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Seasonality of Ichthyofauna Bycatch in Shrimp Trawls from Different Depth Strata in the Southern Brazilian Coast

Jorge Luiz Rodrigues-Filho[†], Joaquim Olinto Branco[‡], Herbert Silva Monteiro[‡], José Roberto Verani[†], and João Pedro Barreiros[§*]

[†]Departamento de Hidrobiologia
Universidade Federal de São Carlos
São Carlos, São Paulo 13565-905, Brasil

[‡]Centro de Ciências Tecnológicas da Terra e do Mar
Universidade do Vale do Itajaí
Itajaí, Santa Catarina, 88301-970, Brasil

[§]Azorean Biodiversity Group (CITA-A)
Platform for Enhancing Ecological Research & Sustainability (PEERS)
Departamento de Ciências Agrárias
Universidade dos Açores
Angra do Heroísmo 9700-042, Portugal

ABSTRACT

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Changes in the species composition and ecological descriptors of fish assemblages in terms of abiotic factors such as depth, temperature, salinity, and granulometry were analyzed. Monthly trawls, from October 2003 to September 2004 (30 minutes each) were analyzed in two areas covering an important shrimp fishing site of the Brazilian coast. Results using bifactorial analysis of variance revealed a seasonal variation of environmental variables ($p < 0.05$), and granulometry analyses showed that the composition of the fishing grounds was similar—mostly sand. A total of 12,613 fish were collected: 7880 in area I and 4733 in area II. The highest values of capture in numerical abundance (catch per unit effort) occurred during winter. Fifty taxa were caught in area I, and 53 taxa were caught in area II. Both values are considered high when compared to previous studies conducted in nearby areas. Sciaenidae was the most speciose family in all samples and in both areas were dominant in number of species (37 species in area I and 42 species in area II). *Cynoscion striatus* was the most abundant and dominant species in both areas. Estimates of ecological descriptors, such as richness, diversity, and evenness, showed that the ichthyofauna structure was strongly influenced by climatic factors, and all values were more pronounced during fall and winter. The permutational multivariate analysis of variance demonstrated that ichthyofauna species composition differs among seasons. The Student's t test applied *a posteriori* showed that the community composition differed (significantly) in the following comparisons: spring *vs.* fall ($p < 0.05$) and winter *vs.* summer ($p < 0.05$). According to similarity percentage analysis, changes in the community structure were mainly correlated with species classified as abundant, which occurred unevenly during the different periods. Our results show that the fish community is influenced by seasonal variations such as salinity and temperature but not by depth or sand grain sizes.

ADDITIONAL INDEX WORDS: *Fishing, abiotic factors, ecological descriptors, specific composition.*

INTRODUCTION

The incidental catch of nontarget species and the subsequent disposal of these organisms constitute a major environmental problem that worldwide fishing activity has been dealing with. This problem is particularly severe when it comes to shrimp trawl doors (Eayrs, 2007; Pascoe and Revill, 2004). In some South American countries, such as Brazil, Argentina, Peru, and Venezuela, shrimp–prawn fisheries are highly important and responsible for huge catches, consequently also raising the bycatch biomass. However, lack of proper legislation in these countries makes it difficult to estimate correctly bycatch importance and impact (Davies *et al.,* 2009; Kelleher, 2005).

In an important revision on this subject, Alverson *et al.* (1994) found that qualitative and quantitative data available about incidental catches are rare, especially for fishery areas in the South Atlantic. Recently, more attention has been given to this issue, increasing the availability of information about bycatch species (Hall and Mainprize, 2005).

This tendency also has been observed for the S and SE regions of Brazil, where there is a concentration of important shrimp fishery efforts. Most studies conducted there focused mainly on bycatch (Graça-Lopes *et al.,* 2002a, b; Haimovici and Mendonça, 1996). Both the abundance and the ecological importance of this economically unexploited ichthyofauna have been responsible for the research conducted in those areas during the past decade (Bail and Branco, 2003; Barreiros *et al.,* 2009; Bernardes *et al.,* 2011; Branco and Verani, 2006; Cattani *et al.,* 2011; Chaves, Cova-Grando, and Calluf, 2003; Gomes and Chaves, 2006; Rodrigues-Filho *et al.,* 2011a, b; Souza and Chaves, 2007; Souza *et al.,* 2008). The ratio between prawn and bycatch biomass varies among study areas (Slavin, 1983). In S and SE Brazil, the following proportions were estimated for distinct localities: for São Paulo, between 1.26:1 (Graça-Lopes *et al.,* 2002b) and 3:1 to 9:1 (Souza *et al.,* 2008); for Espírito Santo, 3:1 (Pinheiro and Martins, 2009); for Rio de Janeiro, 10.5:1 (Vianna and Almeida, 2005); and for Paraná, 0.57:1 (Cattani *et al.,* 2011). In Santa Catarina, these varied between 1:1 to 8:1 in Penha (Branco and Verani, 2006) and 3:1 in Praia

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*Corresponding author: joaopedro@uac.pt

de Gravatá, Navegantes, or Praia de Brava, Itajaí (Bail *et al.,* 2009).

Also in S and SE Brazil, there is a specific regulation for trawling fisheries that imposes strict restrictions in net sizes (length and mesh size), fishing vessels (length, weight, and horsepower allowed), fishing areas, and no-catch periods (Cattani *et al.,* 2011). However, as mentioned earlier, no laws focus on the reduction, use, or management of bycatch.

Studies on the composition and fluctuation of bycatch fish assemblages generate indispensable knowledge that can be used to reduce incidental catch, to evaluate its impact, and to aid in the management of fisheries at both regional and local scales. As a consequence of both biotic and abiotic factors, marine communities are subjected to wide variability both in space and timescales (Gaelzer and Zalmon, 2008), and depth, temperature, salinity, substrate type, and overfishing are commonly mentioned as the most important factors influencing the structure of fish communities (Barletta *et al.,* 2005; Giannini and Paiva-Filho, 1995; Pires-Vanin *et al.,* 1993; Schwarz *et al.,* 2007). In this way, we studied the ichthyofauna bycatch at an important penaeid shrimp fishery area on the southern coast of Brazil to provide ecological base information to the management of fisheries in this region and answer the following questions: Are there differences in the specific community composition caught in two fishery spots? If so, are these related to abiotic factors such as temperature, salinity, granulometry, and depth?

MATERIALS AND METHODS

Description of the Study Area

The study area lies on the coastal region of the state park of the Serra do Tabuleiro, between Pinheira and Gamboa beaches, in the municipality of Palhoça, Santa Catarina, Brazil (Figure 1). The sites were established according to data from the artisanal fleets acting on the fishery of the seabob shrimp *Xiphopenaeus kroyeri* and the pink shrimp *Penaeus brasilienses* and *P. paulensis*. Area I is located from the front of Pinheira beach to Gamboa beach and has an average depth of 17 m; area II is located from the Corais Island to the south border of Santa Catarina Island, with an average depth of 30 m.

Sampling

Between October 2003 and September 2004, always in the first 15 days of a given month, two trawling sessions of 30 minutes were carried out in each area, totaling 24 trawling sessions in an area each year. A single boat (double rigged) for bottom trawling was used (following Galbraith, Rice, and Strange, 2004) with a trawl of 3.0-cm mesh in the wings and 2.0-cm mesh at the cord end, towed at an average speed of 2.0 knots.

We placed the collected material in plastic bags, which were properly labeled with date and area, packed in coolers, and then transported to the laboratory. In addition, we measured depths with an Eagle Cuda 300 probe and collected samples of both sediment and water. Measurement of temperature values was made using a manual thermometer (9793.16.1.00, Incoterm), and salinity was measured using an optical refractometer (ITREF-10, Instrutemp).

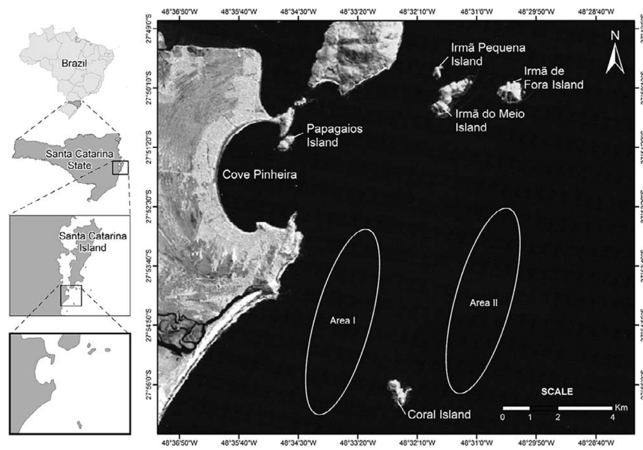

Figure 1. Satellite photograph of the two studied areas (I and II), Palhoça, Santa Catarina, Brazil (Google Earth).

Laboratory Analyses

The samples were sorted and the fish were identified to the lowest possible taxonomical level, according to Figueiredo and Menezes (1978), Menezes and Figueiredo (1980a), Menezes and Figueiredo (1980b), Menezes and Figueiredo (1985), and Menezes *et al*. (2003). Next, we counted the individuals from each species to obtain the total caught by sample. For determining the carbonate content and the content of the organic matter in the sediment, we estimated the calcium carbonate using the gravimetric method, based on a subsample of 100 g, which was mixed with hydrochloric acid at 50°C. The samples were burned in a muffle furnace (800°C) for 8 hours, and the total organic matter content was determined from the difference between initial and final weights. To determine the size grain and texture of the sediment, we subjected the aliquots to the processes of washing, screening in intervals of 1/4φ, weighing and thus obtaining the needed statistical parameters (Folk and Ward, 1954; Krumbein, 1934; Shepard, 1954).

Data Analysis

We compared the values of seasonal data of temperature and salinity between the two study areas by a bifactorial analysis of variance (ANOVA) with a significance level of 0.05 (Zar, 2007). When we observed interactions between factors (area and season), the internal variation within the factors were tested by the Tukey-Kramer pair comparison analysis method (Zar, 2007). In south Brazil, the weather seasonality is more pronounced, so the seasons were divided as spring (October–December 2003), summer (January–March 2004), winter (July–September 2004), and fall (April–June 2004). This grouping follows the reference indicators given by the National Institute of Space Research (CPTEC/INPE, 2010) and associated with samplings in the first 15 days of a given month.

The catch per unit effort in number of individuals (CPUE/number of individuals per tow) was estimated seasonally for each sampling area. Collected fish species were classified into three categories according to their occurrence in a year of sampling: regular (when the species was found in 9–12 of the months studied), seasonal (species found in 6–8 months), and infrequent (species found in 1–5 months; Severino-Rodrigues, Guerra, and Graça-Lopes, 2002).

We estimated the seasonal species' richness by using the scaled rarefaction curves and the respective confidence intervals (95%), according to the number of individuals caught per sampling (Krebs, 1999; Colwell, Mao, and Chang, 2004). The Shannon diversity index (H') and Pielou evenness index (J') were calculated to characterize the sampled communities (Magurran, 2004). Shannon's index was converted to the numeric function $\exp(H')$ to allow the calculation of the real number of species, which according to Jost (2006), is more mathematically applied to describe the diversity of a given community. Those indexes and CPUE values were analyzed for normality and homoscedasticity using, respectively, Kolmogorov-Smirnov and Bartlett tests (Zar, 2007). When the data did not meet the premises of normality and homoscedasticity, they were transformed using logarithms, as suggested by Rodrigues-Filho *et al*. (2011a). A comparison of the seasonal data between the two study areas was performed by a bifactorial ANOVA ($p = 0.05$), and if necessary, the internal variation within the factors were tested by the Tukey-Kramer pair comparison analysis method (Zar, 2007).

Differences in community composition (structure) were tested by the nonparametric permutational multivariate analysis of variance (PERMANOVA) for a significance level of $p = 0.05$ (Anderson, 2001) using the software PC-ORD, version 6 (McCune and Mefford, 2011).

For this purpose, we have designated two orthogonal factors, areas (two levels, random) and seasons of the year (four levels, random) and the interaction among them. In this analysis, we used the Bray-Curtis index, which was calculated from the abundance matrix normalized by the square root to increase the relative importance of the rare species (Clarke *et al.,* 2006).

In those tests, we used a set of 9999 permutations (Monte Carlo's permutation test). Whenever statistical differences were observed, a multivariate Student's t test was applied (Anderson, 2005), and when differences were detected ($p < 0.05$), the contribution of each species in the dissimilarity among factors showing variability was assessed by the similarity percentage analysis (SIMPER; Clarke and Warwick, 1994) using the software PAST (Hammer, Harper, and Ryan, 2001).

The canonic correspondence analysis (CCA) was conducted with the objective to detect patterns of space–time variations and the relation between temperature and salinity with fish species' abundance (several answers) within the study area (Ter Braak, 1986). Pearson's correlation coefficient was estimated between these variables and the axis resulting from the CCA. Both depth and granulometry were not included in this test, because they did not change throughout the study. Dependent variables incorporated in the CCA were those that most contributed to the variations detected during sampling and agreed with the SIMPER analysis. The noncorrelation hypothesis between data sets and answers was tested by means of a significance test of these correlations ($p < 0.05$) after 4999 permutations using the Monte Carlo method from the main matrix (*i.e.* fish abundance). All these analyses were made using the software PC-ORD, version 6 (McCune and Mefford, 2011).

RESULTS

The composition of the bottom sediment of the sampled areas was similar and predominantly sand (area I = 93.25%, area II = 98.89%). In area I, the values of silt (area I = 6.58%, area II = 0.45%) and organic matter (area I = 1.50%, area II = 0.40) were more pronounced than they were in area II; in addition, the carbonates on the area were considerably more abundant (area I = 2.31%, area II = 6.13%).

Temperature varied among the study areas, being higher in area I than in area II. The highest average occurred in summer in both areas (area I = 24.5 ± 0.55°C, area II = 22.5 ± 0.99°C). After this season, temperatures decreased and reached their lowest value in winter (area I = 18.5 ± 0.84°C, area II = 17.8 ± 1.02°C; Figure 2A). When data sets were compared, there were statistical differences between areas ($F = 13.48$, df = 3.6, $p = 0.001$) and between seasons ($F = 23.69$, df = 3.6, $p > 0.001$), without interactions among factors ($F = 2.5$, df = 3.6, $p = 0.07$). The multiple comparison test of Dunn detected statistical differences ($p < 0.05$) between summer *vs*. winter and summer *vs*. fall.

We registered considerable changes in the average levels of salinity during this study, with higher values in summer (area I = 34.67 ± 1.50, area II = 35.33 ± 0.81). In fall, the average salinity was 30.17 ± 3.25 in area I and 33 ± 1.8 in area II, thus reaching the lowest levels of the year. In subsequent seasons, there was an increase in salinity, reaching moderate rates during the winter. Salinity in area II was more pronounced than in area I (Figure 2B), albeit with no significant differences (ANOVA bifactorial: $F = 1.98$, $p = 0.23$, df = 45). There were differences between seasons ($F = 5.74$, $p = 0.02$) but no interactions among factors ($F = 1.36$, $p = 0.27$). The multiple

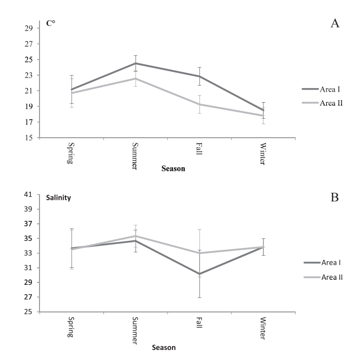

Figure 2. Variation of the average (A) bottom water temperature and (B) salinity registered in the area between Pinheira and Gamboa beaches (Palhoça, Santa Catarina, Brazil).

comparison test showed significant differences ($p < 0.05$) between winter and other seasons.

In total, 24 samplings were conducted in each area per year, with six samplings per season. We caught a total of 12,613 specimens (area I = 7880, area II = 4733) belonging to 31 families distributed into 61 species. Fifty-one species occurred in area I, and 53 species occurred in area II, whereas 41 species occurred in both areas (Table 1).

We observed 26 families occurring in area I, the commonest being Sciaenidae (61.2%) and Monacanthidae (17.0%). Some families, such as Achiridae (4.4%), Carangidae (2.7%), Gadidae (2.2%), and Triglidae (1.8%), were relatively abundant throughout the study (Figure 3). The sciaenids (65%) were the most abundant taxon in area II, followed by Carangidae (14.2%), Monacanthidae (5.6%), Fistulariidae (2.9%), Balistidae (2.6%), and Triglidae (2.4%). The other families (referred to as "other") occurred in low abundance in both areas, corresponding to 10.6% and 11.6% of the total catches in areas I and II, respectively (Figure 3).

The infrequent species were predominant, with 37 species in area I and 42 species in area II. Seven species were considered regular in area I, because of their frequency: *Ctenosciaena gracilicirrhus* (Metzelaar, 1919), *Cynoscion striatus* (Cuvier, 1829), *Paralonchurus brasiliensis* (Steindachner, 1875), *Menticirrhus americanus* (Linnaeus, 1758), *Stephanolepis hispidus* (Linnaeus, 1766), *Peprilus paru* (Linnaeus, 1758), and *Lagocephalus laevigatus* (Linnaeus, 1766). In area II, the first five species mentioned earlier, together with *Pomadasys corvinaeformis* (Steindachner, 1868), were regular in the samples. The most numerous and predominant species was *C. striatus,* whereas *S. hispidus* and *P. brasiliensis* were regularly found in considerable numbers (Table 1). *Gymnachirus nudus* (Kaup, 1858), *Stellifer* spp. (area I), and *Selar crumenophthalmus* (area II) were considered infrequent and were present in fewer numbers (Table 1).

The rarefaction curve in area I was more pronounced and statistically different from the area II curve—more than 4000 specimens, which could be explained by the absence of overlap of the confidence intervals between the two curves (Figure 4A).

When comparing the rarefaction curves for the seasons, we found that fall (49 species) and winter (44 species) were the periods when the highest richness was expected. The overlap between the confidence intervals showed no significant differences between those seasons. The curves of spring and summer indicate a lower richness, and when more than 500 individuals occurred, the curves differed statistically from each other (Figure 4B).

The highest CPUE values occurred during spring, when 1261 individuals were caught in area I and 1399 species were caught in the area II. Captures declined considerably in the other seasons, reaching 466 specimens in winter (area I) and 522 specimens in fall (area II; Figure 5A). There was a pronounced alternation of CPUE values between areas (Figure 5A). However, the two-way ANOVA did not show differences between areas and among seasons (Table 2).

With the exception of summer, the effective number of species $\exp(H')$ was similar in both areas, without spatial variation patterns (two-way ANOVA; Figure 5B and Table 2). However, temporal fluctuations were evident (Figure 5B and Table 2) and significant differences in diversity ($F = 5.36$, df = 3.6, $p = 0.026$) between spring and winter were observed (paired test $p < 0.05$).

Evenness varied almost parallel to diversity. It did not oscillate greatly between areas (spatial) but oscillated considerably between seasons (temporal; Figure 5C and Table 2). The ANOVA ($F = 6.708$, df = 3.6, $p = 0.014$) and successive testing in pairs (Tukey-Kramer), differentiated the spring and the winter seasons ($p < 0.05$) for this community descriptor. According to the statistical analysis, there was no interaction between the factors (area and season) in any of the evaluated parameters, meaning that when the variation occurred it was due to isolated factors in the areas (Table 2).

We observed significant differences (PERMANOVA) in the specific composition when the factor "season" was analyzed, showing the presence of temporal variations in the ichthyofauna throughout the year. We did not observe significant differences between the areas with depths of 17 m (area I) and 30 m (area II) or interaction between the previously mentioned factors (Table 3).

The t test applied *a posteriori* showed that the community composition in spring was different from that during fall and winter ($p < 0.05$) and that the community composition in winter was different from the one in summer (Table 4).

The SIMPER showed which taxa contributed to differences in ichthyofauna composition between the seasons referred to earlier. Between spring and winter, the difference of 69.73% was mainly due to abundance of *C. striatus, S. hispidus,* and *P. brasiliensis;* these taxa were also the most important to the dissimilarity between spring and fall (89.16%). Between winter and summer, the difference in specific composition was 78.03% and there were more species influencing the community structure. In this way, *S. crumenophthalmus, C. striatus, P. brasiliensis,* and *B. ronchus* were the most important (Table 5).

In general, species that were abundant and unevenly dispersed between seasons were mainly responsible for the observed differences. The CCA results show wide variation influenced by the study area's seasonability, something that can be observed in the high agglutination of data from the same season shown in the triplot graphic (Figure 6). Regarding the factor depth, nothing even similar was observed, whereas salinity showed a strong relationship with axis 1 (axis 1, $r = 0.99$; axis 2, $r = -0.20$) and temperature showed a strong relationship with axis 2 (axis 1, $r = -0.24$; axis 2, $r = 0.89$). This may well explain, respectively, the horizontal and the vertical variations observed in this graphic. The abundance of species such as *C. gracilicirrhus, Stellifer* spp., and *P. brasiliensis* showed a negative correlation with salinity, which attained its maximal values in fall at both depths. As for *F. petimba, M. americanus,* and *M. littoralis,* these were more abundant in winter, being associated with lower temperatures and moderate levels of salinity. The species *B. ronchus, S. crumenophthalmus,* and *S. hispidus* were considerably more abundant in summer, when both temperature and salinity were higher compared to the other seasons. The species *P. punctatus* had its highest relative abundance in summer and spring when *U. brasiliensis* and mainly *C. striatus* also reached their highest occurrences.

Table 1. *List of demersal fish species and their occurrences from November 2003 to October 2004 in the area between Pinheira and Gamboa beaches (Palhoça, Santa Catarina, Brazil).*

	Areas*			
Taxon	I	Occurrence	II	Occurrence
Chondrichthyes				
Narcinidae				
Narcine brasiliensis (Olfers, 1831)	1	<	2	<
Rhinobatidae				
Zapteryx brevirostris (Müller & Henle, 1841)	2	<	13	<
Rajidae				
Sympterygia acuta Garman, 1877	7	<	14	<
Sympterygia bonapartii Müller & Henle, 1841	9	<	5	<
Actinopterygii				
Clupeidae				
Pellona harroweri (Fowler, 1917)	129	<	13	<
Chirocentrodus brakerianus (Poey, 1867)	8	<	4	<
Sardinella brasiliensis (Steindachner, 1879)	4	<	4	<
Engraulidae				
Anchoa spinifera (Valenciennes, 1848)	0		2	<
Lycengraulis grossidens (Spix & Agassiz, 1829)	4	<	2	<
Ariidae				
Genidens genidens (Cuvier, 1829)	4	<	0	
Genidens barbus (Lacépède, 1803)	58	<	10	<
Gadidae				
Urophycis brasiliensis (Kaup, 1858)	177	<	81	+
Batrachoididae				
Porichthys porosissimus (Cuvier, 1829)	52	<	62	+
Triglidae				
Prionotus punctatus (Bloch, 1793)	145	+	116	+
Carangidae				
Selar crumenophthalmus (Bloch, 1793)	19	<	645	+
Chloroscombrus crysurus (Linnaeus, 1766)	4	<	18	<
Selene setapinnis (Mitchill, 1815)	186	+	11	<
Selene vomer (Linnaeus, 1758)	4	<	0	
Gerreidae				
Eucinostomus argenteus Baird & Girard, 1854	1	<	6	<
Eucinostomus melanopterus (Bleeker, 1863)	7	<	3	<
Eucinostomus gula (Quoy & Gaimard, 1824)	9	<	1	<
Diapterus rhombeus (Cuvier, 1829)	2	<	0	
Haemulidae				
Pomadasys corvinaeformis (Steindachner, 1868)	80	+	48	>
Orthopristis ruber (Cuvier, 1830)	0		19	<
Sciaenidae				
Larimus breviceps Cuvier, 1830	6	<	15	<
Ctenosciaena gracilicirrhus (Metzelaar, 1919)	545	>	25	>
Cynoscion striatus (Cuvier, 1829)	1605	>	1832	>
Isopisthus parvipinnis (Cuvier, 1830)	110	<	23	<
Paralonchurus brasiliensis (Steindachner, 1875)	997	>	415	>
Stellifer spp.	504	+	234	<
Micropogonias furnieri (Desmarest, 1823)	94	<	9	<
Menticirrhus americanus (Linnaeus, 1758)	217	>	161	>
Menticirrhus littoralis (Holbrook, 1847)	118	+	152	<
Bardiella ronchus (Cuvier, 1830)	626	<	0	
Pomacanthidae				
Peprilus paru (Linnaeus, 1758)	114	>	37	+
Trichiuridae				
Trichiurus lepturus Linnaeus, 1758	8	<	24	<
Cynoglossidae				
Symphurus tessellatus (Quoy & Gaimard, 1824)	37	+	73	<
Monacanthidae				
Stephanolepis hispidus (Linnaeus, 1766)	1342	>	266	>
Tetraodontidae				
Lagocephalus laevigatus (Linnaeus, 1766)	77	>	31	<
Sphoeroides testudineus (Linnaeus, 1758)	1	<	0	
Sphoeroides spengleri (Bloch, 1785)	0		2	<
Diodontidae				
Chilomycterus spinosus spinosus (Linnaeus, 1758)	0		3	<

Table 1. Continued.

Taxon	Areas* I	Occurrence	II	Occurrence
Balistidae				
Balistes capriscus Gmelin, 1789	33	<	5	<
Citharichthys arenaceus Evermann & Marsh, 1902	1	<	0	
Decapterus macarellus (Cuvier, 1833)	0		97	<
Balistes vetula Linnaeus, 1758	0		20	<
Achiridae				
Gymnachirus nudus Kaup, 1858	345	+	4	<
Centropomidae				
Centropomus parallelus Poey, 1860	58	<	0	
Paralichthyidae				
Paralichthys patagonicus Jordan, 1889	8	<	19	<
Etropus crossotus Jordan & Gilbert, 1882	3	<	4	<
Etropus intermedius Norman, 1933	0		1	<
Etropus longimanus Norman, 1933	0		10	<
Muraenesocidae				
Cynoponticus savanna (Bancroft, 1831)	6	<	0	
Dactylopteridae				
Dactylopterus volitans (Linnaeus, 1758)	0		8	<
Fistulariidae				
Fistularia petimba Lacépède, 1803	2	<	138	<
Mullidae				
Mullus argentinae Hubbs & Marini, 1933	106	<	4	<
Upeneus parvus Poey, 1852	4	<	6	<
Serranidae				
Serranus auriga (Cuvier, 1829)	0		1	<
Sparidae				
Diplodus argenteus (Valenciennes, 1830)	0		1	<
Congridae				
Conger orbignianus Valenciennes, 1837	0		1	<
Synodontidae				
Synodus foetens (Linnaeus, 1766)	1	<	33	<
Grand total	7.880		4.733	
Total families	26		29	
Total species	50		53	
Total regular species	7		6	
Total seasonal species	6		5	
Total occasional species	37		42	

* The incidence (1) is represented by (>) regular, (+) seasonal, and (<) infrequent.

DISCUSSION

Catch composition varies considerably according to the nature of the fishery stock, the type of fishing gear used, gear selectivity, towing duration, target species, their price value, depth of capture, and time of year (Costa, Erzini, and Borges, 2008; Larson, House, and Terry, 1996; Merella *et al.,* 1998; Recasens *et al.,* 1998; Rochet, Peronnet, and Trenkel, 2002). The high species diversity in the bycatch is a challenge to monitoring and management due to the low practicality of using traditional stock assessment methods for evaluating the sustainability each species' catches (Stobutzki *et al.,* 2001). The prawn trawling in Palhoça collected both high numbers and a variety of fish species, showing its low selectiveness and incisive impact within the region's ichthyofauna.

The number of fish taxa (31 families and 61 species) in the coastal region of Palhoça was higher than the numbers obtained by other studies from the coast of Santa Catarina, which encompassed all four seasons in Balneário Barra do Sul (21 families and 46 species; Bernardes *et al.,* 2011), in Penha (24 families and 43 species; Bernardes *et al.,* 2011), and in Armação do Itapocoroy and Penha (22 families and 37 species; Bail and Branco, 2003), as well as in a study carried out for 7 years (Branco and Verani, 2006).

In 15 months of sampling, Sousa and Chaves (2007) registered 66 bycatch fish species in the coast of Paraná. Already, the number of taxa obtained by Pina and Chaves (2009) along the northern coast of Santa Catarina during the same sampling time was higher for all previously mentioned groups (31 families and 72 species).

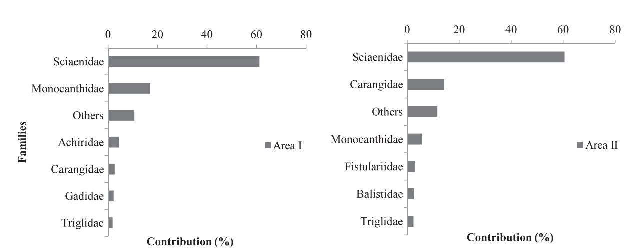

Figure 3. Most abundant fish families caught from November 2003 to October 2004 in the area between Pinheira and Gamboa beaches (Palhoça, Santa Catarina, Brazil).

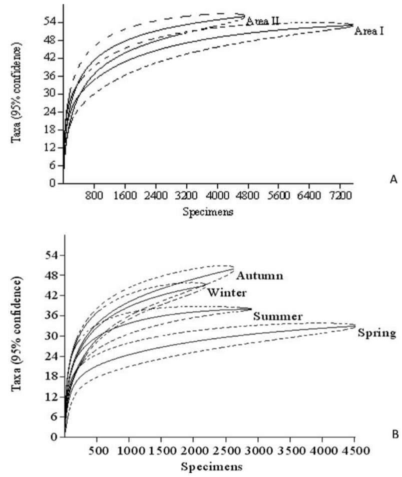

Figure 4. Rarefaction curve and confidence intervals (95%) (A) based on sampling in areas I and II and (B) between seasons based on sampling from November 2003 to October 2004 in the area between Pinheira and Gamboa beaches (Palhoça, Santa Catarina, Brazil).

The sediment of the two sampled areas was similar, with sand fractions predominant, corroborating what had been ascertained for nearby fishing grounds (Abreu, Menezes, and Rosa, 2006; Corrêa *et al.,* 1996). In area I, fine sediments and organic matter were dominant, probably because of the influence of hydrologic processes occurring on the mainland. This is the standard sediment type present all along the coast of Santa Catarina (Horn-Filho, 2003). The kind of substrates are ideal for establishing and growing prawns and shrimp, thus contributing to their ecological relations with Sciaenidae, which preferably inhabit shallow sandy–muddy waters (Figueiredo and Menezes, 1980). This pattern of Sciaenidae dominance is repeated in different fishing spots along the Brazilian coast (Bernardes *et al.,* 2011; Branco and Verani, 2006; Chaves, Cova-Grando, and Calluf, 2003; Coelho *et al.,* 1986; Giannini and Paiva-Filho, 1990; Gomes and Chaves, 2006; Paiva-Filho and Schmiegelow, 1986; Pina and Chaves, 2009; Ruffino and Castello, 1992; Schwarz *et al.,* 2007; Souza *et al.,* 2008; Vianna and Almeida, 2005).

The observation of a large amount of infrequent species in this study is a recurring pattern in tropical shrimp fisheries (Stobutzki *et al.,* 2001) and on the continental shelf of the southern coast of Brazil (Bernardes *et al.,* 2011; Branco and Verani, 2006; Cattani *et al.,* 2011; Pina and Chaves, 2009). Because communities are not closed units, many species occur only occasionally or even a single time in collections (Fisher, Corbet, and Williams, 1943; Melo, 2004). This influx of migrant species is not a characteristic of only the rarest ones but also happen throughout the community, including those considered abundant and frequent in samples. Rare species also contribute with a constant fraction of total richness throughout the years (Magurran and Henderson, 2003). The proximity of the study areas with the surf zone may well increase that influx of species, because this habitat is known as a key one when speaking of fish recruitment factors (Pessanha and Araújo,

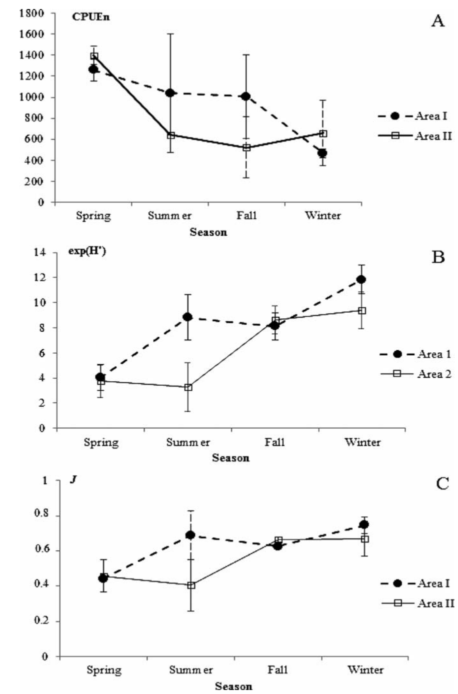

Figure 5. Variation of seasonal average and standard error (±) of (A) CPUE/number of individuals per tow, (B) Shannon-Wiener diversity index, and (C) Pielou evenness index (J) of the ichthyofauna caught from November 2003 to October 2004 in the area between Pinheira and Gamboa beaches (Palhoça, Santa Catarina, Brazil).

2003). *Cathorops spixii, S. setapinnis, T. lepturus, P. harroweri*, and *S. testudineus* were collected in high numbers during our work and are routinely, and abundantly, captured in the surf zone (Dantas, Feitosa, and Araújo, 2012; Santana and Severi, 2009), which may well lead us to suppose that these species inhabit both study areas in distinct phases of their life

Table 2. *ANOVA of CPUE/number of individuals per tow, diversity exp(*H'*), evenness (*J*), and dominance (*d*) of the two factors (area and season) and the interaction between these factors.*

Factors	df	MS	F	p*
CPUE (log)				
Area	1	0.238	4976	0.056
Season	3	0.084	1751	0.234
Area × season	3	0.075	1566	0.272
Error	8	0.048		
exp(H')				
Area	1	15.29	2.411	0.159
Season	3	34.01	5.363	**0.026**
Area × season	3	8.352	1.317	0.335
Error	8	6.343		
J				
Area	1	0.023	3.063	0.118
Season	3	0.051	6.708	**0.014**
Area × season	3	0.022	2.831	0.106
Error	8	0.008		

df = degrees of freedom, MS = mean squares, F = value of F test, p = significance value test.
* Values in bold indicate a significant difference.

Table 3. *PERMANOVA of the community structure of the ichthyofauna analyzing area, season, and the interaction between them.*

Factor	df	SS	MS	F	p*
Area	1	0.09	0.09	0.62	0.86
Season	3	0.91	0.31	2.08	**0.004**
Area × season	3	0.35	0.12	0.78	0.81
Error	8	11.81	0.15		
Total	15	25.35			

df = degrees of freedom, SS = sum of squares, MS = mean squares, F = value of F test, p = significance value test.
* p value obtained through the permutation test of Monte Carlo. Values in bold indicate statistical significance ($p < 0.05$).

Table 4. *Results of pairwise comparisons between seasons.*

Seasons	t	p*
Spring *vs.* summer	14.56	0.09
Spring *vs.* fall	17.8	**0.03**
Spring *vs.* winter	19.09	**0.03**
Summer *vs.* fall	12.8	0.11
Summer *vs.* winter	15.36	**0.03**
Fall *vs.* winter	12.62	0.06

* Values in bold indicate statistical significance ($p < 0.05$).

history and may use them differently for foraging and reproduction.

Some infrequent species sampled, *e.g., P. harroweri, U. brasiliensis,* and *B. ronchus* in area I and *M. littoralis* and *F. petimba* in area II, were present in moderate numbers and concentrated in one sampling period, probably indicating an aggregation behavior in the study area. The causes of these aggregations should be analyzed more deeply in population studies of these species. According to Odum and Barrett (2005), patterns of aggregation may be due to responses to local differences in habitats, climatic seasonal variations and environmental variables, reproductive processes, and social attractions.

In S and SE Brazil, the fish species most commonly caught as bycatch are *P. brasiliensis, C. gracilicirrhus, M. furnieri, M. americanus, L. breviceps, S. brasiliensis, Stellifer rastrifer, Cynoscion jamaicensis,* and *I. parvipinnis* (Branco and Verani, 2006; Coelho *et al.,* 1986; Muto, Soares, and Rossi-Wongtschowski, 2000; Paiva-Filho and Schmiegelow, 1986; Schwarz *et al.,* 2007; Souza *et al.,* 2008). Besides the aforementioned, recent studies conducted off Santa Catarina's coast found high numbers of *T. lepturus, P. harroweri, S. tessellatus, S. setapinnis,* and *C. spixii* (Bernardes *et al.,* 2011; Cattani *et al.,* 2011; Pina and Chaves, 2009).

The occurrence of species that are considered uncommon elsewhere off the Brazilian coast dominates Palhoça's ichthyofauna (Bernardes *et al.,* 2011; Branco and Verani, 2006; Chaves, Cova-Grando, and Calluf, 2003; Coelho *et al.,* 1986; Giannini and Paiva-Filho, 1990; Gomes and Chaves, 2006; Paiva-Filho and Schmiegelow, 1986; Pina and Chaves, 2009; Ruffino and Castello, 1992; Schwarz *et al.,* 2007; Souza *et al.,* 2008; Vianna and Almeida, 2005). Even in nearby areas, our dominant species (*C. striatus* and *S. hispidus*) were either infrequent or did not occur (Bail and Branco, 2003; Bernardes *et al.,* 2011; Cattani *et al.,* 2011; Pina and Chaves, 2009; Sousa and Chaves, 2007). These species reached their higher abundance in periods of high temperature and salinity, as shown in the CCA test. In the particular case of *C. striatus,* their high abundance may well be related to a type of aggregation of this species caused by seasonal movements stimulated between autumn and spring, when leaving from the fishing grounds of Uruguay and Argentina to the coastal

Table 5. *Results of SIMPER analysis showing the species that contributed most to the differences in the communities of the different periods and the total contribution, cumulative contribution, and abundance of species in the analyzed periods.*

Taxa	Contribution	% Cumulative	Mean Abundance (1)	Mean Abundance (2)
Spring (1) × Fall (2) dissimilarity: 89.16%				
Cynoscion striatus	32.61	39.21	602	38.8
Stephanolepis hispidus	12.97	54.81	276	33.3
Paralonchurus brasiliensis	7.87	64.27	24.5	152
Ctenosciaena gracilicirrhus	5.05	70.34	0	116
Stellifer spp.	4.53	75.78	34.8	91.5
Fistularia petimba	2.31	78.56	0	31.3
Selar crumenophthalmus	1.99	80.96	27.3	0.75
Spring (1) × Winter (2) dissimilarity: 69.73%				
Cynoscion striatus	29.01	41.6	602	108
Stephanolepis hispidus	13.32	60.71	276	38.5
Paralonchurus brasiliensis	7.35	71.24	24.5	146
Selar crumenophthalmus	2.02	74.13	27.3	1.5
Stellifer spp.	2.00	77	34.8	33.8
Menticirrhus littoralis	1.95	79.79	5	39.3
Menticirrhus americanus	1.80	82.37	12.3	38.8
Summer (1) × Winter (2) dissimilarity: 78.03%				
Selar crumenophthalmus	13.97	17.91	137	1.5
Cynoscion striatus	10.32	31.13	103	108
Paralonchurus brasiliensis	9.77	43.65	31.3	146
Bardiella ronchus	7.95	53.84	157	0
Stephanolepis hispidus	3.59	58.44	54	38.5
Stellifer spp.	3.06	62.36	24.5	33.8
Urophycis brasiliensis	2.91	66.08	24.5	16.3

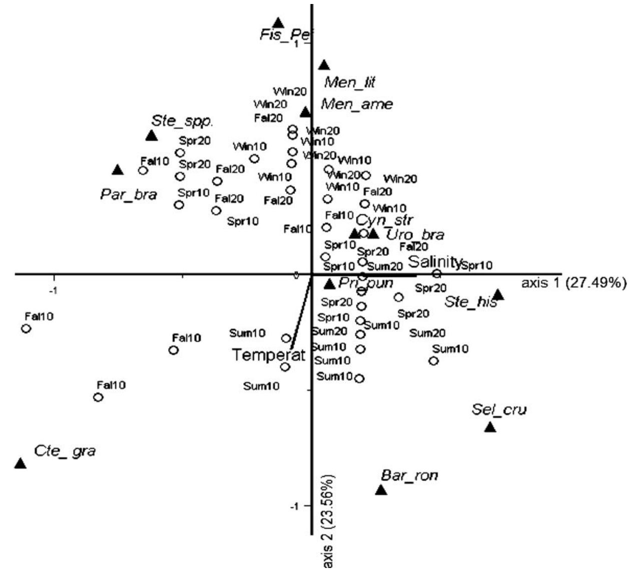

Figure 6. Results of the CCA among salinity, temperature, dominant fish species *(Cyo_gra = Ctenosciaena gracilicirrhus, Par_bra = Paralonchurus brasiliensis, Ste_*ssp = *Stellifer* spp., *Cyo_str = Cynoscion striatus, Fis_pet = Fistularia petimba, Men_ame = Menticirrhus americanus, Men_lit = Menticirrhus littoralis, Pri_puc = Prionotus punctatus, Sel_cru = Selar crumenophthalmus, Bar_ron = Bardiella ronchus),* seasons (Sum = summer, Fal = fall, Win = winter, Spr = spring), and sampled depths (10 and 20) between Pinheira and Gamboa beaches (Palhoça, Santa Catarina, Brazil).

waters of southern Brazil and back southward in summer, by seasonal movements performed by small juveniles recruited in spring and summer to coastal waters less than 25 m deep (Haimovici, Martins, and Vieira, 1996), or by both types of seasonal movement. *S. hispidus* is a major component of the *Sargassum* spp. community (Rogers, Hare, and Lindquist, 2001). In our study, *S. hispidus* was abundant in coastal shallow waters, thus being associated with higher temperatures and *Sargassum* colonies. In these conditions, and mainly during summer months, such colonies are denser and attain their highest biomass values (Oneshigue-Valentin and Nassar, 2009), suggesting an apparent correlation between these taxa.

The oscillations of temperature and salinity were clearly influenced by the seasonality of the mass of coastal water, which is characterized by low levels of salinity and high temperatures (Schettini, Carvalho, and Truccolo, 1999). Nevertheless, the seasonal changes in abiotic factors were apparently responsible for the quantitative and qualitative differences in the ichthyofauna composition. The higher incidence of fish in spring could be related to reproduction periods and with the aggregation of the sciaenids at that time of the year (Muniz and Chaves, 2008; Robert, Michels-Souza, and Chaves, 2007; Rodrigues-Filho *et al.,* 2011a, b; Sousa and Chaves, 2007), something that could make them more vulnerable to catches (Bernardes *et al.,* 2011).

The ecological descriptors and specific composition of the communities also vary seasonally and were evidenced by the results of the statistical tests. The effective number of species $\exp(H')$ in area I varied from 4.30 in spring up to 11.84 in winter. In area II, lesser values occurred in spring (3.73) and summer (3.29), with a sudden increase until spring (9.41). The low levels of spring diversity are correlated to lesser evenness and richness values during this same season in both sampling areas. In area II, a similar pattern (low evenness and richness values) was detected in summer, thus indicating the low diversity of this season. In these situations, evenness values were always less than 0.50, which according to Magurran (2004), indicates inadequate homogeneity within species' distribution in their respective communities. The high dominance of *C. striatus, S. hispidus,* and *S. crumenophthalmus* in spring and summer samplings was a factor that corroborated the low diversity and then verified. When compared with other fishing spots, the strong temporal variation observed in this study was similar. In the work of Bernardes *et al*. (2011), the higher evenness and diversity indices were determined for winter in Barra do Sul and for fall in Penha; these are clearly similar to ours. In those regions, Bernardes *et al*. (2011) noted that the dominance of species such as *P. brasiliensis, I. parvipinnis,* and *S. rastrifer* in spring and summer months were a major contribution for low diversity levels in fishing areas. Sedrez *et al*. (2013) observed that Shannon's highest diversity levels occurred during the warmer months in shallower waters (10–20 m deep) and in spring for deeper waters (30 m). These results differ from ours. As Jost (2006) has shown, indices that estimate entropy (*e.g.*, the Shannon index) do not represent diversity as we see it and may often induce to misinterpretations when comparing recurrence of more or less diverse communities to these indices, mainly when differences between them are low, something also detected by Sedrez *et al*. (2013).

In our study, we observed that the shallowest, as well as the closest to the intertidal, area (area I) presented the highest values of all estimated ichthyofauna parameters (CPUE, richness, diversity, and evenness). However, when comparing our two areas, we have not found significant differences in abundance, ecological descriptors (diversity and evenness), or species composition (PERMANOVA). The similarity between our two areas, even taking different depths into account, may well be related to their proximity and clearly to the great mobility the fish have, thus attenuating the eventual contrast between fishing bottoms (Stobutzki, Jones, and Miller, 2003). Only the species' richness, estimated by the rarefaction curve, showed a significant difference, being higher in the shallower area (area I). Schwarz (2009), when analyzing fish species caught at diverse depths, registered differences in the abundance and in the total number of species but did not show differences in the ecological descriptors (diversity and evenness), these being similar to our results in Palhoça.

The restructuring of the ichthyofauna throughout the seasons was detailed by the SIMPER analysis. The main factor responsible for the differences between seasons was the species classified as regular with high abundance, such as *C. striatus, P. brasiliensis, S. hispidus,* and *S. crumenophthalmus*. Moreover, infrequent species with low abundance, namely, *F. petimba* and *B. ronchus,* had a minor supporting role in the community structure.

CONCLUSIONS

According to our results, the ichthyofauna of Palhoça is diverse, with a high number of captured organisms and specific composition or patterns similar to other fishing bottoms, such as the dominance of Sciaenidae, high presence of infrequent species, and small number of species considered abundant in the samplings. Nevertheless, the species considered such in this study are not common in other fishing spots of the Brazilian coastline or even in spots geographically closer. The specific composition of the ichthyofauna and the ecological descriptors of the community were not influenced by differences between areas (depth and grain size); instead, they only depend on the time factor and the seasonality of the abiotic variables. Such scientific work is essential to characterizing ecosystems, overfishing, and detection of factors that may act on the composition of bycatch. The information will be valuable for measures and management practices that would significantly contribute to strongly reducing bycatch by shrimp–prawn fisheries.

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□ RESUMO □

As alterações na composição específica e nos descritores ecológicos das assembleias de peixes em função dos fatores abióticos, tais como profundidade, temperatura, salinidade e granulometria, foram analisadas no presente trabalho. Arrastos mensais de trinta minutos de duração foram realizados em duas áreas com diferentes profundidades em um importante ponto de pesca camaroeira do litoral sul brasileiro. Paralelamente, registrou—se os valores de temperatura e salinidade da água, bem como foi amostrado o tipo de substrato dos fundos de pesca. A aplicação do teste t de Student demonstrou variação sazonal dessas variáveis ambientais no estudo ($p < 0,05$) e a análise granulométrica demonstrou que a composição dos fundos de pesca foi bastante similar, sendo composta principalmente por areia. No total foram capturados 12.613 exemplares, sendo 7.880 na área I e 4.733 na área II. Os maiores valores de captura (CPUE) ocorreram no inverno. Foram capturados 50 táxons na área I e 53 na área II, um alto valor quando comparado com estudos pretéritos em localidades próximas. A família dos sciaenideos foi a mais representativa nas coletas, predominando em ambas as áreas espécies incidentais (37 na área I e 42 na área II). *Cynoscion striatus* foi a espécie mais abundante e predominante em ambas as áreas. As estimativas dos descritores ecológicos, tais como a riqueza, a diversidade e equitabilidade, evidenciaram que a estrutura da ictiofauna foi fortemente influenciada pelo fator tempo e que os valores mais acentuados ocorreram no outono e inverno. A aplicação da PERMANOVA demonstrou que a composição especifica da ictiofauna diferiu entre as estações. O teste t de Student *a posteriori* demonstrou que a composição da comunidade na primavera diferiu do outono e inverno ($p < 0,05$) e que o inverno diferiu do verão. De acordo com a análise de similaridade, as alterações na estrutura das comunidades foram causadas, sobretudo, por espécies classificadas como abundantes e que ocorreram de forma desigual entre os períodos. Nossos resultados demonstraram que a comunidade ictiica foi influenciada por variações sazonais da temperatura e salinidade e não por diferenças de profundidade e granulométrica entre as áreas.