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Scientific Article

ICHTHYOFAUNA BYCATCH OF THE ARTISANAL FISHERY OF PENAEID SHRIMPS IN PERNAMBUCO, NORTHEASTERN BRAZIL*

Carlos Antonio Beserra da Silva-Júnior[1]

Alex Souza Lira[1]

Leandro Nolé Eduardo[1]

Andrea Pontes Viana[2]

Flávia Lucena-Frédou[1]

Thierry Frédou[1]

[1]Universidade Federal Rural de Pernambuco – UFRPE, Departamento de Pesca e Aquicultura, Rua Dom Manoel de Medeiros, s/n, CEP 52171-900, Recife, PE, Brasil. E-mail: carlosjunior88@gmail.com (corresponding author).

[2]Universidade Federal do Oeste do Pará – UFOPA, Programa de Pós-graduação em Recursos Aquáticos Continentais Amazônico, Avenida Mendonça Furtado, s/n, CEP 68040-470, Santarém, PA, Brasil.

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ABSTRACT

The shrimp trawl fisheries are highly efficient in capturing target species but is an unselective gear that commonly catches untargeted organisms, which are usually discarded due to their small size or no commercial value. To understand and, eventually, mitigate the impacts of trawling on bycatch species, the whole capture should be addressed. The present study has the objective of determining the seasonal importance of the fish bycatch within shrimp trawling fishery in south Pernambuco, Sirinhaém. It also quantifies the importance of each fish caught within this fishery. Samples were collected monthly, between August 2011 and July 2012. Fish bycatch was described as % in number (%N) and weight (%W), while the seasonal abundance of the shrimp and fish bycatch was assessed based on the monthly catch rate given as the Capture Per Unit of Area (CPUA) in weight (CPUAb) and in number of individuals (CPUAn). Considering the fish bycatch, a total of 608 kg of organisms were sampled: 9,723 fish specimens from 17 families, 38 genera and 51 species. The largest CPUAb value of bycatch was observed in the months of June (488 kg.km^{-2}), February (285 kg.km^{-2}) and April (276 kg.km^{-2}). The proportion target species: bycatch in weight was of 1:0.39. A clear annual cyclic pattern of the species composition of the bycatch based both CPUAn and CPUEb could be observed, following the rainfall patterns, possibly related to a higher productivity associated to river runoffs. Impacts on bycatch have been extensively reported in Brazil and around the world, with most of this bycatch being a relevant additional food source for the local community. However, basic information on bycatch from small-scale fisheries is still missing in many areas, making it difficult to identify and evaluate the management recommendations needed to sustain the resources and ecosystems.

Key words: trawling; discard; fish; seasonal patterns.

ICTIOFAUNA ACOMPANHANTE DA PESCA ARTESANAL DE CAMARÕES PENEÍDEOS NO ESTADO DE PERNAMBUCO, NORDESTE DO BRASIL

RESUMO

A pesca de arrasto de camarão é eficiente na captura da espécie alvo, porém, por ser uma arte de baixa seletividade, captura organismos que não são alvo da pescaria, os quais geralmente são descartados devido ao tamanho pequeno ou por não ter valor comercial. Diante disso, o presente estudo teve como objetivo avaliar os peixes capturados como fauna acompanhante na pescaria de arrasto de camarão em Sirinhaém, litoral sul de Pernambuco. As amostras foram coletadas mensalmente, entre agosto de 2011 e julho de 2012. A ictiofauna acompanhante foi descrita em % em número (%N) e peso (%W), enquanto a abundância sazonal do camarão e da fauna acompanhante foram quantificadas como Captura por unidade de área (CPUA) em peso (CPUAb) e número de indivíduos (CPUAn). Considerando a ictiofauna acompanhante, um total de 608 Kg foi capturado: 9.723 espécimes de peixes, pertencentes a 17 famílias, 38 gêneros e 51 espécies. Os maiores valores da CPUAb da fauna acompanhante foram observados nos meses de junho (488 kg.km^{-2}), fevereiro (285 kg.km^{-2}) e abril (276 kg.km^{-2}). A proporção camarão:fauna acompanhante em peso foi 1:0,39, 72% de camarão (439 kg) para 28% de peixes (171 kg). Um claro padrão anual cíclico na composição de espécies das capturas acessórias baseado tanto em CPUAn como em CPUEb pôde ser observado, seguindo os padrões de precipitação, possivelmente relacionado a uma maior produtividade associada aos escoamentos fluviais. Impactos na fauna acompanhante têm sido reportado no Brasil e em todo o mundo, com a maior parte do bycatch sendo uma importante fonte adicional de alimento para as comunidades locais. Entretanto, informações básicas sobre o bycatch oriundo da pesca de pequena escala ainda são desconhecidas em muitas áreas, dificultando a identificação e avaliação do tipo de gerenciamento necessário para sustentar os recursos e ecossistemas.

Palavras-chave: arrasto; descarte; peixes; padrões sazonais.

INTRODUCTION

The shrimp trawl fisheries is highly efficient in capturing target species but is an unselective gear that commonly has an associated catch of untargeted organisms (e.g. fin-fish, turtles and miscellaneous invertebrates), the "bycatch", which is usually discarded due to their small size or no commercial value (Pina and Chaves, 2009). These unwanted catches may lead to adverse impacts on populations and ecosystems, reducing the sustainability of the fishery, and inducing to bias in stock assessments and population models, which do not account for unobservable fishing mortality (Broadhurst et al., 2006). The amount of bycatch caught by trawling is high and often exceeds the quantity of the commercial shrimp captured (Branco and Verani, 2006). For commercial species, the economic extinction of exploited populations will occur before biological extinction, but this is not valid for bycatch species caught in multispecies fisheries (Dulvy et al., 2003, 2004). In Northeast Brazil, the shrimp trawling activity is carried out mainly by motorized artisanal boats that operate predominantly in shallow and coastal waters (Dias-Neto, 2011). In this region, approximately 100,000 persons depend directly or indirectly of this fishery for their living (Santos et al., 2006). In Pernambuco, Sirinhaém has the most productive motorized shrimp fishing fleet among the coastal communities (Tischer and Santos, 2003) and penaeids are the most exploited crustaceans (IBAMA, 2008).

According to Kelleher (2005), the global discard from trawl fisheries is approximately 1.9 million ton, which corresponds to 63% of the total caught while, in Brazil, the annual discard is about 55.000 tons, corresponding to approximately 23% of the total landed. Various studies have provided information on bycatch of the shrimp trawling fisheries in Brazil (Braga et al., 2001; Cattani et al., 2011; Freitas et al., 2011; Sedrez et al., 2013; Silva Júnior et al., 2013, 2015; Costa et al., 2016; Pinheiro and Farias, 2016; Rodrigues-Filho et al., 2016; Santos et al., 2016). These studies, mainly performed in the southern and south region of Brazil, have contributed to our understanding of many aspects of the bycatch along the Brazilian coast. The studies carried out in Pernambuco were developed during early 2000's, mainly focused in describing the bycatch composition and diversity (Tischer and Santos, 2003), and did not consider the overall contribution of this unwanted catch in the whole fishery, its seasonal aspects and the relationship with environmental drivers, which is consistent with the new paradigm of the 'Ecosystem Approach to Fisheries Management' (EAFM).

The EAFM (also known as Ecosystem Approach to Fisheries – EAF and Ecosystem-Based Fisheries Management – EBFM) can be defined as an integrated approach to management that considers the entire ecosystem, in order to maintain an ecosystem in a healthy, productive and resilient condition so it may continue to provide the services that humans want and need (Garcia et al., 2003; Garcia and Cochrane, 2005). According to Bellido et al. (2011), within EAFM framework, the bycatch must be taken into account since (1) it potentially leads to reduced income from fisheries; (2) it directly affects the diversity, functioning and balance of the ecosystem; and (3) besides causing a great waste and being highly ineffective.

The present study has the main goal of evaluating the fish as bycatch in the shrimp trawling fishery in south Pernambuco, Sirinhaém by (1) determining the importance of the fish bycatch within shrimp trawling fishery in the area; (2) quantifying the importance of each fish caught within this fishery; and (3) describing the seasonal variation of the species composition of the incidental catch related to the seasonal patterns of the main environmental driver in the region, the rainfall as a proxy to the river runoffs.

MATERIAL AND METHODS

This study was carried out in Sirinhaém, Pernambuco, 70 km south of the state capital, Recife, northeastern Brazil (Figure 1).

Samples were collected monthly during full moon, between August 2011 and July 2012, using a 9-meter local wooden-hulled shrimp trawler. For each sample, three sets were carried out during the daytime using a double trawl measuring 10 m in length, with an opening of 6.10 m, with meshes of 30 mm in the main body, and 25 mm in the cod-end. The pluviometry data were obtained through the Agência Pernambucana de Águas e Clima (APAC, 2015) for the years of 2011 and 2012. The months of September to May were considered as dry season and the months of June, July and August as the rainy season. The fish caught were separated, identified to the lowest possible taxonomic level using specialized literature (*e.g.* Carpenter, 2002a, 2002b, 2002c). The weight and the number of individuals of each species were recorded.

Data analysis

The seasonal abundance of the shrimp and fish bycatch was measured using the monthly catch rate. Two catch rates were calculated: the Capture Per Unit of Area (CPUA) in weight (CPUAb) and in number of individuals (CPUAn). The CPUA was calculated using the catch in weight (W; kg) or number of individuals (N) divided by the estimated swept area (a; km^2): CPUAb= W/a and CPUAn= N/a. The covered area was estimated as: a= D.H.X; where, D is the distance covered (km) obtained by GPS tracking; H is the head-rope length (0.012 km) and X is the fraction of the head rope length = 0.5 (Pauly, 1980). The difference between CPUA by months was tested using ANOVA. The CPUA data were log10 transformed to attend the assumption of normality and homoscedasticity, when necessary. When a significant difference was observed, the post-hoc Tukey's test (Zar, 2009) was used to determine which monthly catch rates were significantly different from the others.

The fish bycatch was expressed as % in number (%N) and weight (%W). To describe the seasonal variation of the abundance of the fish by-catch, the fish assemblage trend along the year was also evaluated using a non-metric Multidimensional Scaling (nMDS) analysis based on a distance matrix of Bray-Curtis, obtained from two types of input data: (1) the CPUAb and CPUAn per fishing sets and (2) the monthly average of CPUAb and CPUAn. The Wisconsin double standardization was applied on the raw data to improve the gradient detection ability of dissimilarity indices (Bray and Curtis, 1957). The monthly rainfall data was selected as the main driver for distribution and abundance of

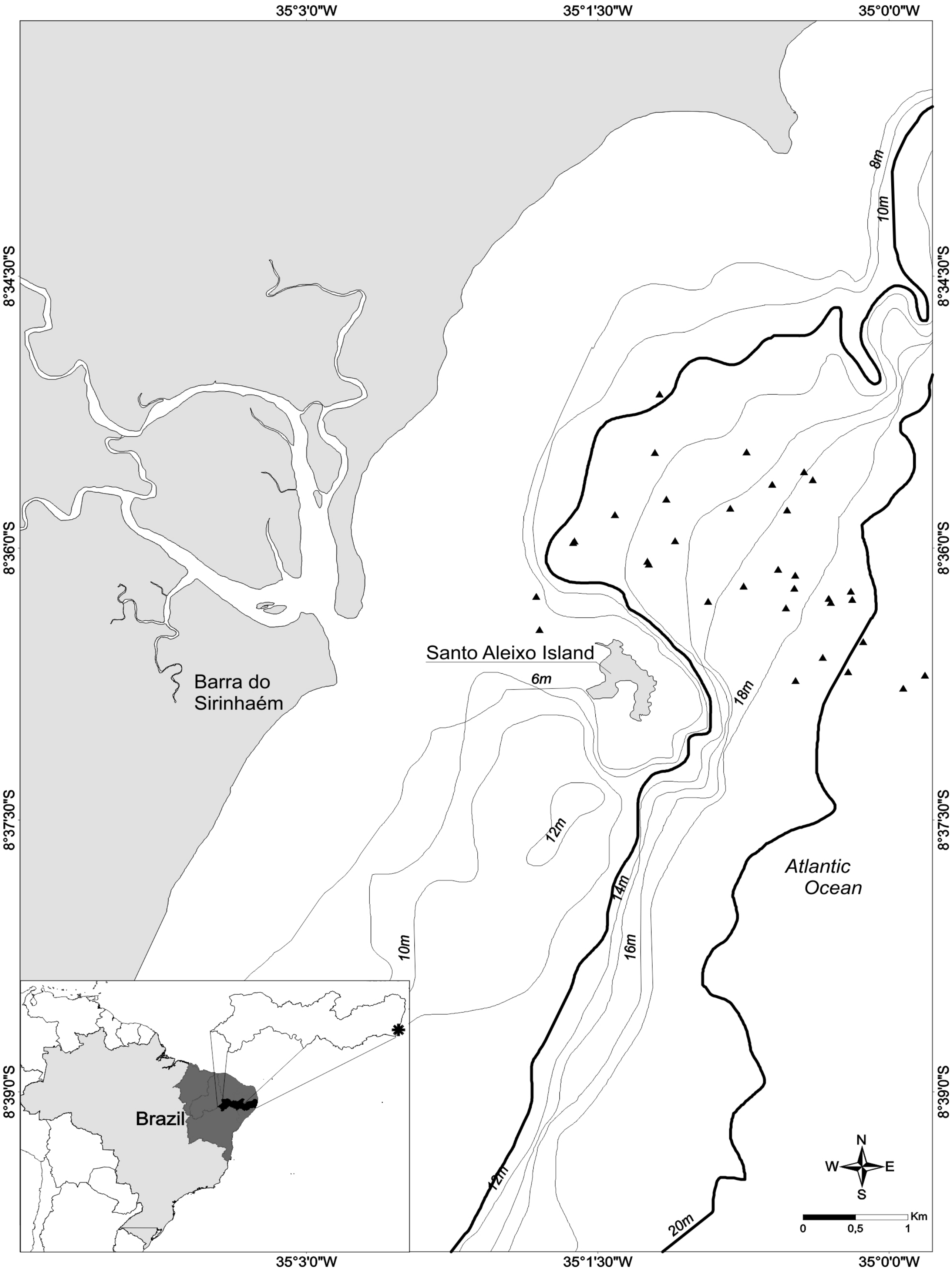

Figure 1. Map of the study area, coast of the state of Pernambuco, Brazil.

organisms (Alber, 2002). It was then superposed onto the 2D nMDS representation as secondary information.

All analyses were performed using the R environment (R Core Team, 2018) using Vegan package (Oksanen et al., 2017).

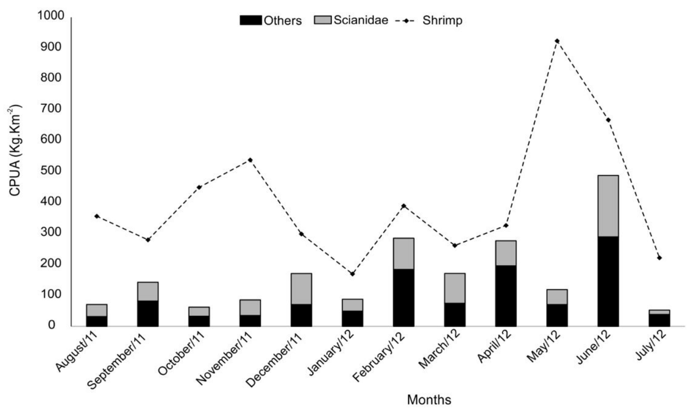

Figure 2. Temporal analyses of the Capture Per Unit of Area in weigh (CPUAb) of the species of fish and shrimp caught by the shrimp trawling.

RESULTS

The importance of the fish bycatch within shrimp trawling fishery in Sirinhaém (PE)

The shrimp catch rates (CPUAb) were higher all year round (Figure 2) and, although no significant differences between months were observed ($p>0.05$), it presented high intramonth variations. The largest CPUAb value of bycatch was observed in the months of June (488 kg.km^{-2}), February (285 kg.km^{-2}) and April (276 kg.km^{-2}). The proportion "target species:bycatch" in weight was of 1:0.39, 72% of shrimp (439 kg) to 28% of fish (171 kg). Within the fish bycatch, sciaenids showed higher catch rates of biomass than the remaining families in 4 months (August, November, December and March; Figure 3), with a minimum of 13.86 kg.km^{-2} in July/12 and a maximum of 198 kg.km^{-2} in June/12.

Composition and seasonal variation of the abundance of the fish bycatch

Considering the fish bycatch, a total of 608 kg of organisms were sampled: 9,723 fish specimens from 17 families, 38 genera and 51 species (Table 1). Three families represented 50% of the sampled species: Sciaenidae (32% - 16 species), Haemulidae

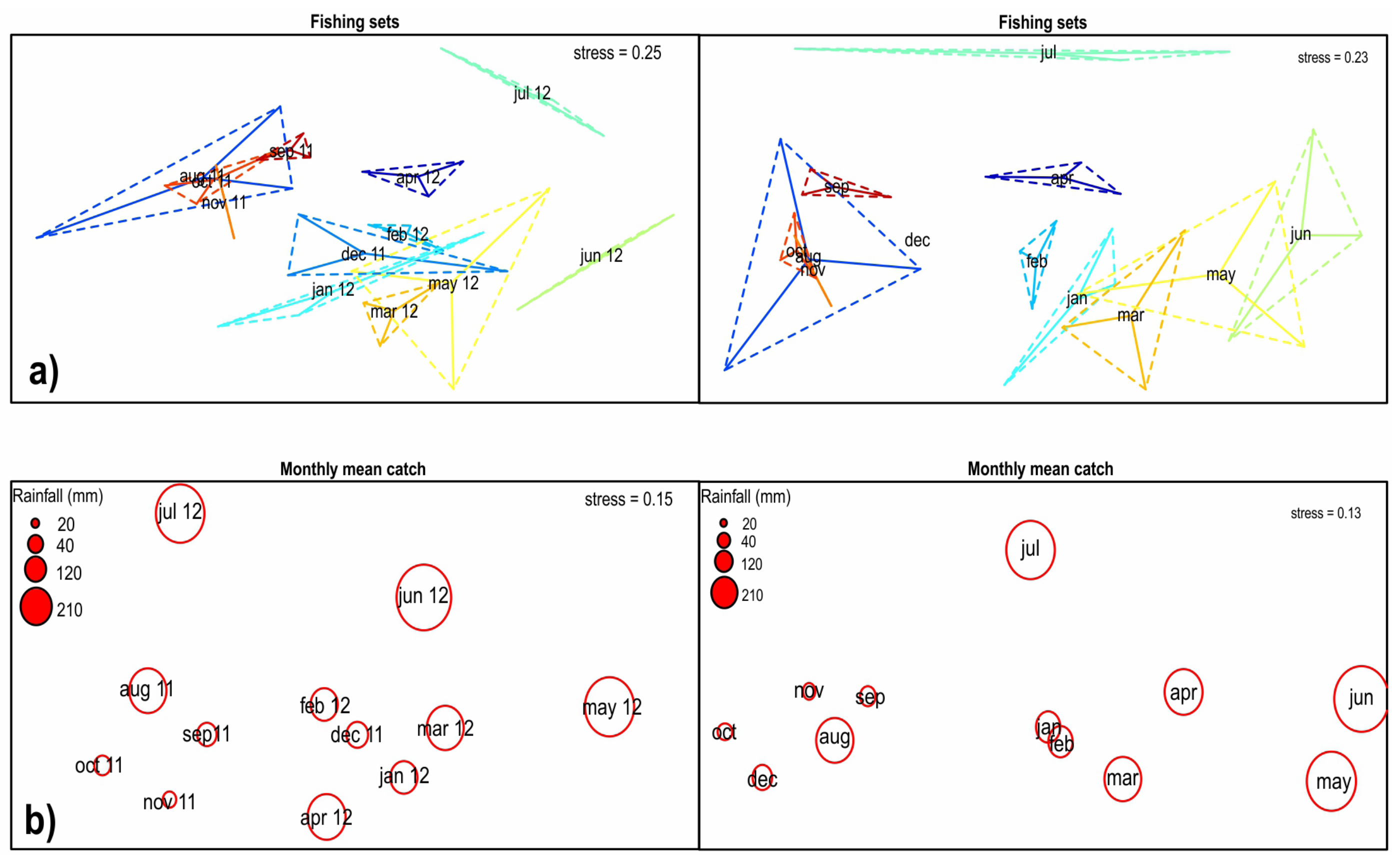

Figure 3. nMDS method, based in the CPUAn and CPUAb data (a) and in the annual precipitation pattern (b).

Table 1. Relation and contributions in number (%N) and weight (%W) of families and species of fishes caught as bycatch in Sirinhaém coast, Northeastern Brazil.

Family/Specie	Common name	%N	%W
CLUPEIDAE		**16.33**	**7.42**
Chirocentrodon bleekerianus (Poey, 1867)	Dogtooth herring	4.95	1.69
Harengula clupeola (Cuvier, 1829)	False herring	0.36	0.21
Odontognathus mucronatus Lacepède, 1800	Guiana longfin herring	10.99	5.41
Opisthonema oglinum (Lesueur, 1818)	Atlantic thread herring	0.03	0.11
PRISTIGASTERIDAE		**34.14**	**20.00**
Pellona harroweri (Fowler, 1917)	American coastal pellona	34.14	20.00
ENGRAULIDAE		**3.20**	**3.44**
Anchoa spinifer (Valenciennes, 1848)	Spicule anchovy	0.33	0.26
Cetengraulis edentulus (Cuvier, 1829)	Atlantic anchoveta	1.88	1.92
Lycengraulis grossidens (Spix & Agassiz, 1829)	Atlantic sabretooth anchovy	0.99	1.26
ARIIDAE		**0.29**	**0.28**
Aspistor luniscutis (Valenciennes, 1840)	Sea catfish	0.01	0.14
Bagre marinus (Mitchill, 1815)	Gafftopsail sea catfish	0.28	0.14
CARANGIDAE		**0.64**	**0.63**
Chloroscombrus chrysurus (Linnaeus, 1766)	Atlantic bumper	0.01	0.02
Selene brownii (Cuvier, 1816)	Caribbean moonfish	0.57	0.45
Selene vomer (Linnaeus, 1758)	Lookdown	0.06	0.16
ACHIRIDAE		**1.34**	**2.78**
Achirus declivis Chabanaud, 1940	Slipper sole	0.61	1.35
Achirus lineatus (Linnaeus, 1758)	Slipper sole	0.10	0.26
Trinectes paulistanus (Miranda Ribeiro, 1915)	Slipper sole	0.63	1.17
SPHYRAENIDAE		**0.15**	**0.22**
Sphyraena guachancho Cuvier, 1829	Guachanche barracuda	0.15	0.22
PARALICHTHYIDAE		**0.14**	**0.23**
Citharichthys macrops (Dresel, 1889)	Spotted whiff	0.01	0.06
Citharichthys spilopterus Günther, 1862	Bay whiff	0.13	0.17
CYNOGLOSSIDAE		**0.60**	**0.83**
Symphurus plagusia (Bloch & Schneider, 1801)	Duskycheek tonguefish	0.04	0.04
Symphurus tesselatus (Linnaeus, 1766)	Duskycheek tonguefish	0.56	0.79
TRICHIURIDAE		**0.72**	**1.73**
Trichiurus lepturus (Linnaeus, 1758)	Largehead hairtail	0.72	1.73
GERREIDAE		**0.36**	**0.66**
Diapterus auratus Ranzani, 1842	Irish mojarra	0.25	0.51
Diapterus rhombeus (Cuvier, 1829)	Caitipa mojarra	0.05	0.10
Eucinostomus gula (Quoy & Gaimard, 1824)	Jenny mojarra	0.06	0.05
PEMPHERIDAE		**0.02**	**0.02**
Pempheris schomburgkii Müller & Troschel, 1848	Glassy sweeper	0.02	0.02
HAEMULIDAE		**7.13**	**13.8**
Conodon nobilis (Linnaeus, 1758)	Barred grunt	1.57	3.57
Genyatremus luteus (Bloch, 1790)	Torroto grunt	0.04	0.09
Haemulon aurolineatum Cuvier, 1830	Tomtate grunt	0.02	0.01
Haemulon plumieri (Lacepède, 1801)	White grunt	0.01	0.01
Haemulon steindachneri (Jordan & Gilbert, 1882)	Chere-chere grunt	0.06	0.12
Haemulopsis corvinaeformis (Steindachner, 1868)	Roughneck grunt	5.43	10.00

Table 1. Continued...

Family/Specie	Common name	%N	%W
LUTJANIDAE		**0.23**	**0.38**
Lutjanus synagris (Linnaeus, 1758)	Lane snapper	0.23	0.38
POLYNEMIDAE		**1.03**	**1.64**
Polydactylus virginicus (Linnaeus, 1758)	Barbu	1.03	1.64
EPHIPPIDAE		**0.09**	**0.22**
Chaetodipterus faber (Broussonet, 1782)	Atlantic spadefish	0.09	0.22
SCIAENIDAE		**32.95**	**45.35**
Cynoscion virescens (Cuvier, 1830)	Green weakfish	0.98	2.13
Isopisthus parvipinnis (Cuvier, 1830)	Bigtooth corvina	3.42	6.73
Larimus breviceps (Cuvier, 1830)	Shorthead drum	5.85	7.18
Macrodon ancylodon (Bloch & Schneider, 1801)	King weakfish	1.23	1.57
Menticirrhus americanus (Linnaeus, 1758)	Southern kingcroaker	1.16	2.60
Menticirrhus littoralis (Holbrook, 1847)	Gulf kingcroaker	0.02	0.02
Micropogonias furnieri (Desmarest, 1823)	Whitemouth croaker	0.53	2.73
Nebris microps (Cuvier, 1830)	Smalley ecroaker	0.32	0.51
Ophioscion sp.	Spotted croaker	2.52	2.76
Ophioscion punctatissimus Meek & Hildebrand, 1925	Spotted croaker	0.45	0.99
Paralonchurus brasiliensis (Steindachner, 1875)	Banded croaker	3.02	3.87
Stellifer sp.	Croakers	0.50	0.25
Stellifer brasiliensis (Schultz, 1945)	Croakers	1.90	1.42
Stellifer microps (Steindachner, 1864)	Croakers	5.61	6.48
Stellifer rastrifer (Jordan, 1889)	Rak estardrum	3.35	4.40
Stellifer stellifer (Bloch, 1790)	Little croaker	2.09	1.71

(10% - 5 species) and Clupeidae (8% - 4 species) (Table 1). These families were also more abundant in number, including the family Pristigasteridae that, although represented by a single species, *Pellona harroweri* (Fowler, 1917), was the most representative (34.3%). Together with this species, the families Sciaenidae (33.2%), Clupeidae (16.4%) and Haemulidae (7.8%) represented 91.1% of the catches in number. Among the 51 species caught as bycatch, only seven were responsible for 70.9% of the total caught in numbers: *P. harroweri*, *Odontognathus mucronatus*, *Larimus breviceps*, *Stellifer microps*, *Haemulopsis corvinaeformis*, *Chirocentrodon bleekerianus* and *Stellifer rastrifer*. A similar pattern was observed for the total biomass (%W), the families Sciaenidae (45.7%), Pristigasteridae (20%), Haemulidae (13.8%) and Clupeidae (7.4%) were the most representative, corresponding to 86.9% of the total biomass (Table 1). In relation to species, *P. harroweri,* followed by *H. corvinaeformis,* showed the highest biomass values, and, together with *L. breviceps*, *S. microps* and *I. parvipinnis*, contributed with approximately 51.3% of the total catch of fish by weight.

The Sciaenidae family was considered the most representative in the bycatch, since 16 species and 10 genera were recorded. In terms of relative weight (%W), this group represented 45.7% of the fish bycatch, with the highest contribution for *L. breviceps* (16.1%), *S. microps* (15.3%), *I. parvipinnis* (15.0%) and *S. rastrifer* (10%). In terms of abundance (%N), of the 3,230 individuals caught, *L. breviceps* (17.7%), *S. microps* (17%), *S. rastrifer* (12%), *I. parvipinnis* (10.3%) and *Paralonchurus brasiliensis* (9.1%) dominated, accounting for 66.1% of the total Sciaenidae.

A clear annual cyclic pattern of the species composition of the bycatch based both on CPUAn and CPUEb could be observed (Figure 3). Variations in community structure followed the annual precipitation pattern, with a slight exception in April mainly due to a massive occurrence of *P. harroweri* in the bycatch.

DISCUSSION

Fish are among the most representative organisms in the bycatch of the shrimp trawl fisheries, and, in some regions, around 55 million tons are caught annually (Kelleher, 2005; Zeller et al., 2018). Worldwide, it is reported higher ratios of fish versus shrimps caught. Maharaj and Recksiek (1991) registered a proportion of 10:1 in Venezuelan waters; Paighambari and Daliri (2012) observed a ratio of 8:1.2 in the Persian Gulf, while Ye et al. (2000) reported 15.2:1 in Kuwait. In Brazil, these ratios greatly vary, from a maximum of 10.5:1, in the State of Rio de Janeiro, to a minimum of 0.57:1 in the State of Paraná (Graça Lopes et al., 2002; Vianna and Almeida, 2005; Cattani et al., 2011; Oliveira-Freitas et al., 2011; Sedrez et al., 2013; Santos et al., 2016). In the present study, the proportion of the fish bycatch was the lowest ever observed, with 0.39kg of fish for each 1 kg of shrimp (0.39:1). According to Catchpole et al. (2011), the proportion of fish as bycatch may considerably vary depending on the gear used, intensity of fishing effort, community composition and recruitment intensity.

The trawling can be, in many cases, efficient in obtaining the target species, but due to the low selectivity of the fishing gear, it catches a very rich and diversified fauna (Klippel et al., 2005), with a great variety of organisms such as fish, crustaceans, molluscs, echinoderms and cnidarians (Rodrigues et al., 1985; Graça Lopes et al., 2002; Branco and Verani, 2006). A total of 51 species was recorded as bycatch of the shrimp trawl fisheries in Sirinhaém, similar to that registered in 2001/2002 for the same area (Tischer and Santos, 2003), despite the long-term fishing and a potential climate change. This richness however was lower than the observed in other locations of the southern region of Brazil, such as Santa Catarina – 62 species (Sedrez et al., 2013) and Paraná – 68 species (Cattani et al., 2011).

The fish bycatch was dominated, in weight and number, by the family Sciaenidae, similarly to other studies in Brazil, from both Southern and Southeastern regions (Branco and Verani, 2006; Bernardo et al., 2011; Chaves et al., 2003; Rodrigues-Filho et al., 2015), and Northern and Northeastern of Brazil (Isaac and Braga, 1999; Braga et al., 2001; Tischer and Santos, 2003; Oliveira-Silva et al., 2008; Dantas et al., 2012; Silva Júnior et al., 2013). In the southern Brazil, in some cases, this family contributes to approximately 68% of the total number of individuals captured (Godefroid et al., 2004). The high representativeness of sciaenids is common, as they are frequent in sandy-muddy bottom areas where shrimp trawling occurs (Santos, 2006), especially during the period of reproductive activity and recruitment, which occurs mainly in the summer and fall months in the southern region of Brazil (Robert et al., 2007). For the study area, Silva-Júnior et al. (2015) observed that the reproductive period of some species of Sciaenidae occurs during the months of December to July, as for the main target shrimps (Silva et al., 2016; Lopes et al., 2017).

The rainfall are considered one of the main driver of fish assemblages (Rueda and Defeo, 2003; Ramos et al., 2011), since, in addition to physical disturbances, it provides a greater concentration of nutrients and a decrease in salinity indices, favoring an increase in primary productivity, higher trophic levels and, therefore, promoting an increase in the number of individuals (Trujillo and Thurman, 2008) however it did not have any clear effect on the relative abundance of the fish caught. The nMDS analyses based on catch rates (CPUAn and CPUAb) showed a clear cyclic annual configuration, following the rainfall patterns, possibly related to a higher productivity related to river runoffs (Mallin et al., 1993). The main species that contribute to such shifts were *Pellona harroweri, Haemulopsis corvinaeformis* and *S. microps* that dominated the area during the dry season, and *Menticirrhus americanus, Micropogonias furnieri* and *Bagre marinus*, dominant during the wet season.

Impacts on bycatch have been extensively reported in Brazil (Alverson et al., 1994; Komoroske and Lewison, 2015; Zeller et al., 2018) and around the world (Maharaj and Recksiek, 1991; Ye et al., 2000; Paighambari and Daliri, 2012). However, basic information (e.g. biological, technical and socio-economic aspects) on bycatch from small-scales fisheries are still missing in many areas, making it difficult to identify and evaluate different regulations needed to sustain the resources and ecosystems (Kalikoski and Vasconcellos, 2012). This is notably the case for shrimp trawl fisheries in the Northeastern Brazil, where only a few studies on the qualitative and quantitative aspects of bycatch are available (Tischer and Santos, 2003; Cattani et al., 2011). In this context, information generated in this study may be useful to provide essential information for the development of sustainable management practices. Considering the Ecosystem Approach to Fisheries, management plans for a multispecific fishery, such as the shrimp trawling fishery, should always consider the biological and ecological aspects of the various species (or at least the main species) of the bycatch. This would help the establishment of, for example, seasonal closed seasons, which in this area, could be the summer months, given the known spawning peaks of the shrimps and main species of the bycatch. Moreover, when we consider all the variety of species caught incidentally in this study, the addition of escape mechanisms to the nets, known as By-catch Reduction Devices (BRD) (McHugh et al., 2017), would be another appropriate recommendation, since it may reduce bycatch in shrimp trawlers up to 40% (Brewer et al., 2006; García-Caudillo et al., 2000). A FAO initiative called "Reduction of Environmental Impact from Tropical Shrimp Trawling, through the Introduction of Bycatch Reduction Technologies and Change of Management" (Rebyc, FAO 2018), implemented in Brazil, is in cours in the study area, and will contribute to a better management of shrimp trawling activity, hopefully reducing its impact on fish species populations.

CONCLUSION

The proportion of target species: fish bycatch in weight was of 1:0.39 in Sirinhaem (Pernambuco), much lower than in other regions in Brazil and around the world, with most of this bycatch being a relevant additional food source for the local community. However, this incidental catch may change the ecological structure by removing key species, resulting in shifts in the food web and ecosystem functioning, since a large amount of juvenile fish is caught along with shrimps (Alverson and Hughes, 1996; Kelleher, 2005; Silva Júnior et al., 2013, 2015). Within the fish bycatch, sciaenids showed higher catch rates of biomass. A clear annual cyclic pattern could be observed in the catch composition, since variations in community structure followed the annual precipitation pattern. Given the multispecific nature of this fishery and the recommended application of the Ecosystem Approach to Fisheries, any management plan for this fishery in Pernambuco, must consider the biological and ecological knowledge of the target (in this case shrimps) and the main by catch species, such as the ones provided in this study.

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REFERENCES

Alber, M. 2002. A conceptual model of estuarine freshwater inflow management. Estuaries and Coasts, 25(6): 1246-1261. **http://dx.doi.org/10.1007/BF02692222**.

Alverson, D.L.; Freeberg, M.H.; Pope, J.G.; Murawski, S.A. 1994. A global assessment of fisheries bycatch and discards. Rome: FAO. 233p. (FAO Fisheries Technical Paper, 339).

Alverson, D.L.; Hughes, S.E. 1996. Bycatch: from emotion to effective natural resource management. Reviews in Fish Biology and Fisheries, 6(4): 443-462. **http://dx.doi.org/10.1007/BF00164325**.

APAC – Agência Pernambucana de Águas e Clima. 2015. Available from: <http://www.apac.pe.gov.br/meteorologia/monitoramento-pluvio.php> Access on: 2 feb. 2017.

Bellido, J.M.; Santos, M.B.; Pennino, M.G.; Valeiras, X.; Pierce, G.J. 2011. Fishery discards and bycatch: solutions for an ecosystem approach to fisheries management? Hydrobiologia, 670(1): 317-333. **http://dx.doi.org/10.1007/s10750-011-0721-5**.

Bernardo, C.; Spach, H.L.; Junior, R.S.; Stoiev, S.B. 2011. A captura incidental de cianídeos em arrasto experimental com rede-de-portas utilizada na pesca do camarão-sete-barbas, *Xiphopenaeus kroyeri*, no estado do Paraná, Brasil. Arquivos de Ciência do Mar, 44(2): 98-105. http://dx.doi.org/10.32360/acmar.v44i2.168.

Braga, M.S.C.; Salles, R.; Fonteles-Filho, A.A. 2001. Ictiofauna acompanhante da pesca de camarões com rede-de-arrasto na zona costeira do município de Fortaleza, estado do Ceará, Brasil. Arquivos de Ciência do Mar, 34(1): 49-60. http://dx.doi.org/10.32360/acmar.v34i1-2.11652.

Branco, J.O.; Verani, J.R. 2006. Análise quali-quantitativa da ictiofauna acompanhante na pesca do camarão sete-barbas, na Armação do Itapocoroy, Penha, Santa Catarina. Revista Brasileira de Zoologia, 23(2): 381-391. **http://dx.doi.org/10.1590/S0101-81752006000200011**.

Bray, J.R.; Curtis, J.T. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs, 27(4): 325-349. **http://dx.doi.org/10.2307/1942268**.

Brewer, D.; Heales, D.; Milton, D.; Dell, Q.; Fry, G.; Venables, B.; Jones, P. 2006. The impact of turtle excluder devices and bycatch reduction devices on diverse tropical marine communities in Australia's northern prawn trawl fishery. Fisheries Research, 81(2-3): 176-188. **http://dx.doi.org/10.1016/j.fishres.2006.07.009**.

Broadhurst, M.K.; Suuronen, P.; Hulme, A. 2006. Estimating collateral mortality from towed fishing gear. Fish and Fisheries, 7(3): 180-218. **http://dx.doi.org/10.1111/j.1467-2979.2006.00213.x**.

Carpenter, K.E. 2002a. The living marine resources of the Western Central Atlantic: introduction, molluscs, crustaceans, hagfishes, sharks, batoid fishes, and chimaeras. Rome: FAO. v. 1, 600 p. (FAO Species Identification Guide for Fishery and American Society of Ichthyologists and Herpetologists Special Publication, 5).

Carpenter, K.E. 2002b. The living marine resources of the Western Central Atlantic: bony fishes part 1 (Acipenseridae to Grammatidae). Rome: FAO. v. 2, p. 601-1374. (FAO Species Identification Guide for Fishery and American Society of Ichthyologists and Herpetologists Special Publication, 5).

Carpenter, K.E. 2002c. The living marine resources of the Western Central Atlantic: bony fishes part 2 (Opistognathidae to Molidae), sea turtles and marine mammals. Rome: FAO. v. 3, p. 1375-2127. (FAO Species Identification Guide for Fishery and American Society of Ichthyologists and Herpetologists Special Publication, 5).

Catchpole, T.L.; Enever, R.; Maxwell, D.L.; Armstrong, M.J.; Reese, A.; Revill, A.S. 2011. Constructing indices to detect temporal trends in discarding. Fisheries Research, 107(1-3): 94-99. **http://dx.doi.org/10.1016/j.fishres.2010.10.012**.

Cattani, A.P.; Santos, L. DE O.; Spach, H.L.; Budel, B.R.; Guanais, J.H.D.G. 2011. Avaliação da ictiofauna da fauna acompanhante da pesca do camarão sete-barbas do município de pontal do Paraná, litoral do Paraná, Brasil. Boletim do Instituto de Pesca, 37(3): 247-260.

Chaves, P.; Cova-Grando, G.; Calluf, C. 2003. Demersal ichthyofauna in a continental shelf region on the south coast of Brazil exposed to shrimp trawl fisheries. Acta Biológica Paranaense, 32(1): 69-82. http://dx.doi.org/**10.5380/abpr.v32i0.618**.

Costa, R.C.; Carvalho-Batista, A.; Herrera, D.R.; Pantaleão, J.A.F.; Teodoro, S.; Davanso, T.M. 2016. Carcinofauna acompanhante da pesca do camarão-sete-barbas *Xiphopenaeus kroyeri* em Macaé, Rio de Janeiro, Sudeste Brasileiro. Boletim do Instituto de Pesca, 42(3): 611-624. **http://dx.doi.org/10.20950/1678-2305.2016v42n3p611**.

Dantas, N.C.F. DE M.; Feitosa, C.V.; Araújo, M.E. 2012. Composition and assemblage structure of demersal fish from São Cristóvão beach, Areia Branca, RN. Biota Neotropica, 12(3): 108-117. **http://dx.doi.org/10.1590/S1676-06032012000300012**.

Dias-Neto, J. 2011. Proposta de plano nacional de gestão para o uso sustentável de camarões marinhos no Brasil. Brasilia: MMA/IBAMA. 242p.

Dulvy, N.K.; Ellis, J.R.; Goodwin, N.B.; Grant, A.; Reynolds, J.D.; Jennings, S. 2004. Methods of assessing extinction risk in marine fishes. Fish and Fisheries, 5(3): 255-276. **http://dx.doi.org/10.1111/j.1467-2679.2004.00158.x**.

Dulvy, N.K.; Sadovy, Y.; Reynolds, J.D. 2003. Extinction vulnerability in marine populations. Fish and Fisheries, 4(1): 25-64. **http://dx.doi.org/10.1046/j.1467-2979.2003.00105.x**.

FAO – Food and Agriculture Organization of the United Nations, FAO Fisheries and Aquaculture Department. 2018. Reduction of environmental impact from tropical shrimp trawling through the introduction of by-catch reduction technologies and change of management. REBYC Phase II. FI Institutional Websites. Rome: FAO. Available from: <http://www.fao.org/fishery/> Access on: 9 feb. 2018

Freitas, M.; Spach, H.; Hostim-Silva, M. 2011. Variação espaço-temporal da assembleia de peixes demersais em uma área de pesca do camarão sete-barbas no sul do Brasil. Neotropical Biology and Conservation, 6(1): 44-54. **http://dx.doi.org/10.4013/nbc.2011.61.06**.

Garcia, S.M.; Cochrane, K.L. 2005. Ecosystem approach to fisheries: a review of implementation guidelines. ICES Journal of Marine Science, 62(3): 311-318. **http://dx.doi.org/10.1016/j.icesjms.2004.12.003**.

Garcia, S.M.; Zerbi, A.; Aliaume, C.; Do Chi, T.; Lasserre, G. 2003. The ecosystem approach to fisheries. Rome: FAO. (FAO Fisheries Technical Paper, 443). 71p. Available from: <http://www.fao.org/3/a-y4773e.pdf> Access on: 2 feb. 2017.

García-Caudillo, J.M.; Cisneros-Mata, M.A.; Balmori-Ramírez, A. 2000. Performance of a bycatch reduction device in the shrimp fishery of the Gulf of California, Mexico. Biological Conservation, 92(2): 199-205. **http://dx.doi.org/10.1016/S0006-3207(99)00053-1**.

Godefroid, R.S.; Spach, H.L.; Santos, C.; Maclaren, G.; Schwarz Junior, R. 2004. Mudanças temporais na abundância e diversidade da fauna de peixes do infralitoral raso de uma praia, sul do Brasil. Iheringia. Série Zoologia, 94(1): 95-104. **http://dx.doi.org/10.1590/S0073-47212004000100017**.

Graça Lopes, R.; Tomás, A.R.G.; Tutui, S.L.S.; Severino Rodrigues, E.; Puzzi, A. 2002. Fauna acompanhante da pesca camaroeira no litoral do estado de São Paulo, Brasil. Boletim do Istituto de Pesca, 28(2): 173-188.

IBAMA – Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. 2008. Estatística da pesca 2006: grandes regiões e unidades da federação. Brasília.

Isaac, V.; Braga, T. 1999. Rejeição de pescado nas pescarias da região norte. Arquivos de Ciência do Mar, 32(1): 39-54. http://dx.doi.org/10.32360/acmar.v32i1-2.31342.

Kalikoski, D.C.; Vasconcellos, M. 2012. Case study of the technical, socio-economic ad enviromental conditions of small-scale fishiries in the estuary of patos lagoon, Brazil. Rome: FAO. 190p. (FAO Fisheries and Aquaculture Circular, 1075). Available from: <http://www.fao.org/docrep/015/i2589e/i2589e.pdf/> Access on: 2 feb. 2017.

Kelleher, K. 2005. Discards in the world's marine fisheries: an update. Rome: FAO. 131p. (FAO Fisheries Technical Paper, 470). Available from: <http://www.fao.org/docrep/008/y5936e/y5936e00.htm/> Access on: 2 feb. 2017.

Klippel, S.; Vooren, C.M.; Lamónaca, A.F.; Peres, M.B. 2005. A pesca industrial no sul do Brasil. In: Vooren, C.M.; Klippel, S. (Ed.). Ações para a conservação de tubarões e raias no sul do Brasil. Porto Alegre: Igaré. p. 135-178.

Komoroske, L.M.; Lewison, R.L. 2015. Addressing fisheries bycatch in a changing world. Frontiers of Materials Science, 2: 83. http://dx.doi.org/**10.3389/fmars.2015.00083**.

Lopes, D.; Frédou, F.L.; Silva, E.; Calazans, N.; Peixoto, S. 2017. Reproductive cycle of seabob shrimp *Xiphopenaeus kroyeri* (Crustace, Penaeidea) from the northeast coast of Brazil. Invertebrate Reproduction & Development, 61(3): 137-141. **http://dx.doi.org/10.1080/07924259.2017.1311951**.

Maharaj, V.; Recksiek, C. 1991. The by-catch from the artisanal shrimp trawl fishery, Gulf of Paria, Trinidad. Marine Fisheries Review, 53(2): 9-15.

Mallin, M.A.; Paerl, H.W.; Rudek, J.; Bates, P.W. 1993. Regulation of estuarine primary production by watershed rainfall and river flow. Marine Ecology Progress Series, 93(1-2): 199-203. **http://dx.doi.org/10.3354/meps093199**.

McHugh, M.J.; Broadhurst, M.K.; Sterling, D.J. 2017. Choosing anterior-gear modifications to reduce the global environmental impacts of penaeid trawls. Reviews in Fish Biology and Fisheries, 27(1): 111-134. **http://dx.doi.org/10.1007/s11160-016-9459-5**.

Oksanen, J.; Blanchet, F.G.; Friendly, M.; Kindt, R.; Legendre, P.; Mcglinn, D.; Minchin, P.R.; O'Hara, R.B.; Simpson, G.L.; Solymos, P.; Henry, M.; Stevens, H.; Szoecs, E.; Wagner, H. 2017. vegan: Community Ecology Package. R package version 2.4. Vienna: R Foundation for Statistical Computing. Available from: <https://CRAN.R-project.org/package=vegan/> Access on: 2 feb. 2017.

Oliveira-Freitas, M.; Spach, H.; Hostim-Silva, M. 2011. Variação espaço-temporal da assembleia de peixes demersais em uma área de pesca do camarão sete-barbas no sul do Brasil. Neotropical Biology and Conservation, 6(1): 44-54. **http://dx.doi.org/10.4013/nbc.2011.61.06**.

Oliveira-Silva, J.T.; Peso Aguiar, M.C.; Lopes, P.R.D. 2008. Ictiofauna das praias de Cabuçu e Berlinque: Uma contribuição ao conhecimento das comunidades de peixes na Baía de Todos os Santos – Bahia – Brasil. Biotemas, 21(4): 105-115. **http://dx.doi.org/10.5007/2175-7925.2008v21n4p105**.

Paighambari, S.Y.; Daliri, M. 2012. The by-catch composition of shrimp trawl fisheries in Bushehr Coastal Waters, the Northern Persian Gulf. Journal of the Persian Gulf, 3(7): 27-36. Available from: <http://jpg.inio.ac.ir/article-1-57-en.html/> Access on: 2 feb. 2017.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temparature in 175 fish stocks. Journal du Conseil, 39(2): 175-192. **http://dx.doi.org/10.1093/icesjms/39.2.175**.

Pina, J.V.; Chaves, P.T. 2009. Incidência da pesca de arrasto camaroeiro sobre peixes em atividade reprodutiva: uma avaliação no litoral norte de Santa Catarina, Brasil. Atlântica, 31(1): 99-106. **http://dx.doi.org/10.5088/atl.2009.31.1.99**.

Pinheiro, W.M.; Farias, A.C.S. 2016. Specific composition, bioecology and ecomorphology of marine ichthyofauna from small scale fishery. Boletim do Instituto de Pesca, 42(1): 181-194. **http://dx.doi.org/10.20950/1678-2305.2016v42n1p181**.

R Core Team. 2018. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing. Available from: <https://www.R-project.org/> Access on: 2 feb. 2017.

Ramos, J.A.A.; Barletta, M.; Dantas, D.V.; Lima, A.R.A.; Costa, M.F. 2011. Influence of moon phase on fish assemblages in estuarine mangrove tidal creeks. Journal of Fish Biology, 78(1): 344-354. **http://dx.doi.org/10.1111/j.1095-8649.2010.02851.x**. PMid:21235566.

Robert, M.C.; Michels-Souza, M.A.; Chaves, P.T. 2007. Biologia de *Paralonchurus brasiliensis* (Steindachner) (Teleostei, Sciaenidae) no litoral sul do estado do Paraná, Brasil. Revista Brasileira de Zoologia, 24(1): 191-198. **http://dx.doi.org/10.1590/S0101-81752007000100024**.

Rodrigues, E.S.; Graça-Lopes, R.; Pita, J.B.; Coelho, J.A. 1985. Levantamento das espécies de camarão presentes no produto da pesca dirigida a camarão sete-barbas (Xiphopenaeus kroyeri Heller, 1862) no estado de São Paulo, Brasil. Boletim do Instituto de Pesca, 12(4): 77-85. Available from: <https://www.pesca.sp.gov.br/sumario_12_4_77-85.pdf> Access on: 2 feb. 2017.

Rodrigues-Filho, J.L.; Branco, J.O.; Monteiro, H.S.; Verani, J.R.; Barreiros, J.P. 2015. Seasonality of ichthyofauna bycatch in shrimp trawls from different depth strata in the Southern Brazilian Coast. Journal of Coastal Research, 300(2): 378-389. **http://dx.doi.org/10.2112/JCOASTRES-D-13-00024.1**.

Rodrigues-Filho, J.L.; Couto, E.; Barbieri, E.; Branco, J.O. 2016. Ciclos sazonais da carcinofauna capturada na pesca do camarão-sete-barbas, *Xiphopenaeus kroyeri* no litoral de Santa Catarina. Boletim do Instituto de Pesca, 42(3): 648-661. **http://dx.doi.org/10.20950/1678-2305.2016v42n3p648**.

Rueda, M.; Defeo, O. 2003. Spatial structure of fish assemblages in a tropical estuarine lagoon: Combining multivariate and geostatistical techniques. Journal of Experimental Marine Biology and Ecology, 296(1): 93-112. **http://dx.doi.org/10.1016/S0022-0981(03)00319-8**.

Santos, C. 2006. Comunidade de peixes demersais e ciclo reprodutivo de quatro espécies da família Sciaenidae na plataforma interna entre Superagui e Praia de Leste, PR. Curitiba. 142f. (Tese de Doutorado. Universidade Federal do Paraná). Avaliable from: <http://digital.csic.es/bitstream/10261/128759/4/Santos_Tesis_2006.pdf> Access on: 30 june 2018.

Santos, M.C.F.; Silva, K.C.A.; Cintra, I.H.A. 2016. Carcinofauna acompanhante da pesca artesanal do camarão-sete-barbas ao largo da foz do rio São Francisco (Alagoas e Sergipe, Brasil). Acta of Fisheries and Aquatic Resources, 4(1): 1-10.

Santos, M.; Pereira, J.; Ivo, C. 2006. A pesca do camarão branco *Litopenaeus schmitt*i (BURKENROAD, 1936) (Crustacea, Decapoda, Penaeidae) no Nordeste do Brasil. Boletim Técnico Científico Cepene, 14(1): 33-58. Available from: <http://www4.icmbio.gov.br/cepene/images/stories/publicacoes/btc/vol14/art03-v141.pdf> Access on: 2 feb. 2017.

Sedrez, M.C.; Branco, J.O.; Freitas Júnior, F.; Monteiro, H.S.; Barbieri, E. 2013. Ictiofauna acompanhante na pesca artesanal do camarão sete-barbas (*Xiphopenaeus kroyeri*) no litoral sul do Brasil. Biota Neotropica, 13(1): 165-175. **http://dx.doi.org/10.1590/S1676-06032013000100019**.

Silva Júnior, C.A.B.; Feitosa, C.V.; Araújo, M.E. 2013. Sustainability of capture of fish bycatch in the prawn trawling in northeastern Brazil. Neotropical Ichthyology, 11(1): 133-142. http://dx.doi.org/**10.1590/S1679-62252013000100016**.

Silva Júnior, C.A.B.; Viana, A.P.; Frédou, F.L.; Frédou, T. 2015. Aspects of the reproductive biology and characterization of Sciaenidae captured as bycatch in the prawn trawling in the northeastern Brazil. Acta Scientiarum, 37(1): 1-8. http://dx.doi.org/**10.4025/actascibiolsci.v37i1.24962**.

Silva, E.F.; Calazans, N.; Nolé, L.; Branco, T.C.; Soares, R.; Guerra, M.M.P.; Frédou, F.L.; Peixoto, S. 2016. Reproductive dynamics of the southern pink shrimp *Farfantepenaeus subtilis* in northeastern Brazil. Aquatic Biology, 25: 29-35. **http://dx.doi.org/10.3354/ab00653**.

Tischer, M.; Santos, M.C.F. 2003. Composição e diversidade da ictiofauna acompanhante de peneídeos no litoral sul de Pernambuco. Arquivos de Ciência do Mar, 36(2): 105-118.

Trujillo, A.P.; Thurman, H.V. 2008. Essentials of Oceanography. 9th ed. New Jerse: Pearson Prentice Hall. 534p.

Vianna, M.; Almeida, T. 2005. Bony fish bycatch in the Southern Brazil pink shrimp (*Farfantepenaeus brasiliensis* and *F. paulensis*) fishery. Brazilian Archives of Biology and Technology, 48(4): 611-623. **http://dx.doi.org/10.1590/S1516-89132005000500014**.

Ye, Y.; Alsaffar, A.H.; Mohammed, H.M.A. 2000. Bycatch and discards of the Kuwait shrimp fishery. Fisheries Research, 45(1): 9-19. **http://dx.doi.org/10.1016/S0165-7836(99)00105-8**.

Zar, J. 2009. Biostatistical analysis. 5th ed. New Jersey:Prentice-Hall. 944p.

Zeller, D.; Cashion, T.; Palomares, M.; Pauly, D. 2018. Global marine fisheries discards: a synthesis of reconstructed data. Fish and Fisheries, 19(1): 30-39. **http://dx.doi.org/10.1111/faf.12233**.