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Dry season distribution of hydroids in a small tropical estuary, Pernambuco, Brazil

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Hydroid distribution patterns along a horizontal ecocline in the Rio Formoso/Rio Ariquindá/Rio Porto Alegre system, a small and seasonally poikilohaline estuary on the tropical northeast coast of Brazil, were investigated. Collecting was undertaken during the dry season, in November 1993, by diving (with and without SCUBA). Nine stations were sampled on a transect extending from a reef outside the river mouth to a mangrove system at the upper end of the estuary. Four major regions were distinguished along the ecocline based on numerical analyses of hydroid species/station location data: (1) nearshore reef — a sandstone ledge outside the entrance of the estuary; (2) river mouth — a sandy and shelly flood-tidal delta area inside the entrance of the Rio Formoso; (3) mid-estuary — a muddy and rocky, mangal-fringed, poikilohaline region in the middle reaches of the Rio Ariquindá; (4) upper estuary — a muddy, mangal-dominated, strongly poikilohaline region at the upper end of the estuary in the Rio Porto Alegre. Species numbers were highest in mid-estuary and on the nearshore reef, intermediate at the river mouth, and lowest in the upper estuary. Only three eurytopic species, including two euryhaline opportunists (*Clytia gracilis*, *Obelia bidentata*) and an estuarine endemic (*Garveia franciscana*), were found at the two landwardmost stations in the upper estuary. Euryhaline marine species comprised part or all of the fauna at stations along the rest of the system. Changes in hydroid species composition along the estuarine gradient were attributed primarily to differences in substrate types and salinity characteristics from one site to another.

Introduction

The familiar community gradient or 'coenocline' within estuarine systems has been compared ecologically with the vertical zonation of biota on rocky intertidal shores (Boesch, 1977). Along both the horizontal environmental gradient or 'ecocline' from mouth to head of an estuary (Remane, 1971), and the vertical ecocline from low to high tide in the rocky intertidal (Lewis, 1976), there is increasing physical stress accompanied by decreasing biotic diversity. Moreover, low diversity biocoenoses of upper estuarine and high intertidal environments are reputed to possess greater community stability than higher diversity assemblages of the lower estuary and lower intertidal (Boesch, 1974; Lewis, 1976).

Information about zonation patterns of hydroids in estuaries is based largely on studies in temperate rivers, especially of Germany (Thiel, 1970; Meyer, 1973) and South Carolina, USA (Calder, 1976). In South Carolina, hydroid diversity was highest in areas of high and relatively stable salinity, if suitable substrates were available. Regions of low salinity or fresh water, those alternating between fresh and brackish conditions, those subjected to wide salinity oscillations, and those with a scarcity of firm substrates, had a comparatively impoverished fauna. Faunal change in homoiohaline estuaries (i.e., those with relatively small oscillations in salinity) was most pronounced between salinities of 15-20 ‰, more or less corresponding with the boundary between mesohaline and polyhaline zones of the Venice System (Anonymous, 1958). In decidedly poikilohaline estuaries (i.e., those characterized by large fluctuations in salinity), hydroid species typical of low salinity areas occupied much of the system as predicted by the estuarine coenocline model of Boesch (1977).

Goals of this study were to determine the species diversity and zonation patterns of hydroids in a small tropical estuary, on the coast of northeastern Brazil, during the dry season.

Study area

The study was carried out along a 10-km long transect of the Rio Formoso/Rio Ariquindá/Rio Porto Alegre system, a shallow (<5 m) coastal plain estuary located near the town of Tamandaré, Pernambuco state, northeast Brazil (fig. 1). Wide fluctuations of salinity occur in the Rio Formoso, especially in the middle and upper estuary (e.g., Lira et al., 1979; Lira & Fonsêca, 1980). Fresh water input to the rivers is sporadic and results from local runoff of precipitation, notably during the rainy season. Much of the estuary is euhaline (>30 ‰) during dry periods. In November 1993 (dry season), observed salinities ranged from 34 ‰ just off the mouth of the Rio Formoso to 26 ‰ near the headwaters of the Rio Porto Alegre (table 1). By contrast, salinities during July 1994 (rainy season) varied from 35 ‰ to 12 ‰ over the same stretch of the estuary (Maÿal, unpublished data). Annual fluctuations of water temperature in this tropical estuarine system are small.

River banks from headwaters to lower estuary are mostly muddy and fringed with red mangroves (*Rhizophora mangle*). Rocky outcrops are fairly common on bottom in the middle reaches of the system. Near the river mouth, muddy and rocky bottoms give way to a flood-tidal delta of sand and broken shell, and mangrove-lined shores are replaced by sandy beaches. Pilings of a shallow fish pound inside the inlet area were overgrown by algae. Immediately seaward of the river entrance are shallow ledges or "reefs" running parallel with the coastline. Such reefs, common in nearshore waters along the coast of northeast Brazil, are drowned relics of the Barreiras Formation (Schaeffer-Novelli et al., 1990). They are composed of sandstone rather than being of coral or algal origin. The entire estuary is microtidal, with a mean tidal range of about 1.5 m, and tides are semidiurnal.

Materials and methods

Collections of hydroids were made at nine stations along a transect from a mangrove swamp near the headwaters of the Rio Porto Alegre to a sandstone reef immediately seaward of the mouth of the Rio Formoso (table 1, fig. 1). Collecting was undertaken by diving, with and without SCUBA, during November 1993. Equivalent collecting effort was expended at each of the nine stations. Two divers (DRC, EMM) worked for 30 minutes each at stations PE-A through PE-7, and one diver (DRC) collected for 60 minutes at station PE-8. Part of the sampling at PE-8, on the reef, was undertaken in shallow crevices and large tidepools on the reef crest. Hydroids and

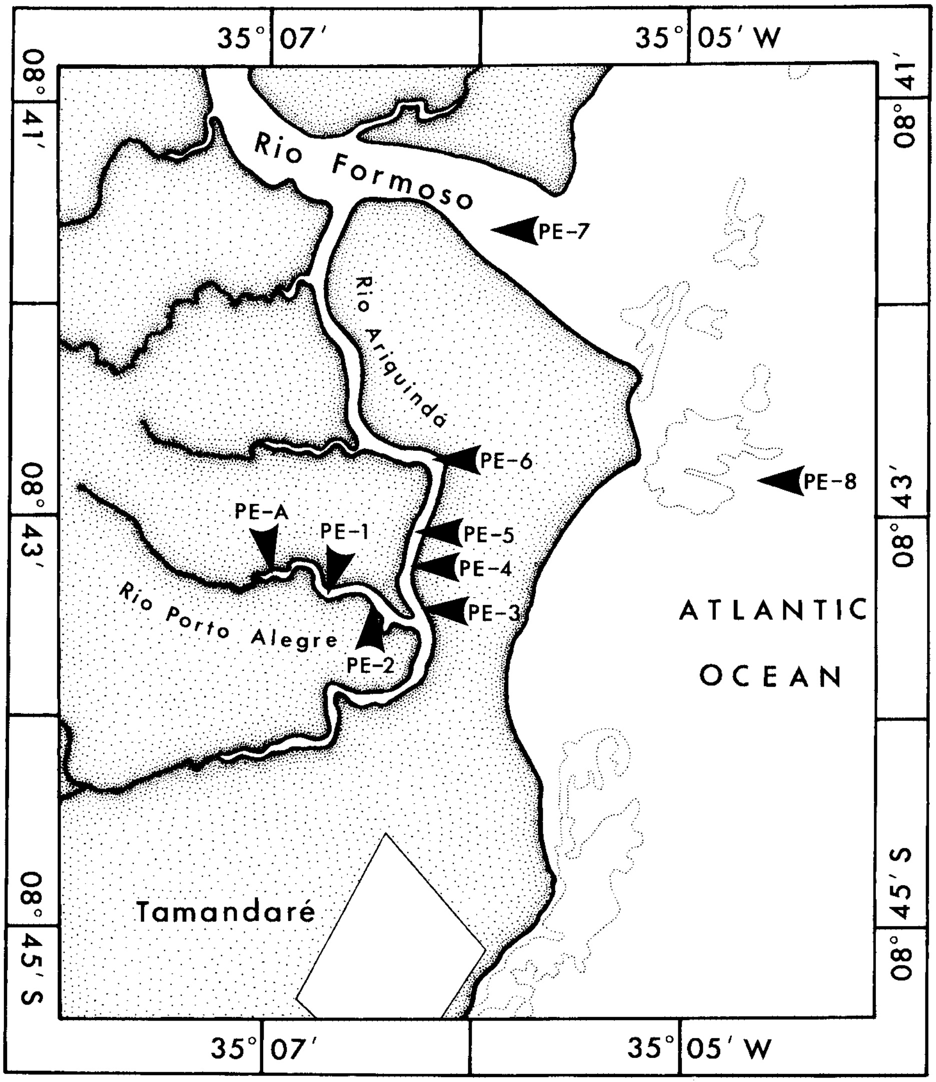

Fig. 1. Tamandaré, Brazil, and vicinity, with locations of stations sampled during the study in the estuary formed by the Rio Formoso/Rio Ariquindá/Rio Porte Alegre.

representative substrates from each station were placed in bottles of ambient sea water and returned alive to the laboratory for examination, sorting, identification, and preservation. Only attached hydroids, with hydranths present, were recorded as part of this study. Salinities were measured with a refractometer, and water temperatures were determined with a stem thermometer.

Normal (station group) cluster analysis was undertaken on a species-station data matrix using NTSYS-pc (Rohlf, 1990). Qualitative hydroid faunal similarity among the nine stations was calculated by the program SIMQUAL, using the Dice coeffi-

Table 1. Stations occupied on the Rio Formoso/Rio Ariquindá/Rio Porto Alegre estuary, and salinity data from dry season (November 1993) and rainy season (July 1994) periods.

Station	Major substrates	Salinity (‰) Nov. 1993	Salinity (‰) July 1994	Temp. (°C) Nov. 1993
PE-A	mud, *Rhizophora* roots, wood	26	12	28
PE-1	mud, *Rhizophora* roots, shells	31	15	
PE-2	mud, *Rhizophora* roots, shells	30	18	
PE-3	mud, *Rhizophora* roots, shells	32	21	
PE-4	mud, *Rhizophora* roots, rocks, shells, algae	33	27	
PE-5	mud, *Rhizophora* roots, rocks, wood, algae, shells	32	27	
PE-6	rocks, mud, *Rhizophora* roots, algae, shells	32	33	28
PE-7	sand, shell hash, wood pilings, algae, rocks	32	35	
PE-8	sandstone reef, algae	34	35	28

cient. Clustering was performed using the SAHN program, employing the UPGMA clustering method and a beta value of -0.25. Principal components analysis was computed by PRINCOMP, employing a correlation matrix of variables (Podani, 1988).

Voucher specimens of species identified during the study have been deposited in collections at the Royal Ontario Museum (invertebrate zoology section).

Results

Hydroids were collected at each of the nine stations in the study area, and a distinct coenocline was apparent along its estuarine gradient (table 2). The fauna was made up largely of euryhaline marine species, and no limnic species were represented. Of 31 species distinguished overall, diversity was lowest at the uppermost end of the estuary (stations PE-A, PE-1). Only three species (*Garveia franciscana, Clytia gracilis, Obelia bidentata*), all decidedly eurytopic, were found at these two stations. Hydroid diversity was highest at two stations in mid-estuary (PE-4, PE-5) and at a reef station just outside the mouth of the Rio Formoso (PE-8). The most ubiquitous species (*Clytia gracilis, Eudendrium carneum, Obelia bidentata, Turritopsis nutricula*) were present at five or more of the nine stations.

Four major regions were recognized in the estuary by a normal cluster analysis (fig. 2), using a similarity cutoff point of 0.45 or less. The greatest dichotomy in the dendrogram was that between a nearshore reef station (PE-8) and the remaining eight stations, all located within the estuary. This reflected marked differences in species composition of hydroids from two quite dissimilar environments. Of 12 species identified from the nearshore station during the study, eight were found only at that location (table 2). One of these, *Millepora alcicornis*, was the largest and most conspicuous hydroid on the reef.

Three regions were distinguished inside the river system. The upper estuary region included stations PE-A, PE-1, and PE-2, all located in the Rio Porto Alegre. Species composition was identical at stations PE-A and PE-1, comprising only three

Table 2. Observed dry season distribution of hydroids along a transect of the Rio Formoso/Rio Ariquindá/Rio Porto Alegre estuary, Brazil.

Species	Stations								
	PE-A	1	2	3	4	5	6	7	8
Corydendrium parasiticum (Linnaeus, 1767)					+				
Turritopsis nutricula McCrady, 1857				+	+	+	+	+	+
Garveia franciscana (Torrey, 1902)	+	+	+	+					
Bougainvilliidae, indet.				+	+	+			
Stylactaria sp.						+			
Pandeidae, indet.					+				
Eudendrium carneum Clarke, 1882			+	+	+	+	+	+	+
Cladocoryne floccosa Rotch, 1871									+
Zyzzyzus warreni Calder, 1988				+	+	+	+		
Pennaria disticha Goldfuss, 1820									+
Millepora alcicornis Linnaeus, 1758									+
Lafoeina amirantensis (Millard & Bouillon, 1973)					+	+	+		
Halecium bermudense Congdon, 1907				+	+	+	+		
Halecium tenellum Hincks, 1861			+	+					
Halecium sp. 1						+			
Lafoeidae, indet.				+					
Clytia gracilis (M. Sars, 1850)	+	+	+	+	+	+	+	+	
Clytia hummelincki (Leloup, 1935)							+		
Clytia paulensis (Vanhöffen, 1910)									+
Obelia bidentata Clark, 1876	+	+	+	+	+	+	+		
Thyroscyphus ramosus Allman, 1877								+	+
Dynamena crisioides Lamouroux, 1824									+
Dynamena disticha (Bosc, 1802)									+
Diphasia digitalis (Busk, 1852)							+		
Tridentata distans (Lamouroux, 1816)									+
Ventromma halecioides (Alder, 1859)				+		+			+
Monotheca margaretta Nutting, 1900									+
Plumularia floridana Nutting, 1900			+		+	+			
Halopteris carinata Allman, 1877								+	
Schizotricha tenella (Verrill, 1874)					+	+			
Macrorhynchia philippina Kirchenpauer, 1872					+	+	+	+	
Number of species	3	3	6	11	13	14	10	6	12

species. Two of these were eurytopic and ubiquitous taxa (*Clytia gracilis, Obelia bidentata*). The third (*Garveia franciscana*) was the most prevalent hydroid at both sites, although many colonies of this estuarine endemic species were dormant or at least partly so. Colonies of *G. franciscana* were observed further downriver (at stations PE-2 and PE-3), but the species was replaced there as the most conspicuous hydroid by *Eudendrium carneum*. The fauna at station PE-2 included the same hydroids found at PE-A and PE-1, augmented by three euryhaline marine species (*Eudendrium carneum, Halecium tenellum, Plumularia floridana*).

The mid-estuary region included four consecutive stations in the middle reaches of the Rio Ariquindá (PE-3, PE-4, PE-5, PE-6), all with relatively diverse and quite

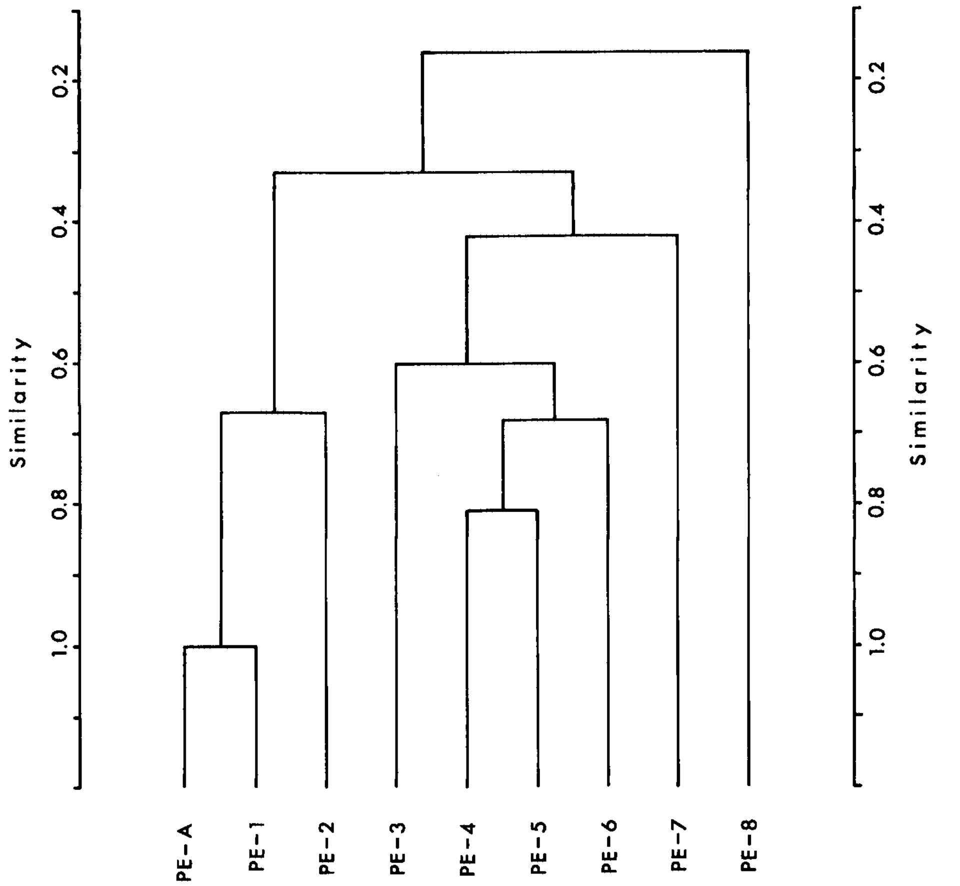

Fig. 2. Station associations in a normal cluster analysis of data on hydroids from the estuary of the Rio Formoso/Rio Ariquindá/Rio Porte Alegre, Brazil.

similar hydroid assemblages. Six species, including a mix of both euryhaline opportunists (*Clytia gracilis, Obelia bidentata*) and euryhaline marine species (*Turritopsis nutricula, Eudendrium carneum, Zyzzyzus warreni, Halecium bermudense*) were found at all of these stations. The most conspicuous hydroid at each of the four sites was *Eudendrium carneum*. *Garveia franciscana* was observed downriver only as far as PE-3.

Among the eight sampling locations within the river system, a station at the mouth of the Rio Formoso (PE-7) sorted out alone. With its sandy and shelly bottom, and algal-dominated wood pilings, this station differed considerably from predominantly muddy and mangal-fringed sites upriver. Hydroids were scarce and diversity was quite low in this region, with most species being collected from wood pilings of a fish pound.

Groupings of stations by principal components analysis (fig. 3) were consistent with the results of cluster analysis. Two stations (PE-A and PE-1) in the upper estuary region overlapped, having the same species composition. Also part of this cluster was the next station (PE-2) downestuary. Low hydroid diversity in the Rio Porto Alegre,

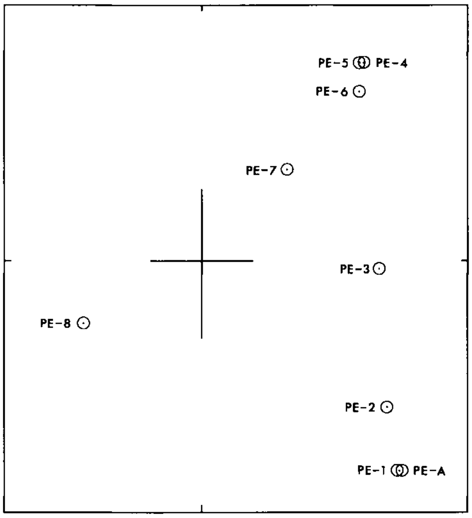

Fig. 3. Principal components analysis of data on hydroids from nine stations along the estuary of the Rio Formoso/Rio Ariquindá/Rio Porte Alegre, Brazil.

where these stations were located, is attributed here to wide seasonal fluctuations in salinity.

The mid-estuary region, comprising a cluster of four stations in the middle reaches of the Rio Ariquindá, was segregated along the vertical axis from the upper estuary region. The similarity of stations PE-4, PE-5 and PE-6 within this cluster was marked. Also apparent were the intermediate affinities of station PE-3, located between stations of the upper estuary and the three other stations within the mid-estuary group. Mid-estuary stations, with their higher diversity and greater numbers of euryhaline marine species, appeared to be impacted to a lesser extent than those of the upper estuary by poikilohaline conditions.

Station PE-7 (Rio Formoso mouth), with its different substrate characteristics, stood apart from stations up-estuary and from the rocky reef station outside the entrance. Yet the affinities of its hydroids were unmistakably with those of other stations located inside the river system, and particularly with those of the mid-estuarine region.

Clearly different from all of the river sites, and located alone in the lower left quadrant, was station PE-8 on the nearshore sandstone ledge. A combination of factors, including but not limited to rocky substrate, exposed coastal location, and generally more stable salinity regime, set this site and its hydroid fauna apart from all others.

Discussion

Hydroids are common inhabitants of estuaries (e.g. Fraser, 1926; Vervoort, 1946, 1964; Naumov, 1969; Watling & Maurer, 1972; Meyer, 1973; Wedler, 1973; Morri & Bianchi, 1983). As with the biota of brackish waters generally (Remane, 1971), however, hydroids inhabiting estuarine areas are largely eurytopic marine species and species diversity is reduced over that of euhaline marine environments (Thiel, 1970; Calder, 1976). While 31 species of hydroids were identified during this study in the estuary of the Rio Formoso/Rio Ariquindá/Rio Porto Alegre, more than 100 have been reported from the coast of Brazil (Migotto, 1996).

The pattern of decreasing species richness with decreasing salinity along the estuarine gradient (Remane, 1971) is now well known. In the study area, hydroid diversity was highest (12-14 species) at two stations in mid-estuary and on a nearshore reef adjacent to the entrance of the Rio Formoso. A marked decline in numbers of species was observed (table 2) from mid-estuary (station PE-4) to the upper reaches of the Rio Porto Alegre (stations PE-A, PE-1). The only hydroids found at the two uppermost stations on this river were a couple of euryhaline opportunists (*Obelia bidentata* and *Clytia gracilis*) and an estuarine endemic (*Garveia franciscana*). The latter, a widespread 'fouling organism' in brackish waters (Vervoort, 1964; Morri, 1982), was particularly abundant although all three species were frequent. These eurytopic hydroids are also common at the heads of certain temperate estuaries elsewhere, including rivers in eastern North America (Calder, 1976, unpublished data).

In addition to differences in numbers of species, the species composition of hydroids varied from one site to another in the study area. The fauna on a nearshore reef (station PE-8) was particularly distinctive, with 2/3 of the hydroid species found there being collected only at that station in the study area. This reflected the distinct environment constituted by the reef. Its substrate was rocky instead of predominantly muddy or sandy, it was exposed to the open South Atlantic rather than being sheltered within a river, and its salinity regime seemed more stable given the coastal location. Inside the estuary, hydroid assemblages near the river mouth (PE-7) stood apart from those upriver. The bottom sediment in this region, consisting of sand and shell hash, provided a generally unfavourable substrate for hydroids. Wood pilings of a fish pound were also present, but much of the available space on them was occupied by dense algal growth. Upriver, the most notable changes in hydroid faunal assemblages were the reductions in species numbers between stations PE-4 and PE-1. The bottom was predominantly muddy at all stations from PE-6 to PE-A, and riverbanks were fringed with red mangroves (*Rhizophora mangle*). Hydroid faunal changes along this stretch of the river system were attributed largely to salinity differences from one site to another.

The distribution of hydroids in the study area generally conformed with Boesch's (1977) model of estuarine benthic community zonation. Boesch demonstrated that the widely used Venice System classification of estuarine zones has limited relevance in characterization of poikilohaline estuaries, with their wide salinity fluctuations and abrupt coenocline changes. Instead, he showed that the zonation of benthos in poikilohaline estuaries is strongly influenced by conditions of low salinity, the impact of which displaces species with limited tolerance of brackish conditions downestuary (or excludes them entirely). Under such conditions, euryhaline opportunists and estuarine endemics penetrate further downriver and may dominate much of the estuary. Only euryhaline opportunists (*Obelia bidentata* and *Clytia gracilis*) and the estuarine endemic *Garveia franciscana* were found at stations PE-A and PE-1, even though salinities at those stations were high (26-31‰) during November 1993. Salinities measured in this part of the estuary during the rainy season were much lower (12-15‰), restricting the distribution of euryhaline marine species to localities downriver. Coenocline changes were rapid between the mid-estuarine (Rio Ariquindá) and upper estuarine (Rio Porto Alegre) regions (i.e., between stations PE-3 and PE-1) as various euryhaline marine species reached upriver distributional limits and dropped out of the fauna. By contrast, the brackish water *Garveia franciscana* reached its downriver limit in this area and was replaced as the most conspicuous hydroid by *Eudendrium carneum*, a euryhaline marine species.

The extent to which impacts of seasonal poikilohalinity on hydroid zonation in the study area are camouflaged by life cycle phenomena is unknown. Conceivably, certain relatively stenohaline marine hydroids may colonize upestuary during the dry season, when salinities are high, only to be exterminated during the rainy season when salinities are low. Conversely, the estuarine endemic *Garveia franciscana* may spread downriver under brackish conditions but die back there when salinities are high. Such seasonal range extensions and contractions of epibenthos, due to annual salinity oscillations, have been observed elsewhere (e.g. Sandison & Hill, 1966). In addition to possible fluctuations in distributions resulting from seasonal mortality and repopulation, dormant stages may enable certain hydroid species to survive periodically unfavourable environmental conditions at a given location (e.g., see Wedler, 1973; Calder, 1990). Colonies of *Garveia franciscana* in the upper estuary were unmistakably regressing into a dormant state during this study, most likely in response to unfavourably high salinities. The species, found active but in generally poor condition at 26-32‰, is usually most prevalent in nature at salinities of 10-12‰ or less (Morri, 1982). Thus the hydroid species composition of a site may differ from rainy season to dry season in response to changes in salinity, much as it does from winter to summer in temperate estuaries of Virginia and South Carolina in response to extreme fluctuations of water temperature (Calder, 1990).

The identical species composition at stations PE-A and PE-1 suggests that low diversity hydroid assemblages in the upper estuary (Rio Porto Alegre) are quite stable. Boesch (1974) argued that stability of low diversity benthic communities in the upper estuary is greater than that of higher diversity communities downriver. Similar observations have been reported on stability of some low diversity communities in marine and estuarine environments (Copeland, 1970) and rocky intertidal communities (Lewis, 1976).

Five species from the Rio Formoso/Rio Ariquindá/Rio Porto Alegre area (*Garveia franciscana, Lafoeina amirantensis, Clytia paulensis, Halopteris carinata, Schizotricha tenella*) are reported for the first time from Brazil (see Migotto, 1996). All are known from locations farther north in the western Atlantic (Calder, 1991, unpublished data).

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