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Composition of the aquatic invertebrate fauna associated to the mangrove vegetation of a coastal river, analyzed through a manipulative experiment

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Abstract. The present study analyzed the composition of the aquatic fauna associated to the mangrove forest in a southeastern Brazilian river. The composition of the macrofauna in the roots of the marginal vegetation located at three different salinity stretches was analyzed by sampling pieces of the submerged branches of the vegetation (natural substrate) and pieces of "sisal" rope (artificial substrate), installed close to the natural vegetation and sampled after a period of 14 colonization days. In both types of substrate, twelve taxonomic groups were sampled, representing three phyla (Cnidaria, Annelida and Arthropoda). The crustaceans, corresponding to the most diversified group, were represented by Copepoda, Tanaidacea, Isopoda, Amphipoda and Decapoda. The highest salinity stretch showed the highest abundance, with a progressive decrease from high to low salinity for both substrates. Copepoda and Tanaidacea predominated on both substrates, although the artificial substrate exhibited the highest total abundance and species richness. Considering the relative abundance of the taxonomic groups on both substrates, the majority of groups predominated in the highest salinity range. Significant differences on the longitudinal distribution of abundance were associated to the variation on salinity and with the complexity of the substrate.

Key words: Artificial substrate, colonization, macroinvertebrates, natural substrate, salinity stretches.

Resumo. Composição da fauna de invertebrados aquáticos associados à vegetação de manguezal de um rio costeiro, analisada através de um experimento de manipulação. No presente estudo foi analisada a composição da fauna aquática associada a um rio em um manguezal do sudeste do Brasil. A composição da macrofauna presente nas raízes da vegetação marginal foi estudada pela amostragem de pedaços dos galhos submersos da vegetação (substrato natural) e pedaços de corda de sisal (substrato artificial), instalados em três trechos de diferente salinidade, perto da vegetação natural e retirados depois de um período de 14 dias de colonização. Em ambos os tipos de substrato, foram amostrados um total de 12 grupos taxonômicos, representando três filos (Cnidaria, Annelida e Arthropoda). Os crustáceos, grupo mais diversificado, foram representados por Copepoda, Tanaidacea, Isopoda, Amphipoda e Decapoda. A região de salinidade alta apresentou maior abundância, com uma diminuição progressiva da abundância da salinidade alta para a baixa em ambos os substratos. Copepoda e Tanaidacea predominaram em ambos os substratos, embora o substrato artificial exibisse a maior abundância e riqueza destes dois grupos. Considerando a abundância relativa dos grupos taxonômicos nos dois substratos, a maioria dos grupos predominou no trecho de salinidade mais alta. As diferenças significativas de abundância na distribuição longitudinal foram associadas à variação na salinidade e na complexidade do substrato.

Palabras clave: substrato artificial, colonização, macroinvertebrados, substrato natural, trechos de salinidade

Introduction

Coastal ecosystem is traditionally known as an important nursery area for both estuarine-resident and temporary-resident species (Chaves & Bouchereau 1999). Nursery area for Penaeidae juveniles in this ecosystem have been associated with food availability and shelter from predators, supplied by physical structures, such as substratum and turbidity, in combination with the agonistic behavior of shrimps (Primavera 1997). Due to the contrasting environmental conditions of the coastal ecosystem, the geometric complexity of the substratum can increase the colonization rates by protecting the organisms from environmental constraints and increasing the area available for the fauna establishment (Jacobi & Langevin 1996).

The study of the associated aquatic fauna on mangrove forest becomes a complex task because of the high richness and because of the great influence of tides on salinity variation and on the colonization process. An appropriated methodology for these studies is the utilization of experimental structures that allows habitat simplification and enables control of environmental variations upon sampling areas (Brower & Zar 1984; Uieda 1999). According to Deutsch (1980), seasonal experimentation of short or long substrate exposition are useful for studies on macroinvertebrates colonization rate, allowing the determination of how, where and when the colonization occur.

Few experimental studies were developed in coastal regions. Some of the available papers deserve attention like as Hulberg & Oliver (1980) in rocky shores, Heck & Thoman (1981) in muddy habitats and Fitzhugh & Fleeger (1985) in estuary.

The preservation of mangroves is very important for the maintenance of the biodiversity of this important link between the continental waters and the sea. Mangroves are susceptible to high environmental impact (Grasso 1998), which may have strong negative effect upon the local fishery. Mangroves are found in Brazil from 04º30'N to 28º30'S, under a wide range of environmental conditions (Schaeffer-Novelli *et al*. 1990). Unfortunately, despite its importance as feeding, growth and reproduction areas for a diversified fish fauna, the knowledge of the ichthyofauna on intertidal environment is still very restricted (Paiva Filho & Toscano 1987; Barletta-Bergan *et al*. 2002; Felix et al. 2006; Corrêa & Uieda 2007).

The aims of the current study were: to analyze the diversity of the macroinvertebrate fauna associated to the roots of the mangrove vegetation, to analyze the variation in the composition of this fauna in function of salinity variation, and, at the same time, to test the efficiency of an artificial substratum through an experimental manipulation. This work intends to analyze two predictions: 1) The artificial substratum allows a colonization process similar to the one in natural vegetation, 2) The community composition changes in function of differences in salinity.

Material & Methods

Study site

The study was carried out in the mangrove of the Rio da Fazenda (23º31' to 23º34'S, 45º02' to 45º05'W), located in the Serra do Mar State Park, Picinguaba Unit (Núcleo Picinguaba). The Picinguaba Unit is situated in the State of São Paulo, and preserves all the environments that compose the coastal ecosystem complex: beach, rocky shore, "restinga" (coastal dune forest), mangroves, coastal plain forest and hillside forest. Rio da Fazenda is a coastal river, aprox. 6 km long. Its headwaters are on the slopes of the Serra do Mar, and its mouth at Fazenda Beach; its course is entirely contained within the boundaries of the Picinguaba Unit (Fig. 1).

In order to determine the variation of the fauna composition in relation to the variation on salinity, common in mangroves, the study was conducted in stretches with different ranges of salinity. Three stretches were selected to conduct the work: a downstream stretch with the highest salinity (6.4 ± 2.0; 23º22'24"S, 44º50'62"W), an upstream stretch with the lowest salinity (0.9 ± 0.8; 23º21'11"S, 44º50'83"W), and a median stretch with intermediate values of salinity (2.0 ± 0.9; 23º21'15"S, 44º50'78"W). Although these stretches differed in salinity, they showed similar values of some abiotic characteristics measured during the study period, like dissolved oxygen (7.0, 7.9 and 7.8 $mgO_2L^{-1,}$ respectively for each stretch) and water temperature (27.6, 24.9 and 25.6ºC). The mangrove vegetation is composed mainly by *Hibiscus pernambucensis* Arruda (Malvaceae), *Laguncularia racemosa* (L.) C. F. Gaertn. (Combretaceae) and *Eugenia* sp Linnaeus (Myrtaceae).

Data collection and analyses

The fauna composition was sampled directly from the roots of the mangrove vegetation (Fig. 1) and also from the artificial substrata installed in the same area. In this way, we could use the results not only for a fauna characterization, but also to test the efficiency of colonization on artificial substratum.

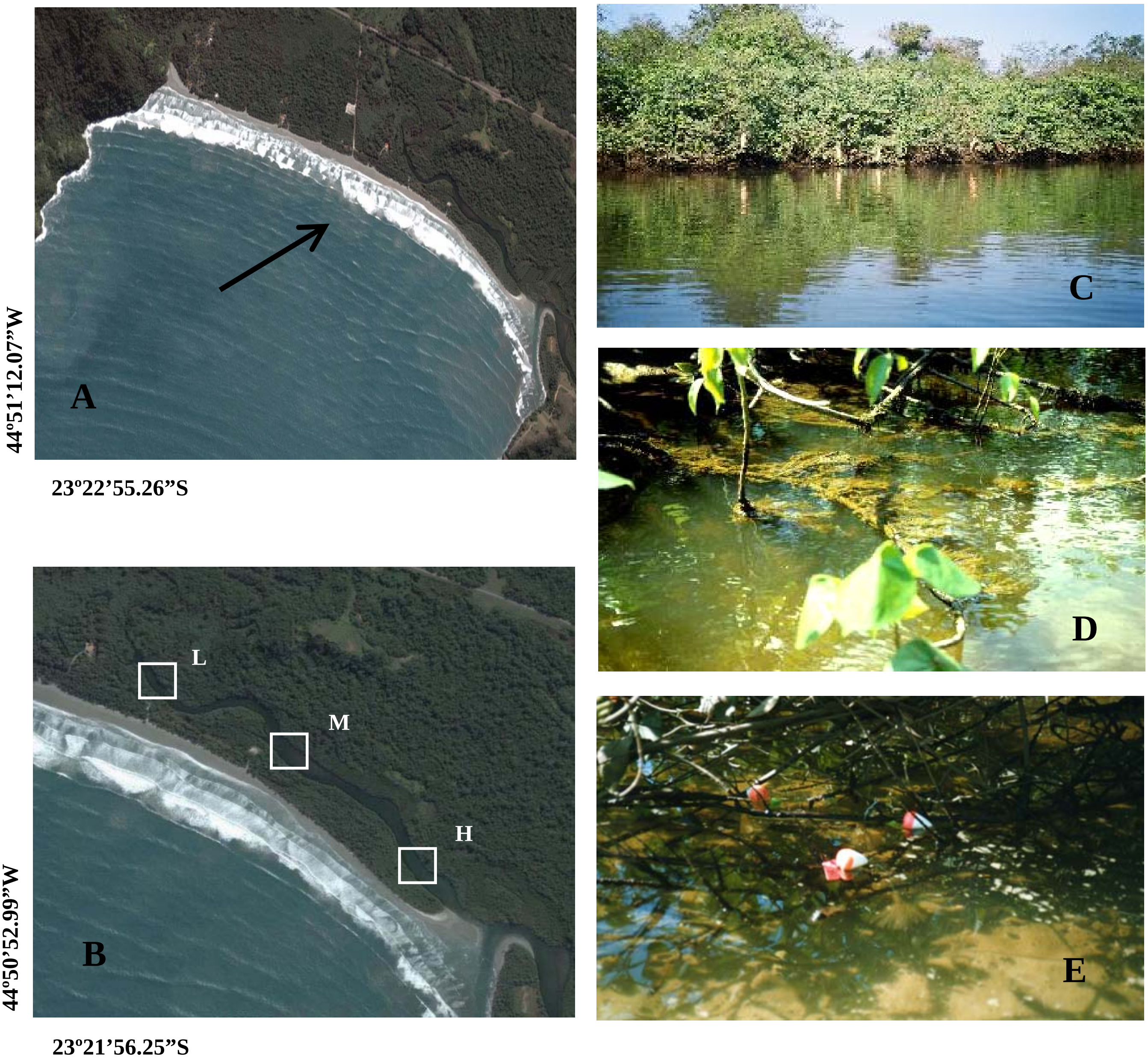

Figure 1. Study area at the Rio da Fazenda mangrove. Satellite photo (earth.google.com) of the Fazenda Beach (arrow in A) and of the Rio da Fazenda mangrove with the position of the three stretches of salinity (H- high, M- median, L- low, in B). Detail of the mangrove marginal vegetation (median stretch in C) and of the natural (branches with algae and organic matter adhered to the roots, in D) and artificial substrata (colored buoys supporting a piece of sisal rope, in E).

The use of artificial substratum has a great advantage upon the use of natural one by allowing the standardization of the colonization time and of the sampling area (Lambert & Resh 1985; Uieda 1999; Carvalho & Uieda 2004).

The macroinvertebrates were sampled during the 2003 rainy season (February). On each selected stretch of salinity, ten replicates of artificial substrata were installed. The artificial substratum was composed by a piece of sisal rope (7.5 cm), attached to a weight for its maintenance under the water (Fig. 2) and tied to the branches of the mangrove vegetation. The natural substratum consisted on a branch piece with roots and adhered algae.

Fourteen days after the installation of the artificial substrata, ten replicates of the natural substrata and ten of the artificial substrata were removed and packed in flasks with formaldehyde 5%. In the laboratory, the substratum was washed in the formaldehyde to dislodge the adhered animals. The liquid was poured under three granulometric sieves (meshes of 1.0, 0.5 and 0.25 mm). The sieves were inspected under stereomicroscope and the macorinvertebrates were sorted, identified and counted (the taxonomic level depends on the group).

Because Copepoda occurred in a great number of individuals and because they passed through the small sieve mesh, their abundance was analyzed by sub samples. The liquid that passed through the sieves was agitated and ten replicates were separated and analyzed under stereomicroscope in SedgWick-Rafter chamber.

Relative abundance curves of species, or species importance curve, were constructed by plotting the log (x+1) of absolute abundance of each animal group against the corresponding rank, in decreasing order of abundance (Brower & Zar 1984). After testing for normality (Shapiro-Wilks; αλφα = 0.05) and homocedasticity (Levene; αλφα = 0.05), an analysis of variance (ANOVA one-way) followed by a multiple comparison test (Tuckey) was used in order to evaluate significant differences between salinity (three stretches) and substrata (two types).

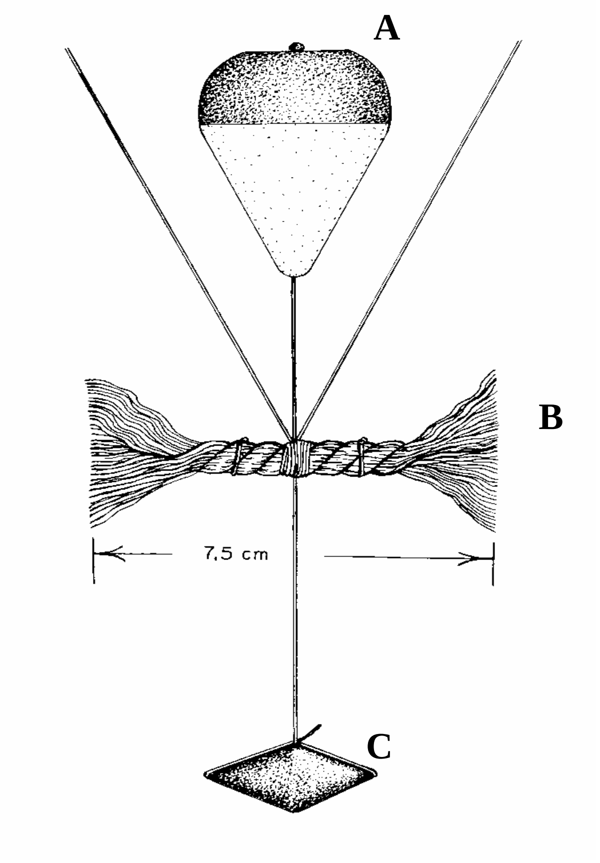

Figure 2. Schematic design of artificial substratum: A- colored buoy; B- sisal rope of 7.5 cm length; C- weight.

Results

The taxonomic groups identified included macroinvertebrates of three phyla: Cnidaria (Hydrozoa), Annelida (Polychaeta) and Arthropoda (Arachnida, Insecta and Crustacea). The insects were represented only by Diptera (Chironomidae) and Ephemeroptera, with the predominance of the first one. Crustaceans, the most diversified group, were represented by Copepoda (Harpacticoida and Cyclopoida), Tanaidacea (Tanaidae), Isopoda (Sphaeromatidae and Munnidae), Amphipoda (Gammaridea) and Decapoda (Caridea and Brachyura).

Copepoda and Tanaidacea predominated on both substrata, although the artificial substratum exhibited the greatest abundance and species richness (Table I). When compared by the dominance curve, the similarities between the natural and artificial substrata were evident, with the dominance of Copepoda (rank 1) and Tanaidacea (rank 2) found on both substrata (Fig. 3). However, the groups intermediate in abundance that prevailed on the natural substratum were Isopoda and Diptera and on the artificial substrata were Diptera and Polychaeta (Table I).

Apparently the differences between substrata were related to the dominance of Copepoda at all salinity ranges on the artificial substratum (Table I). This result was confirmed by the ANOVA, with a significant difference between substrata when all groups were considered ($p = 0.002$, $F = 9.970$, df = 1), but not when the abundance of Copepoda was excluded from the analysis ($p = 0.792$, $F = 3.191$, df = 1).

The spatial variation on abundance was significant when considered the sum of both substrata, with the low salinity stretch presenting the lowest abundance in the two situations, including and excluding Copepoda (Fig. 4). The longitudinal variation on macrofauna abundance was also confirmed when the two substrata were analyzed separately (Fig. 5). The significant difference between salinities for natural substratum is related to the dominance of Copepoda on the high and median salinity stretches and the dominance of Isopoda and Tanaidacea on the low salinity stretch (Table I). The significant difference between salinities for

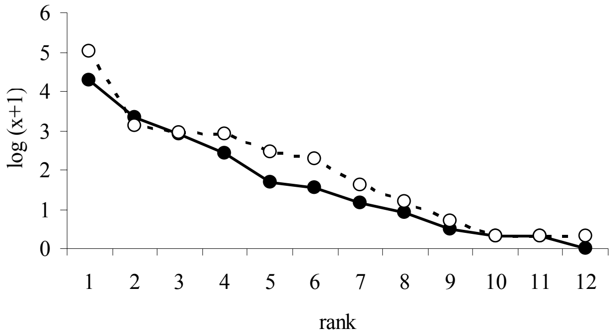

Figure 3. Relative abundance curves of the taxonomic groups sampled on the natural (blak points) and artificial (white points) substrata (sum of the three stretches of different salinity). The absolute abundance [log (x+1)] was plotted against the corresponding rank, presented in decreasing order of abundance.

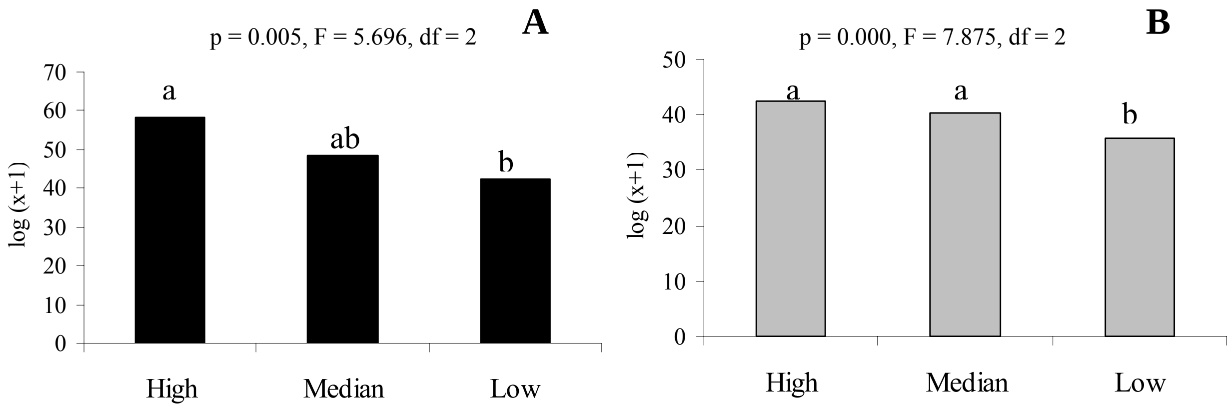

Figure 4. Abundance [log (x+1)] of macroinvertebrates sampled on High, Median and Low salinity stretches (sum of natural and artificial substrata), including (A) and excluding (B) Copepoda values, and the results of Tuckey test (different letters indicate significant differences, α = 0.05).

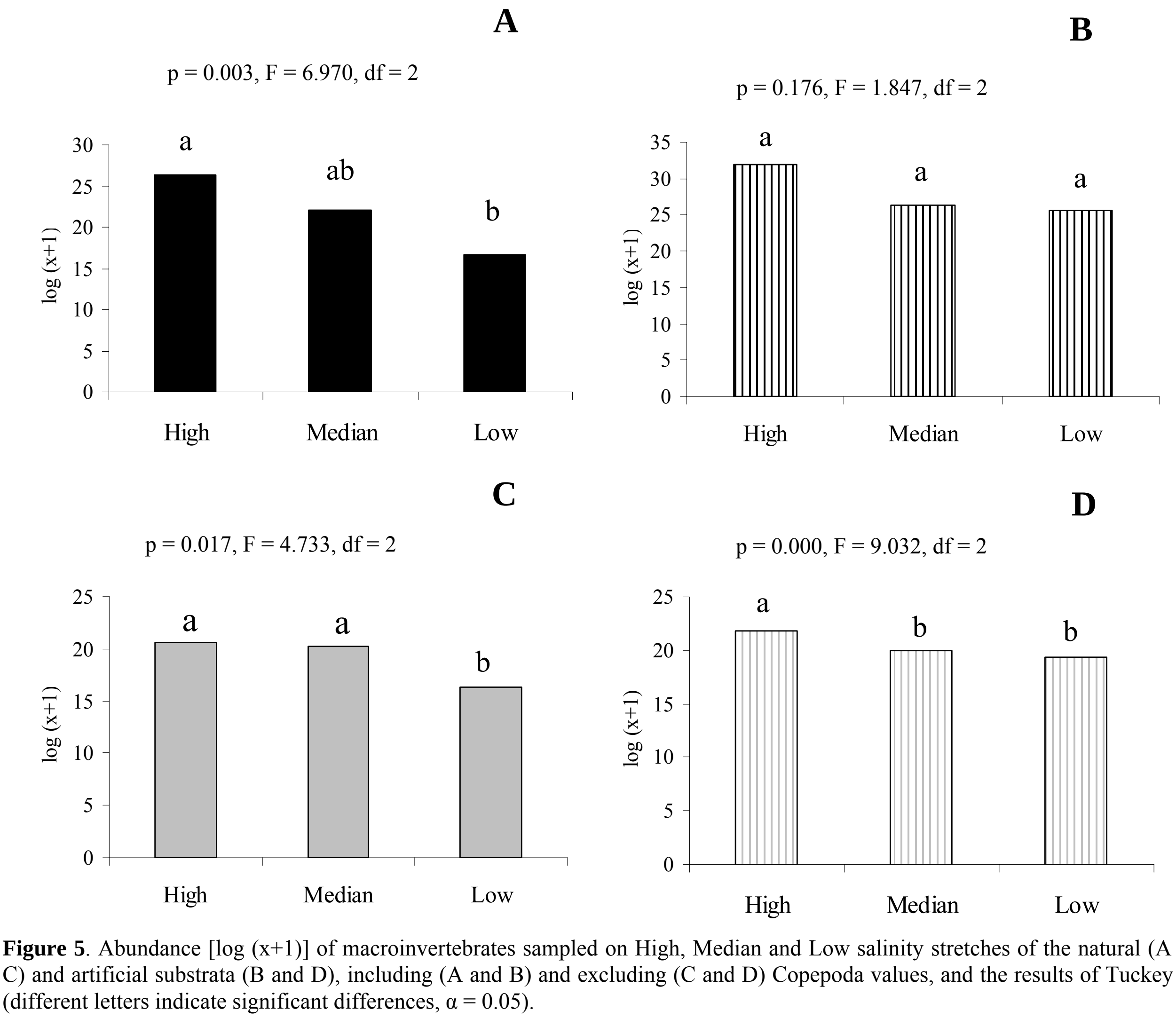

Figure 5. Abundance [log (x+1)] of macroinvertebrates sampled on High, Median and Low salinity stretches of the natural (A and C) and artificial substrata (B and D), including (A and B) and excluding (C and D) Copepoda values, and the results of Tuckey test (different letters indicate significant differences, α = 0.05).

artificial substratum, when Copepoda abundance was removed, is related to the dominance of Tanaidacea and Polychaeta at high salinity, of Tanaidacea, Polychaeta and Diptera at median salinity, and of Diptera and Tanaidacea at low salinity.

The analysis of the relative abundance by salinity stretch of the taxonomic groups presented in the natural and artificial substrata (Table I, Fig. 6) showed that the majority of groups were found in the three stretches. However, if considered only the six most abundant groups (Polychaeta, Diptera, Copepoda, Tanaidacea, Isopoda, and Amphipoda; Table I), the majority was predominant in the higher salinity on both substrates, except for Diptera and Isopoda.

Table I. Absolute (total number of individuals) and relative abundance (%) of macroinvertebrates sampled on the natural and artificial substrata installed in three stretches of different salinity (high, median and low) during the colonization experiment realized in February/2003 on the mangrove of Fazenda River.

Taxonomic groups	Natural Substratum								Artificial Substratum							
	High		Median		Low		TOTAL		High		Median		Low		TOTAL	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Hydrozoa	-	-	-	-	1	0.1	1	<0.0	2	<0.0	12	0.1	-	-	14	<0.0
Polychaeta	30	0.2	16	0.4	-	-	46	0.2	254	0.3	235	1.2	77	0.6	886	0.8
Arachnida	-	-	-	-	1	0.1	1	<0.0	-	-	-	-	1	<0.0	1	<0.0
Diptera	48	0.3	111	2.5	97	14.6	256	1.1	62	<0.0	229	1.1	498	3.8	789	0.7
Ephemeroptera	-	-	1	<0.0	1	0.1	2	<0.0	-	-	-	-	1	<0.0	1	<0.0
Copepoda	16,161	91.3	3,242	72.3	48	7.2	19,451	58.1	75,50	98.0	19,00	94.6	12,12	93.2	106,63	96.8
Tanaidacea	1,39	7.9	643	14.3	194	29.2	2,227	9.7	588	0.8	461	2.3	230	1.8	1,279	1.2
Isopoda	49	0.3	452	10.1	316	47.5	817	3.6	107	0.1	115	0.6	73	0.6	295	0.3
Amphipoda	21	0.1	11	0.3	1	0.1	33	0.1	190	0.2	3	<0.0	1	<0.0	194	0.2
Caridea	6	<0.0	4	<0.0	3	0.5	13	<0.0	14	<0.0	23	0.1	3	<0.0	40	<0.0
Brachyura-crabs	1	<0.0	3	<0.0	3	0.5	7	<0.0	1	<0.0	-	-	3	<0.0	4	<0.0
Brachyura-larvae	-	-	-	-	-	-	-	-	1	<0.0	-	-	-	-	1	<0.0
TOTAL	11,706	77.5	4,483	19.6	665	2.9	22,854	16.0	77,04	70.0	20,08	18.2	13,01	11.8	111,13	84.0

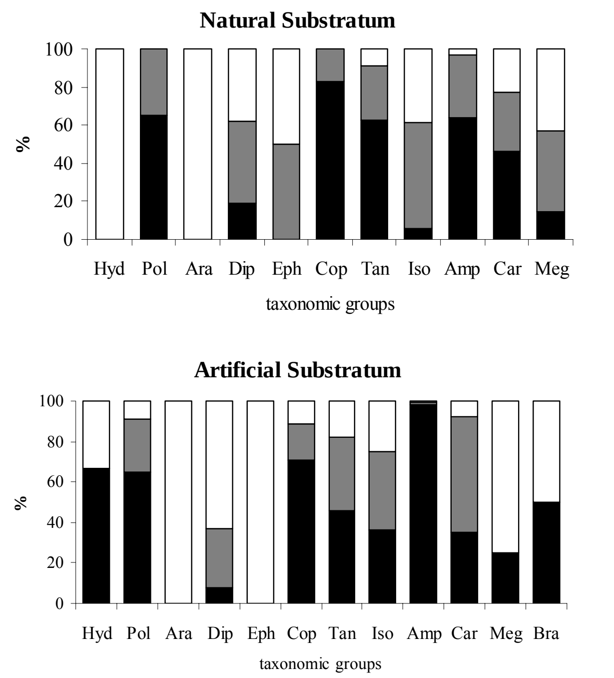

Figure 6. Relative abundance (%) of macroinvertebrates on natural and on artificial substrata sampled on the three stretches (high, median and low salinity ranges). Hyd-Hydrozoa, Dip- Diptera, Tan- Tanaidacea, Car- Caridea, Pol- Polychaeta, Eph- Ephemeroptera, Iso- Isopoda, Meg-Megalopa, Ara- Arachnida, Cop- Copepoda, Amp- Amphipoda, Bra- Brachyura.

Discussion

Nowadays Copepoda is the most studied crustacean taxa in Brazil, although plankton studies are still scarce (Amaral & Jablowski 2005). Species that carry their eggs, like Cyclopoida species, are more abundant in estuaries, where the depth is small and fish predation is not as common as in open sea (Vuorinen *et al.* 1983). The use of vegetation as shelter is supposed to be related to the high mortality of Copepoda in the plankton (Bell & Westoby 1986).

Although we sampled only on February, based on the literature (Bell 1980) we can speculated that the great abundance of Copepoda found in the Fazenda River mangrove, mainly in the high salinity stretch, may be related to its reproductive peak during summer months. In a South Carolina salt marsh, about 80% of Copepoda occurred on summer and only less than 5% represented the whole community on other seasons (Bell 1980).

For Tanaidacea, the second most abundant macroinvertebrate taxa sampled on the Fazenda River, little can be discussed here due to the scarcity of literature data. In a review of Tanaidacea on the coastal region of two Brazilian States (Rio de Janeiro and Santa Catarina), Gutu (1996) stressed the low occurrence in the Brazilian coast and the limitation of biological data. In Brazil, 28 species are known, 17 belonging to the Suborder Apseudomorpha and 11 to the Suborder Tanaidomorpha (Gutu 1996). The family Tanaidae, the one found in the Fazenda River mangrove, belongs to the second Suborder.

Isopoda, the third most abundant crustacean taxa sampled on the Fazenda River, is cited by Pires (1982) as an important group with occurrence on intertidal regions, associated with algae coverage and represented mostly by the family Sphaeromatidae. This group can live in a great variety of habitats and can tolerate a broad range of environmental conditions (Pires 1982).

A number of chironomid species are tolerant of a wide range of salinities and this insect group may be a major component of the fauna of brackish waters (Pinder 1995). According to Pinder (1995), species of Chironomidae adapted to life in the intertidal zone have been recorded from coasts all over the world and they are taxonomically diverse in this habitat. Nevertheless, the taxonomic and ecological knowledge of this group in Brazil is restricted, mainly at mangrove habitats (Trivinho-Strixino & Strixino 1995).

Manipulative experiments of natural communities has been growing and generating important contributions for the comprehension of the colonization, maintenance and persistence of communities (Hulberg & Oliver 1980). In colonization experiments, it is important to evaluate the efficiency of the artificial substratum. The great advantage of the artificial substratum is to allow a sampling standardization, regarding the sampled area and the recording of the initial time of colonization process, difficult when using natural substratum (Carvalho & Uieda 2004). In the present experiment, the artificial substratum proved to be appropriated making ease the installation and allowing the sampling standardization.

In experimental studies it is also important to analyze if the artificial substratum provides the same conditions of the natural one, like protection and shelter against predators and good foraging conditions. In the present work, the existence of these conditions on the artificial substratum was indirectly evaluated by the analysis of the community structure at the end of the experiment. At the three studied stretches, the natural vegetation, composed by submerged branches covered with algae, was well reproduced by the artificial substrate, which allowed the colonization of algae and macrofauna similar to the one colonizing the roots of the mangrove vegetation.

The significant difference between the

artificial and the natural substrata, associated here with the spatial variation (salinity ranges) of Copepoda abundance in the natural substratum, may be related to the structure of this substratum. At the end of the field work it was observed that the natural vegetation of the median salinity stretch showed large quantities of branches, algae, and organic matter, the low salinity stretch showed high quantities of branches and algae, and the high salinity stretch showed few branches and algae. Spatial differences in the structure of the natural substratum probably provided different conditions for macroinvertebrates colonization, with strong effect on Copepoda. On the other hand, no differences for the artificial substratum structure between stretches were recorded, even at the end of the 14 colonization days. The structural complexity of habitat seems to affect the abundance and diversity of animal communities, with more structurally complex algae species allowing a higher richness and diversity (Hull *et al.* 2001). The complexity of habitat can not only increase the number of available niches for colonization, but can also provide refuge against predation (Coull & Wells 1983), or even reduce predation effects for changing the efficiency of forage. Some authors, such as Heck & Thoman (1981) and Underwood *et al.* (2000), suggested that predation intensity is lower in habitats with more vegetation than in habitats without vegetation, what can be related to the highest density of animals in this substratum.

Besides the structural complexity of the natural substratum, the sampling area can influence the colonization process. For example, in a colonization experiment conducted at two shallow subtidal sites in North Carolina, Eggleston *et al.* (1999) compared the abundance of macroinvertebrates colonizing small ($0.25m^2$) and large patches ($1m^2$) of artificial plants. They found that the density of Decapoda, Amphipoda and Isopoda was larger in small patches than in large patches, probably related to an increase in foraging rates, since estuarine macrofauna is influenced by the heterogeneity of habitat in a small spatial scale (Eggleston *et al.* 1999). In the Fazenda River experiment the influence of the substratum area was controlled as the artificial and the natural substrata had similar areas.

Thus, the significant spatial difference on abundance of macroinvertebrates associated to the mangrove vegetation found in the Rio da Fazenda emphasized the salinity as an important environmental factor affecting the distribution of the aquatic fauna associated to the mangrove vegetation. This vegetation can provide shelter and a place for foraging not only for a diversified and abundant macoinvertebrate fauna, but also for a great variety of fish species. In the same area, Corrêa & Uieda (2007) observed many fish species exploring the submerged branches of the mangrove vegetation as shelter and feeding on the macroinvertebrate fauna that colonizes this vegetation (2007).

Acknowledgments

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