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

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.

Impactos na bycatch têm sido reportado no Brasil e em todo o mundo, com a maior parte deste bycatch sendo uma importante fonte de alimento para as comunidades locais. No entanto, informações básicas sobre bycatch oriundo de 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.

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

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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 (Brando 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; km²): CPUA= 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).

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 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.

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.

<table>
<thead>
<tr>
<th>Family/Specie</th>
<th>Common name</th>
<th>%N</th>
<th>%W</th>
</tr>
</thead>
<tbody>
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<td>CLUPEIDAE</td>
<td></td>
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<td>20.00</td>
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<td>0.04</td>
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<td>Eucinostomus gula</td>
<td>Jenny mojarra</td>
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<td>White grunt</td>
<td>0.01</td>
<td>0.01</td>
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<td>Haemulon steindachneri</td>
<td>Chere-chere grunt</td>
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<td>0.12</td>
</tr>
<tr>
<td>Haemulopsis corvinaeformis</td>
<td>Roughneck grunt</td>
<td>5.43</td>
<td>10.00</td>
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</tbody>
</table>
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 total biomass (%W). Together with this species, the families Sciaenidae (45.7%), Pristigasteridae (20%), Haemulidae (13.8%) and Clupeidae (16.4%) contributed with approximately 51.3% of the total biomass (%W), corresponding to 86.9% of the total biomass (%W). In relation to species, P. harrower (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 catch in number: Isopisthus parvipinnis (Cuvier, 1830) (15.0%), S. rastrifer (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 Paralichthys 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

Table 1. Continued...

<table>
<thead>
<tr>
<th>Family/Specie</th>
<th>Common name</th>
<th>%N</th>
<th>%W</th>
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<tr>
<td><strong>LUTJANIDAE</strong></td>
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<td>Lutjanus symagris (Linnaeus, 1758)</td>
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<td>Little croaker</td>
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<td>1.71</td>
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</table>

(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 catch in numbers: P. harroweri, Odontognathus macronatus, Larimus breviceps, Stellifer microps, Haemulopsis corvinaformis, 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. harrower, followed by H. corvinaformis, 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 Paralichthys brasiliensis (9.1%) dominated, accounting for 66.1% of the total Sciaenidae.
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 CPÜAb) 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. microops 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 (Alversen et al., 1994; Komoroske and Lewison, 2015; Zeller et al., 2018) and around the world (Maharaj and Recksiek, 1991; Ye et al., 2000; Paighambahri 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 Sirinhaém (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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