------------|---------|----------|----------|-----------------|---------|----------|----------|
| | Df | MS | <i>F</i> | <i>P</i> | Df | MS | <i>F</i> | <i>P</i> |
| Habitat | 1 | 1.44858 | 2.38 | 0.1386 | 1 | 5.43127 | 2.50 | 0.1284 |
| Season | 1 | 0.05846 | 0.09 | 0.7598 | 1 | 0.93749 | 0.43 | 0.5181 |
| Interaction | 1 | 0.40655 | 0.66 | 0.4234 | 1 | 2.13074 | 0.98 | 0.3331 |

Df = degree of freedom, MS = mean sum of squares, *F* = *F*-statistic, *P* = *P*-value.

(Barletta et al. 2005, Whitfield et al. 2012, Campbell and Rice 2014). Specifically, shifts in the salinity create a stressful environment for different species which are typical of these areas (e.g., marine, freshwater, estuarine-resident and brackish-water species), as each group has a distinct osmoregulatory capacity (Whitfield et al. 2012, Telesh et al. 2013), causing species to respond differently

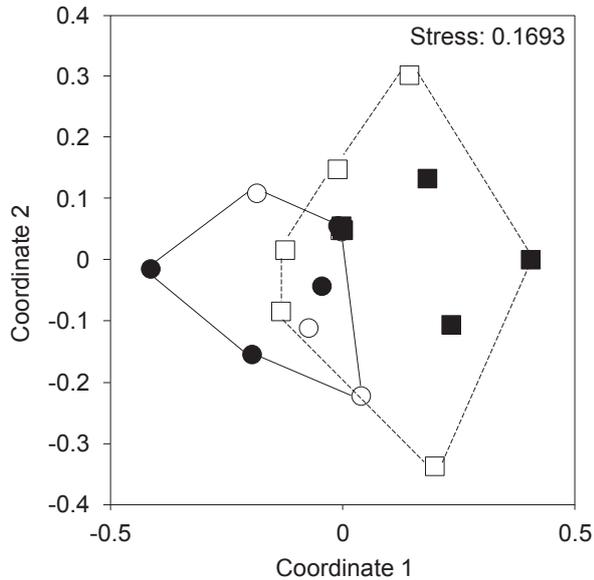


Fig. 4. nMDS ordination of fish abundance per sample among microhabitats in the Santo Antônio River estuary; each point represents a sample: ■ mangrove (rainy season); □ mangrove (dry season); ● sandy beach (rainy season); ○ sandy beach (dry season)

to the salinity gradient. Moreover, the salinity regime promotes changes in organic matter, nutrients, and in dissolved and particulate matter, affecting dissolved oxygen levels (Campbell and Rice 2014) and turbidity (Barletta et al. 2005). These, in turn, may limit the abundance and occurrence of many species (de Jonge and de Jong 2002). On the other hand, since the salinity did not vary in the sandy beach throughout the year, the rainfall appeared to be more associated with the discharge of waters from continental environments, which increases primary and secondary productivity (Oliveira and Kjerfve 1993, Pereira et al. 2015). Besides, wave actions in these environments tend to be stronger during the rainy season, producing a remineralization process of organic matter, which makes a greater quantity of nutrients in water column available, also increasing productivity levels (Rodrigues and Vieira 2013, Lacerda et al. 2014). Greater food availability increases fish diversity and makes the environment more suitable for several species, especially for juveniles which depend on high food availability for growth (Jones 1986).

In conclusion, the results found herein provide some insights about the spatial arrangement of juvenile of fish species in nursery grounds of coastal areas. Our data suggest that the distinct dynamics of habitats located in coastal areas allows different sets of species to inhabit them, not only increasing fish diversity but also playing a key role in the sustaining of fish stocks. Such information is supported by the absence of differences in species richness and total fish abundance in studied fish assemblages, and by the occurrence of distinct species in both habitats. Furthermore, we also highlighted rainfall as the main seasonal factor influencing, directly and indirectly, the spatial structuring of juvenile assemblages

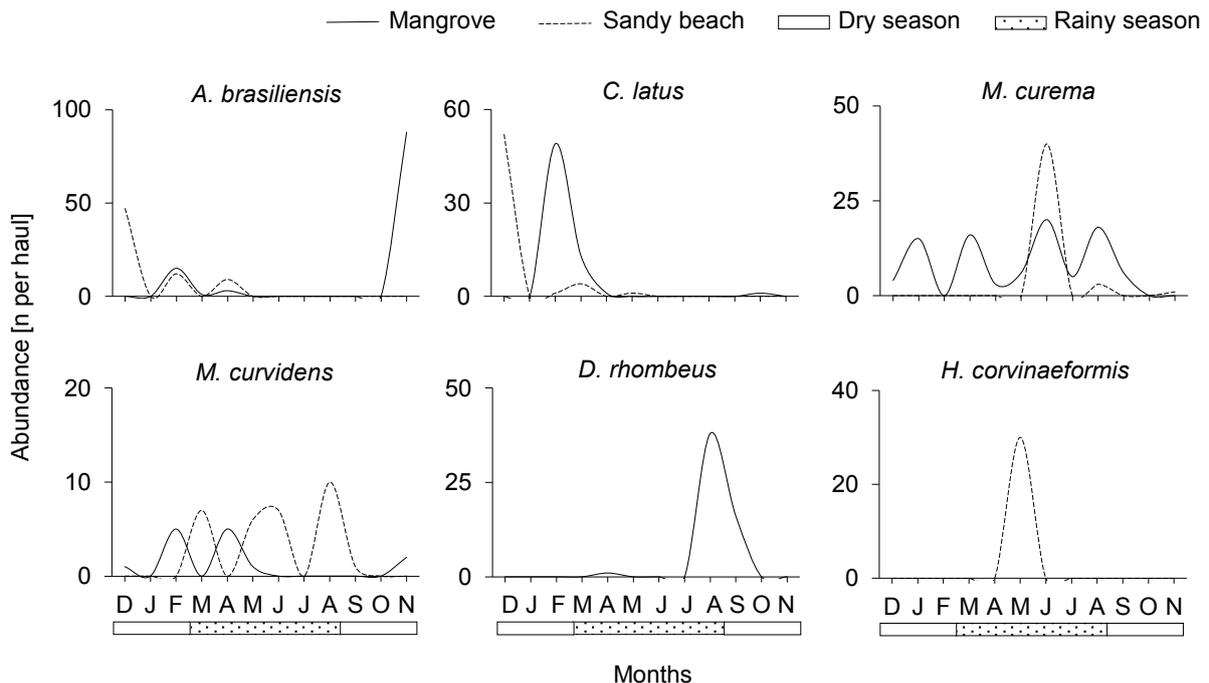


Fig. 5. Fluctuations on the abundance of most common species from the Santo Antônio River estuary

Table 3

Species identified by SIMPER analysis as responsible for total dissimilarity between assemblages in the mangrove and the sandy beach

| Species | Dissimilarity | | Mangrove [Ab%] | Sandy beach [Ab%] |
|-----------------------------------|------------------|-----------------|----------------|-------------------|
| | Contribution [%] | Accumulated [%] | | |
| <i>Mugil curema</i> | 19.55 | 19.55 | 15.47 | 8.85 |
| <i>Atherinella brasiliensis</i> | 16.00 | 35.56 | 17.86 | 16.60 |
| <i>Caranx latus</i> | 10.56 | 46.11 | 10.66 | 14.30 |
| <i>Mugil curvidens</i> | 7.58 | 53.70 | 2.33 | 6.25 |
| <i>Eucinostomus melanopterus</i> | 7.23 | 60.94 | 8.67 | 0.65 |
| <i>Hemiramphus brasiliensis</i> | 5.23 | 66.17 | 0.83 | 5.45 |
| <i>Diapterus rhombeus</i> | 4.93 | 71.10 | 9.17 | 0.00 |
| <i>Anchovia clupeioides</i> | 4.89 | 75.99 | 8.00 | 0.00 |
| <i>Haemulopsis corvinaeformis</i> | 3.78 | 79.78 | 0.00 | 6.00 |
| <i>Harengula clupeiola</i> | 3.47 | 83.25 | 0.00 | 3.10 |
| <i>Albula vulpes</i> | 3.37 | 86.63 | 0.00 | 3.50 |

Ab% = relative abundance in percent.

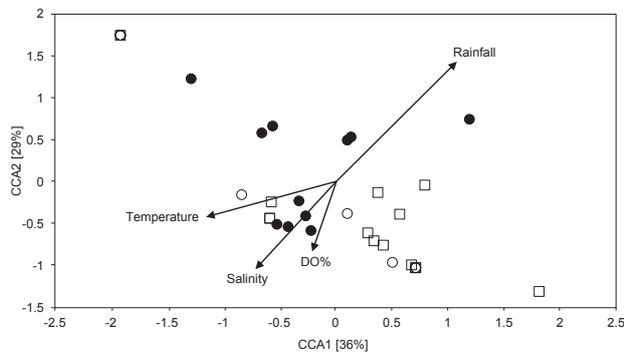


Fig. 6. Canonical correspondence analysis ordination bi-plot based on species found in estuarine habitats (● mangrove; ○ sandy beach; □ both) from the Santo Antônio River in relation to environmental variables (arrows; DO% = dissolved oxygen)

Table 4

Pearson correlation matrix for the environmental variables measured

| | Dissolved oxygen [%] | Rainfall [mm] | Salinity [‰] | Temperature [°C] |
|------------------|----------------------|---------------|--------------|------------------|
| Dissolved oxygen | 1.00 | | | |
| Rainfall | -0.23 | 1.00 | | |
| Salinity | 0.51 | -0.61 | 1.00 | |
| Temperature | 0.48 | -0.20 | 0.61 | 1.00 |

in coastal nursery grounds. However, further investigation on long-term changes in habitats' dynamics is necessary for a better understanding of how this variable affects the fish composition. Our work provides essential data for understanding shifts in the species composition, which are extremely necessary for the development of effective conservation plans for ecosystems as a whole.

ACKNOWLEDGMENTS

We would like to thank colleagues Any Lopes, Cibele Tiburtino, Jordana Rangely, and Marcia Sousa for their assistance during field and laboratory work. This study was supported by the Brazilian National Council for Scientific and Technological Development - CNPq (V.S.B., grant number 303469/2013-7; N.N.F., grant number 306624/2014-1); and the Coordination for the Improvement of Higher Education Personnel - Capes.

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Received: 29 August 2017

Accepted: 2 January 2018

Published electronically: 31 March 2018