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Assemblages of Southeast-South Brazilian Coastal Systems Based on the Distribution of Fishes

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Multivariate principal components analysis and cluster analysis were performed on data representing presence or absence of 498 species of juvenile and adult fish species in twenty-four coastal marine systems (bays, coastal lagoons, estuaries and coastal zones) distributed from southeast to southern Brazil. Five groups of coastal systems were identified based on fish assemblage similarity: estuaries and bays of the southeast area; an estuary of the southern area; coastal lagoons; rocky coastal zones; and the continental platform. Species assemblages for each zone were identified and used as surrogate habitat indicators to compare and contrast the groups. Stepwise multiple regression of environmental and physical variables as predictors of the number of species indicated that only ' area ' was included in the model as the most important variable explaining the variation of the number of species in these data sets. The total number of fish species increased as surface area increased.

Keywords: coastal zones; fish assemblages; PCA; Cluster Analysis, Stepwise multiple regression, Brazil

Introduction

Coastal areas, ranging from semi-closed systems such as coastal lagoons, estuaries and bays, to open areas such as surf zones and deeper areas on the continental shelf, are characterized by presenting a great variability of oceanographic conditions and shelter many species of fish whose distribution is defined by geographical limits and hydrological conditions (Moyle & Cech, 1988; Romero *et al.*, 1997). The composition of species in communities is dictated by a group of biotic and abiotic variables. Territorialism, competition for space and food, and complex species interactions are the main biotic factors influencing the structure of the assemblages (Dodds, 1988; Hacker & Gaines, 1997; Lowe-McConnel, 1999). Temperature, salinity, depth, currents and habitat diversity are the main abiotic factors (Barber *et al.*, 1997; Mothers *et al.*, 1998; Friedlander & Parrish, 1998; Mueter & Norcross, 1999; Connell & Lincoln-Smith, 1999). Environments with similar habitats and environmental conditions frequently present similar assemblages. Assemblages can therefore be used as an element for comparison of habitat and/or environmental conditions.

Fish assemblages inhabiting estuaries, temperate bays and coastal lagoons are relatively well studied (McHugh, 1967; Livingston *et al.*, 1974; Weinstein *et al.*, 1980; De Ben *et al.*, 1990; Marshall & Elliott, 1998), although little attention has been devoted to tropical and subtropical areas. Studies of these environments in the tropics include those in Indo-Pacific (Adjeroud *et al.*, 1998), Southeast Africa (Cyrus & Blaber, 1987), Australia (Blaber *et al.*, 1989), in the lagoons of Mexico (Yáñez-Arancibia *et al.*, 1980; Yáñez-Arancibia & Lara-Domingues, 1983; Amezcua Linares *et al.*, 1987), in the Laguna Joyuda, Puerto Rico (Stoner, 1986), in the Golfo of Nicoya, Costa Rica (Rojas *et al.*, 1994), some South American countries such as Venezuela (Villarroel, 1994), Colombia (Garcia *et al.*, 1998) and in Brazil (Paiva Filho *et al.*, 1987; Araújo *et al.*, 1997, 1998; Chaves & Corrêa, 1998).

Studies of characterization of groups of environments dictated by the ichthyofauna are still scarce in both temperate and tropical areas (Monaco *et al.*, 1992; Vieira & Musik, 1993, 1994; Mahon *et al.*, 1998; Mathieson *et al.*, 2000). Different levels of sampling effort coupled with different socioeconomic regional characteristics and environmental policies are some of the reasons why it is difficult to carry out such comparisons. The objective of this work is to identify groups of marine and estuarine environments of the southeast and south Brazilian coast that present similar fish assemblages and to identify the importance of the physical variables that are correlated with the

Table 1. Published and unpublished works consulted to obtain lists of species

Sites	Code	Authors	Type	Latitude
Sepetiba Bay–RJ	1	Araújo *et al.* (1997, 1998)	Bay	22°54′
Angra Bay–RJ	2	Andreata *et al.* (1994)	Bay	22°58′
Marapendi Lagoon–RJ	3	Andreata *et al.* (1990)	Coastal lagoon	22°59′
Maricá Lagoon–RJ	4	Brum *et al.* (1994)	Coastal lagoon	22°59′
Tijuca Lagoon–RJ	5	Andreata *et al.* (1990)	Coastal lagoon	22°59′
Cabo Frio Island–RJ	6	Ornellas (pers. comm.)	Coastal zone	23°00′
Cabo Frio Coastal–RJ	7	Fagundes-Netto & Gaelzer (1991)	Coastal zone	23°00′
Ilha Grande Bay–RJ	8	Anjos (pers. comm.)	Bay	23°00′
Arraial Cabo–RJ	9	Vianna (pers. comm.)	Coastal zone	23°01′
Paraty Bay–RJ	10	Bernardes (pers. comm.)	Bay	23°14′
São Paulo Coastal	11	Paes (pers. comm.)	Coastal zone	23°15′
Palmas Creek–SP	12	Rocha (pers. comm.)	Coastal zone	23°32′
Santos Bay–SP	13	Ribeiro-Neto (pers. comm.)	Bay	23°55′
Trapande Bay–SP	14	Zani-Teixeira (pers. comm.)	Bay	25°00′
Ararapira Bay–SP	15	Diniz-Filho (pers. comm.)	Bay	25°05′
Bom Abrigo Island–SP	16	Saul (pers. comm.)	Coastal zone	25°07′
Guaratuba Bay–PR	17	Chaves & Corrêa (1998)	Bay	25°52′
Laguna Estuary–SC	18	Monteiro-Neto *et al.* (1990)	Coastal lagoon	28°30′
Cassino Beach–RS	19	Cunha (pers. comm.)	Beach	32°10′
Creek-Patos L. Estuary–RS	20	Marques (pers. comm.)	Estuary	32°10′
Mouth of Patos L. Estuary–RS	21	Pereira (pers. comm.)	Estuary	32°10′
Patos L. Estuary–RS	22	Chao *et al.* (1982)	Estuary	32°10′
São Paulo Beach	23	Giannini (pers. comm.)	Beach	23°–25°
Southeast/South Coastal	24	Facchini (pers. comm.)	Coastal zone	23°–32°

variation of the number of species of fish in these environments.

Material and methods

A data matrix of presence or absence of 498 species of fish in twenty-four marine environments (estuaries, bays, coastal lagoons and open areas on the coastal shelf) was organized using information of lists of species from published and unpublished works (Figure 1; Table 1). Consultations were important to augment published species checklists because coastal systems have been studied to different degrees. Only studies with intensive sampling effort were included; that is, those which sampling were based on at least one year of standardized effort and using replication. These studies are likely to show a relatively accurate list of fish species; some of these studies are published, others were the object of theses. All preliminary lists of species, or censuses based on occasional data collection, have not been considered. Furthermore, since intercalibration data are not available, it was not deemed feasible to convert all surveys to a single standard.

Multivariate principal components analysis (PCA) and cluster analysis were used to explore species distribution patterns. Because of their complementary nature, PCA and cluster analyses together provide a powerful for identifying pattern in the structure of community data (Gauch, 1982). These analyses allow the identification of groups of species with similar distribution, characterizing associations of species from a multispecies matrix. PCA and cluster analysis were performed using the statistical program STATISTICA, version 6.0. PCA was conducted using a Pearson correlation matrix with varimax rotation. Component rotated loadings >0·5 were used to define the groups. Despite PCA being a technique that is used more with quantitative data, in this study it has been applied to presence/absence in order to avoid weighting data from different sampling regimes or methodologies. This approach underestimates the weight of the most abundant species but this bias is not of great importance since most of the studies present some difference in fishing effort. Cluster analysis was performed using the distance percent disagreement and the Ward's method of linkage for the production of the dendrogram.

Environmental and physical data of each environment, such as temperature, depth, salinity, latitude and area were obtained from the consulted works, being natural log transformed in order to address normality requirements of parametric analyses and to balance the effect of different units of measurement.

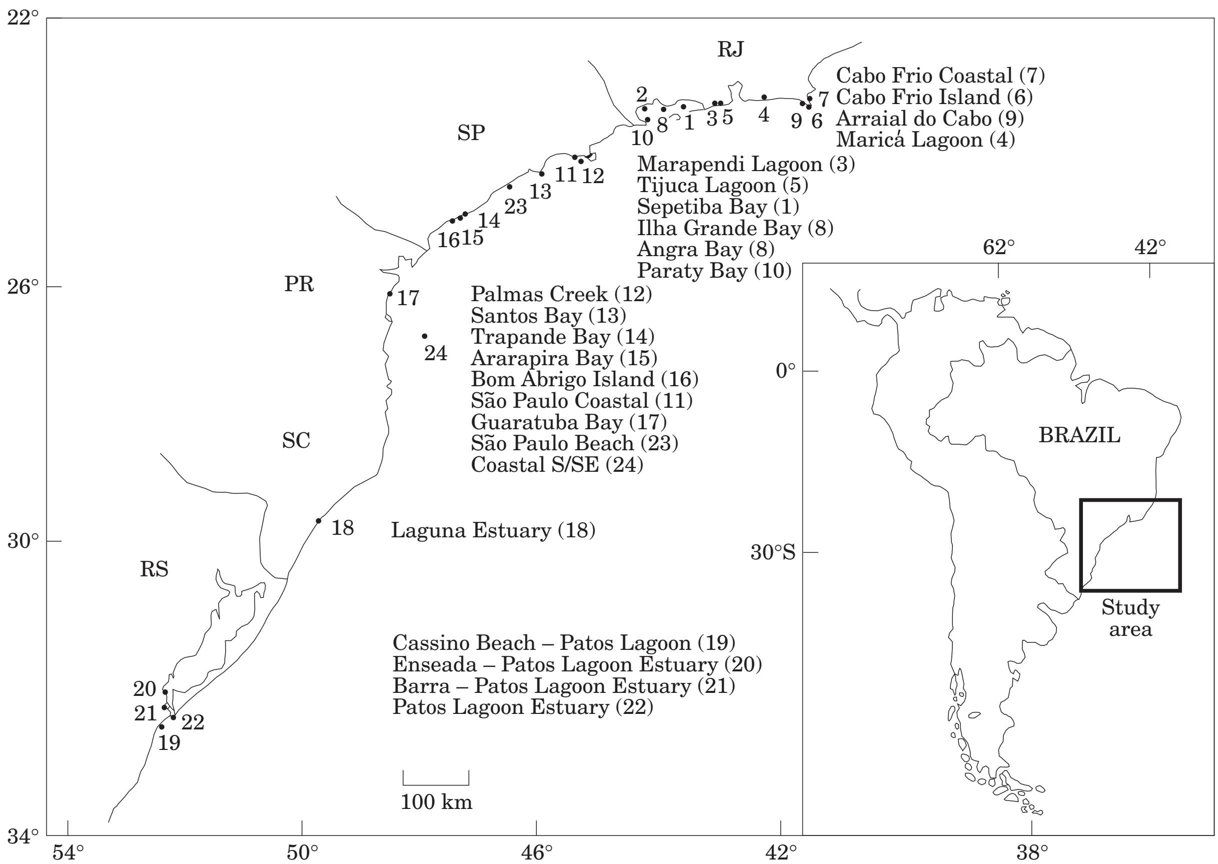

FIGURE 1. Map of southeast and south Brazilian coast with location of the study environments.

This transformation provides the best results and the most suitable approximation of these requirements. The relative importance of the independent environmental and physical variables that explained the variation of the number of species of fish (dependent variable) was determined by stepwise multiple regression. The multiple determination coefficient (R^2) was used to estimate the proportion of the number of fish species variability explained by the independent physical environmental variables. The aim of this linear analysis is to identify statistically significant environmental variables that present a correlation with the number of fish species that use the Brazilian southeast and southern coast. The log transformation of the variables helps to correct and to compensate the assumptions of eventual nonlinear relationship between the independent and the dependent variables. The interactive stepwise procedure included both forward selection and backward elimination to select the best model with less predictor variables based on the highest overall significance and R^2 values, the lowest residual variance and normality of residual plots. Multiple regression analysis was used with an understanding of the potential problems of this technique on species distribution data. Deficiencies may include the danger of inferring cause and effect relationships and the different nature of the sampling used in different studies. The intent of this analysis was to identify statistically significant physical variables that correlate with the number of fish species present and to explore physical and environmental characteristics that are plausible variables that could contribute to the number of fish species utilizing southeast-south Brazilian coastal systems. In addition, this analysis provided a comparison to Monaco *et al.* (1992) and Mahon *et al*'s (1998) studies which conducted a similar analysis on the number of fish species for west and east US coastal systems, respectively.

Results and discussion

Cluster analysis

Cluster analysis on the presence/absence fish data presented 5 groups with a percent disagreement level of about 0·3 (Figure 2). Group 1 represented the estuary of the Patos Lagoon and nearby areas, located in the Rio Grande do Sul State (RS), southern Brazil.

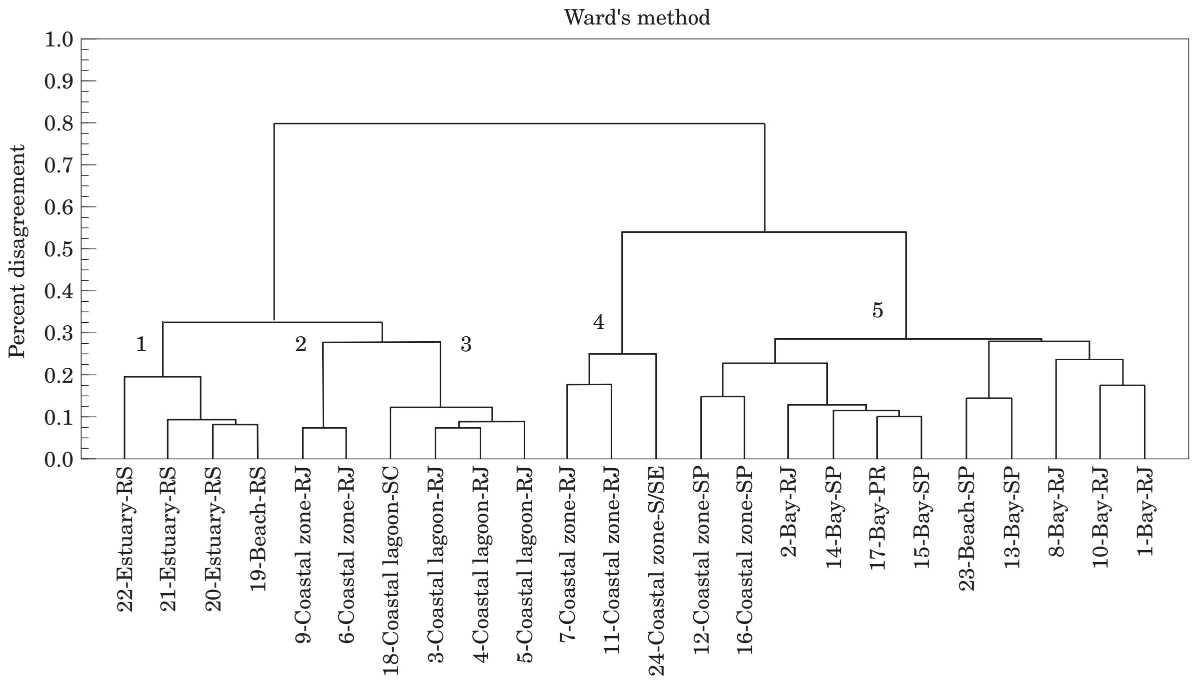

FIGURE 2. Cluster analysis of the data of presence or absence of fish species in 24 coastal systems.

The separation of this estuary from other similar environments from southeast Brazil, indicated differences in the ichthyofauna that can be related with the increased latitude and consequently decreased temperature, influencing the fish community composition. Group 2 was represented by the rocky coastal environment on Rio de Janeiro (RJ) coastal shelf, which presents a characteristic ichthyofauna formed by coastal fish that live close to coast and islands, mainly associated with rocky substratum, formed by stones and surrounded by sand, and coral reefs areas. Group 3 presented the coastal lagoons of Rio de Janeiro (RJ) and Santa Catarina (SC) States, that are shallow environments with freshwater influence, presenting some degree of salinity gradient and narrow communication with the sea. Group 4 is formed by environments on the continental shelf on the southeast-south Brazil, characterized by typically marine and platform fauna. Group 5 is formed by estuaries and bays from Rio de Janeiro (RJ), São Paulo (SP) and Paraná (PR) States. This group can be subdivided in two subgroups, one formed by estuaries and bays located at north end (Rio de Janeiro State), and the other formed mainly by such environments at south end (São Paulo and Paraná States). These environments are characterized by moderate variability of the environmental conditions, mainly salinity and temperature, being used for many coastal marine species as rearing areas, where juveniles grow until maturity. The coastal zones associated with this group are located nearby bays, and could be considered corridor areas for the ichthyofauna in their movements between the coastal zone and the more protected bay areas.

Principal components

The principal components analysis (PCA) of the species presence/absence data revealed that the underlying structure of the distribution of fish for estuaries, bays, coastal lagoon and coastal shelf areas were reduced to five main components. These components identified groups of use of these environments by similar assemblies of fish species and the ordination figures indicate the groupings and link to the environmental variables. Table 2 lists the coastal systems rotated loading for the five main components indicating which environments group together. These five components explained 57·92% of the variance of the data of presence or absence, each one presenting eigenvalue higher than 1. The species that are more important in the identification of the groups present a highest factor score for a specific component. Tables 3–7 list the species for each group that had the highest factor scores for each component.

Principal component 1, the Rio de Janeiro, São Paulo and Paraná bays, and São Paulo beach, explained 21·9% of the variance data set (Table 2),

TABLE 2. Principal component (environment groups) rotated loadings for twenty-four southeast and south Brazilian coastal environments based on presence/absence of 498 fish species

Component	1 RJ/SP Bays	2 South Coast	3 Coastal lagoons	4 SE/S coast	5 RJ coastal areas
Sepetiba Bay–RJ	**0·65593**	0·06774	0·25413	0·13781	0·02890
Santos Bay–SP	**0·71085**	0·16263	0·13547	0·07218	0·02618
Ararapira Bay–SP	**0·77021**	0·03554	0·03489	− 0·02136	0·11320
Paraty Bay–RJ	**0·64569**	0·05699	0·19952	0·27027	− 0·00663
Trapande Bay–SP	**0·72419**	0·13742	− 0·01252	0·00272	0·09695
Bom Abrigo Island–SP	**0·72829**	0·09260	0·03963	0·12445	− 0·08772
Ilha Grande Bay–RJ	**0·52437**	0·03020	0·14519	0·32072	− 0·36238
Angra Bay–RJ	**0·66865**	0·11542	0·00614	0·20998	− 0·06825
Tijuca Lagon–RJ	0·18746	0·07889	**0·77798**	− 0·03003	0·02427
Maricá Lagoon–RJ	0·08190	0·04286	**0·70216**	0·00659	− 0·05453
Palmas Creek–SP	**0·56839**	− 0·02442	− 0·00072	0·35572	− 0·23726
Southeast/South Coastal	0·36726	0·06506	− 0·11143	**0·58983**	0·17698
São Paulo Coastal	0·07940	0·03742	− 0·04163	**0·80383**	0·10555
São Paulo Beach	**0·62841**	0·20002	0·27385	− 0·06551	0·12603
Cassino-Patos L.–RS	0·17147	**0·69040**	0·23411	− 0·00606	0·01845
Enseada-Patos L.–RS	0·09717	**0·74807**	0·09922	− 0·04387	0·02067
Creek-Patos L.–RS	0·06546	**0·81503**	− 0·04787	0·13478	0·05233
Patos Lagoon–RS	0·11674	**0·75876**	0·08843	0·06897	− 0·03443
Cabo Frio Island–RJ	0·00494	− 0·02151	− 0·05336	− 0·09273	− **0·82601**
Arraial Cabo–RJ	− 0·05963	− 0·02522	− 0·01235	− 0·00993	− **0·83517**
Guaratuba Bay–PR	**0·70209**	0·11845	0·20471	0·05755	0·01919
Cabo Frio Coastal–RJ	0·08545	0·07510	− 0·05236	**0·78259**	− 0·05527
Marapendi Lagoon–RJ	0·05168	0·05179	**0·76246**	− 0·06082	0·05665
Laguna Estuary–SC	0·25685	0·34089	**0·55786**	− 0·17199	0·07657
Eigenvalues	5·25	2·55	2·35	2·06	1·68
% explained variance	21·9	10·61	9·78	8·62	7·01

Component loading highlighted in bold identify environments with similar species assemblages.

being comprised mainly by bays of southeast Brazil. These bays with higher rotated loading (>0·7) are rather salinity stable with few estuarine areas between south of São Paulo and north of Paraná States, namely the estuarine-lagoon Cananéia complex (Channel of Ararapira, Trapandé Bay and Bom Abrigo Island), the Santos en São Vicente estuarine complex, and the

TABLE 3. Fish species strongly associated with Rio de Janeiro and São Paulo bays and estuarine areas based on high factor scores

Family	Species	Scores
Carangidae	*Chloroscombrus chrysurus*	3·394
Engraulididae	*Cetengraulis edentulus*	3·364
Sciaenidae	*Cynoscion leiarchus*	3·362
Carangidae	*Selene vomer*	3·277
Synodontidae	*Synodus foetens*	3·269
Serranidae	*Diplectrum radiale*	3·100
Gerreidae	*Diapterus rhombeus*	3·092
Clupeidae	*Pellona harroweri*	3·069
Haemulidae	*Pomadasys corvinaeformis*	3·059
Clupeidae	*Opisthonema oglinun*	2·963
Ephippididae	*Chaetodipterus faber*	2·833
Narcinidae	*Narcine brasiliensis*	2·803
Pomatomidae	*Pomatomus saltator*	2·697
Clupeidae	*Harengula clupleola*	2·648
Bothidae	*Syacium papillosum*	2·646

TABLE 4. Fish species strongly associated with South Coast based on high factor scores

Family	Species	Scores
Carangidae	*Trachinotus marginatus*	4·093
Clupeidae	*Ramnogaster arcuata*	3·831
Engraulididae	*Anchoa marinii*	3·822
Syngnathidae	*Syngnathus folleti*	3·785
Batrachoididae	*Porichthys porosissimus*	3·687
Gadidae	*Urophycis brasiliensis*	3·644
Bothidae	*Paralichthys orbignyana*	3·615
Sciaenidae	*Mentichirrhus americanus*	3·537
Tetraodontidae	*Lagocephalus laevigatus*	3·526
Ariidae	*Netuma barba*	3·508
Jenynsiidae	*Jenynsia lineata*	3·447
Clupeidae	*Brevoortia pectinata*	3·412
Triglidae	*Prionotus punctatus*	3·279
Trichiuridae	*Trichiurus lepturus*	3·256
Sciaenidae	*Micropogonias furnieri*	3·211

Table 5. Fish species strongly associated with coastal lagoons based on high factor scores

Family	Species	Scores
Atherinidae	*Atherinella brasiliensis*	5·142
Poecilidae	*Poecilia vivipara*	5·107
Poecilidae	*Phalloptychus januarius*	4·861
Cichlidae	*Geophagus brasiliensis*	4·633
Mugilidae	*Mugil liza*	4·507
Jenynsiidae	*Jenynsia lineata*	4·498
Gerreidae	*Gerres aprion*	4·454
Centopomidae	*Centropomus undecimalis*	4·371
Elopidae	*Elops saurus*	4·283
Ariidae	*Genidens genidens*	3·910
Gobiidae	*Gobionellus oceanicus*	3·485
Gobiidae	*Gobionelus boleosoma*	3·410
Mugilidae	*Mugil curema*	3·391
Sparidae	*Diplodus argenteus*	3·382
Gobiidae	*Bathygobius soporator*	3·330

Table 6. Fish species strongly associated with SE/S coast based on high factor scores

Family	Species	Scores
Sciaenidae	*Ctenosciaena gracilicirrhus*	3·126
Serranidae	*Diplectrum formosum*	3·029
Dactylopteridae	*Dactylopterus volitans*	2·878
Mulidae	*Mullus argentinae*	2·842
Carangidae	*Trachinotus lathami*	2·806
Mulidae	*Upenaeus parvus*	2·806
Priacanthidae	*Priacanthus arenatus*	2·798
Haemulidae	*Conodon nobilis*	2·723
Ogcocephalidae	*Ogcocephalus vespertilio*	2·699
Lophidae	*Lophius gastrophysus*	2·592
Sparidae	*Pagrus pagrus*	2·592
Haemulidae	*Orthopristis ruber*	2·53
Gadidae	*Urophycis brasiliensis*	2·520
Balistidae	*Balistes capriscus*	2·506
Sciaenidae	*Umbrina coroides*	2·410

swamp area of Guaratuba Bay (PR), all located between 24°S and 25°S latitude. Sepetiba and Ilha Grande Bays, both at south of Rio de Janeiro State and Palmas Creek, North of São Paulo (latitude around 23°S), and São Paulo beach, presented slightly lower components loadings (0·5–0·7). The largest weights were attributed to bays with more typically estuarine areas, which present more marked variation in the environmental variables at relatively higher latitudes, while the lower weights were attributed to more stable environmental variables from coastal bays and beach at lower latitudes.

Table 3 identifies important species based on the highest factor scores for the component 1,

Table 7. Fish species strongly associated with RJ Coastal areas based on high factor scores

Family	Species	Scores
Mullidae	*Pseudopeneus maculatus*	− 4·406
Chaetodontidae	*Chaetodon striatus*	− 4·238
Haemulidae	*Anisotremus virginicus*	− 4·238
Stromateidae	*Prepilus paru*	− 4·218
Pomacentridae	*Abudefduf saxatilis*	− 4·168
Sparidae	*Diplodus argenteus*	− 4·134
Dactylopteridae	*Dactylopterus volitans*	− 4·099
Haemulidae	*Haemulom aurolineatum*	− 4·052
Singnathidae	*Hippocampus reidi*	− 3·988
Sciaenidae	*Pareques acuminatus*	− 3·878
Holocentridae	*Holocentrus ascencionis*	− 3·878
Labridae	*Halichoeres poeyi*	− 3·878
Fistularidae	*Fistularia tabacaria*	− 3·837
Haemulidae	*Haemulom plumieri*	− 3·608
Balistidae	*Balistes vetula*	− 3·501

corresponding to bays and estuarine areas at Rio de Janeiro and São Paulo States. Important species for this group were Carangidae (*Chloroscombrus chrysurus* and *Selene vomer*), Engraulididae (*Cetengraulis edentulus*), Sciaenidae (*Cynoscion leiarchus*) and Synodontidae (*Synodus foetens*). These species use coastal waters, bays and estuarine areas, with sandy and muddy substratum. *C. edentulus* occurs in lower salinity waters, while *C. leiarchus* and *S. foetens* are common in deeper areas at coastal shelf. Tolerance to salinity and temperature changes are important for distribution of species in estuaries and bays with some euryhaline species penetrating into the estuary, once they can cope with harsh environmental conditions. Abundant marine catfish from the Ariidae family unexpectedly did not show a high factor score, although they are common in bays and coastal zones with shallows muddy substratum from Southeast Brazil. According to Paiva-Filho (pers.comm.) those bays and estuaries feature a muddy substratum and shallow waters with low transparency, being dominated by Ariids. Araújo *et al.* (1998), working in the Sepetiba Bay, found that Ariidae and Gerreidae are the most abundant families, and that the area is characterized as relatively stable in relation to salinity.

Component 2 explained 10·61% of the variance of the data set, being characterized by coastal systems from South of Brazil (Table 2). Systems with highest loadings (>0·7) were the estuarine zone of the Patos Lagoon, in Rio Grande do Sul, while creek and surf zones at Cassino beach, nearby this estuarine area, presents loadings between 0·5 and 0·7.

Fish community structure here was dominated by marine species such *Trachinotus marginatus*, *Porichthys* *porosissimus* and *Urophycis brasiliensis* and marine estuarine-dependent families such as Sciaenidae and Ariidae (Table 4). *Ramnogaster arcuata* (Clupeidae) and *Anchoa marinii* (Engraulididade) are species of coastal waters, spawning on the coastal shelf with larvae and juveniles penetrating into low salinity waters of semi-closed and protected systems like estuaries and bays, where they use as rearing grounds. *Netuma barba*, abundant at the south of Brazil, uses the upper reaches of estuaries to spawn, being rare in lower latitudes from Southeast Brazil. Paiva Filho (pers.comm.) and Paiva Filho *et al.* (1987) found that the coastal shelf area is dominated by Sciaenidae and Clupeidae; sand beaches are dominated by juveniles of Carangidae, Mugilidae and Sciaenidae, while estuarine zones are dominated by Mugilidae, Atherinidae and Ariidae.

The estuary of the Patos lagoon in Southern Brazil did not present similar ichthyofauna to the estuaries of the Southeast, probably due to differences in latitude, with a direct influence of temperature. Despite species composition differences between these estuarine systems, their life cycles are similar, with ecological replacement of species along the latitudinal gradient. This can be explained by a faunal transition along the southeast-south Brazilian coast, resulting from the overlapping of tropical and temperate species (Lowe-McConnell, 1999).

Component 3, SE coastal lagoon, accounted for 9·78% of the variance in the data set (Table 2). The coastal systems with highest loadings (>0·7) were Marapendi, Tijuca and Maricá (lat. 23°S), and Laguna (lat. 28°S) coastal lagoons, the latter showing comparatively lower loadings (about 0·5). It was observed that the ichthyofauna of Laguna (SC) was similar to those from Rio de Janeiro coastal lagoons, despite substantial differences in their latitudes, with all coastal lagoons being grouped in the same cluster.

Table 5 identifies important species based on the highest factor scores for RJ and SC coastal lagoons. Twelve families were represented by important species for this component: bay residents Atherinidae (*Atherinella brasiliensis*), Poecilidae (*Poecilia vivipara* and *Phalloptychus januari*), Jenynsiidae (*Jenynsia lineata*); freshwater Cichlidae (*Geophagus brasiliensis*) and estuarine dependent Mugilidae (*Mugil liza*) and Gerreidae (*Gerres aprion*) were the most representative families and species. The influence of freshwater continental drainage on the fish composition is indicated by the high factor scores for Poecilidae, Jenynsiidae and Cichlidae, all freshwater secondary origin families.

Coastal lagoons present a marked stable salinity gradient which is a main determinant of spatial fish distribution in these systems, acting directly on the osmotic potential of the organisms. The ichthyofauna is mainly composed by a few marine species, resident estuarine, and several widely distributed freshwater species distributed along the stable salinity gradient.

Component 4 explained 8·62% of the variance of the data set (Table 2), being strongly associated with systems of the platform of the southeast-south coast. Highest loadings (>0·7) were presented by coastal areas at São Paulo and Rio de Janeiro, namely Cabo Frio and to a lesser extent (loadings 0·5 to 0·7), all over the coastal shelf of the study area, between São Tomé (22°S), RJ, and Torres (30°S) at Rio Grande do Sul State.

Species from this group occur in coastal waters of the continental platform, in depths between 15 and 100 m, in sandy and muddy substratum (Table 6). Fish species that showed high occurrence at São Paulo's north coast also showed high occurrence from Cabo Frio to Torres (Paes, pers. comm.). The ichthyofauna was distributed from the shallows of the intertidal zone to deeper areas at the edge of continental shelf, with their distribution dictated mainly by temperature, salinity and depth.

Pelagic fish assemblages which use the water column are usually planktophagous or top carnivorous. The carnivorous families (Carangidae, Serranidae, and Scianidade), and their common prey (Clupeidae and Engraulididae), are normally abundant near to large estuaries, where they are the base of many regional fisheries.

Component 5, the coastal shelf at North of Rio de Janeiro State, explained 7·01% of the variance (Table 2). The highest loadings (>0·7) were shown by Islands of Cabo Frio and Arraial do Cabo which are shallow marine areas associated with algal banks associated with rocky coastal formations and underlying sand sediments. The composition and distribution of the ichthyofauna suprabenthic is defined, mainly, by geographical position and physical characteristics of the rocky coast. Such variables act directly and effectively on the habitat composition and consequently, on the distribution of most of the resources used by fish.

Species corresponding to the highest factor scores for this component are coastal fish that live close to the coast at low depths associated with sandy and rocky substratum, in coral reefs and tidal zones close to islands (Table 7). Fishes associated with coral reefs and rocky formations generally present an oval and compressed body (Chaetodontidae, Pomacentridae, Labridae and Sparidae), adapted to do manoeuvres through the several structures of this complex habitat. The type of substratum is an important factor for fish distribution. Mud, sands, rocks and coral reefs, each present a peculiar fish and invertebrate community. Structured habitats shelter highly diverse fish communities, such as coral reefs, compared to open habitats with uncovered spaces of sandy or muddy areas (Friedlander & Parrish, 1998).

Stepwise multiple regression

The application of the stepwise multiple regression identified ' the area ' as the most important variable explaining 33·2% of the variance as a predictor of the number of species, with the other variables being excluded from the model. The area is considered as an important component of the diversity, because the total of the number of species of fish seems to increase with the size of the area and with the number of collected individuals in the samples (Vieira & Musik, 1993). The size of the area contributes to structure the systems, because it is related to chemical, physical and hydrological variables, such as salinity, depth and circulation of waters, influencing the constitution of different habitats. The highest habitat diversity appears to be related to the largest areas. Small bays tend to present smaller surface area, and, therefore, low numbers of species. For example, a coastal lagoon as Maricá at Rio de Janeiro, with area of 18 km^2, had only 19 species, while the Bay of Sepetiba, also in Rio de Janeiro, with area of 305 km^2, had 110 fish species.

It is widely held that latitude plays a critical role influencing diversity, with tropical areas being more diverse in species composition than temperate ones (Fischer, 1960; Pianka, 1966). Vieira and Musik (1993, 1994), comparing studies in a wider area in western Atlantic, reported that tropical estuaries show a higher number of fish species than temperate ones, allowing for area and sampling effort. In the present work, latitude was not identified as an important variable predicting the number of species; area, on the other hand, is the main factor to influence diversity for coastal systems in the Southeast-South Brazil. Monaco *et al.* (1992), studying fish assemblages in estuaries in the west coast of United States, found the width of the mouth and surface area as the most important variables to predict the number of species, also not finding a relationship with the latitude. These physical parameters appear to influence access and diversity of habitats, and ultimately the number of fish species occurring within coastal systems. Horn and Allen (1976) found the mouth width of thirteen California bays to be the only significant variable accounting for variation in species number. Large homogeneous areas have a high diversity but also if they are more complex and have more niches then they will have more species (Wootton, 1990), so further analyses comparing environments of similar areas will give additional insights on the factors influencing fish diversity in those areas. Within a narrow latitude range, numbers of species are more likely to vary among the habitats according to productivity, structural homogeneity and suitability of abiotic conditions (Ricklefs, 1996). In the present work, these factors seem to be much more important than latitude in determining the number of species.

Grouping the coastal systems based on fish distribution has a shortcoming with respect to identifying habitat regimes associated with the presence/absence of species. Systems with significantly different habitat regimes can have similar numbers of species. The species assemblages may however, be quite different, as in the case of RJ/SP bays and Coastal zones SE/S, which have approximately the same number of fish species but contain very different fish assemblages. Fish assemblages from RJ/SP bays are similar to RS estuarine areas at Patos Lagoon at the family level, but are quite different at the species level, mainly due to differences in latitude which dictate differences in temperature variations. The coastal lagoons, due to their smaller area and marked influence of freshwater fish fauna, have low diversity, probably due to salinity gradient influences limiting occurrence of marine species since few species can withstand the salinity stresses inherent in this ambient. Ichthyofauna inhabiting areas of different salinity gradients show changes in composition and tend to be less diverse as salinity decreases due to primary effects on osmo- and iono-regulation (Wheatly 1988). Effects of decreasing salinity on decreased diversity in coastal systems have here been superimposed by much stronger effects of size of the area, which dictates diversity in the present study.

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