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The impact of shrimp trawl bycatch on fish reproduction in northeastern Brazil

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ABSTRACT

In the west coast of Rio Grande do Norte many small-scale fisheries targeting mostly shrimp but accidentally catch a large number of fish. Our aim was to evaluate the Ichthyofauna composition and distribution in Potiguar Basin, northeastern Brazil, in order to elucidate the impact of bycatch on fish reproduction. The study area was divided into four stretches (A, B, C and D), and we sampled 1,426 specimens classified into 10 orders, 23 families and 49 species. We obtained biometric data and gonadal tissue in order to determine the reproductive aspects of the studied fish. Stretch A had the highest values of evenness and dominance; the highest values of abundance, biomass, richness and diversity were found in stretches B, C and D. Analysis based on faunal similarity revealed three groups: I (found in stretches B and D), II (C), and III (A). In regards to reproductive phase, 76.3% of the specimens were classified as 'immature', 16.7% as 'maturing' and 7% as 'mature'. Through the anatomical and histological analyzes of the gonads and the size of first maturation, we verified that the species *Pomadasys corvinaeformes*, *Menticirrhus littoralis* and *Larimus breviceps* were negatively related to fishing activity; on the other hand, *Pellona harroweri* was positively related. Our findings indicate that the incidental capture of some non-target species can affects predominantly individuals considered immature, i.e. without reproductive potencial, an indicative of non-sustainable fishing in region.

Keywords: coastal zone; diversity; ichthyofauna; reproductive stages; sexual maturity.

O impacto da pesca acessória do arrasto camaroeiro na reprodução de peixes no nordeste do Brasil

RESUMO

Na costa oeste do Rio Grande do Norte, muitas pescarias de pequena escala têm como alvo principal camarões, mas acidentalmente capturam um grande número de peixes. Nosso objetivo foi avaliar a composição e distribuição da ictiofauna na Bacia Potiguar, Nordeste do Brasil, a fim de elucidar o impacto das capturas acessórias na reprodução dos peixes. A área de estudo foi dividida em quatro trechos (A, B, C e D), e foram amostrados 1.426 espécimes classificados em 10 ordens, 23 famílias e 49 espécies. Obtivemos dados biométricos e tecido gonadal para determinar os aspectos reprodutivos dos peixes estudados. O Trecho A apresentou os maiores valores de equitabilidade e dominância; os maiores valores de abundância, biomassa, riqueza e diversidade foram encontrados nos trechos B, C e D. A análise baseada na similaridade faunística revelou três grupos: I (trechos B e D), II (C) e III (A). Em relação à fase reprodutiva, 76,3% dos espécimes foram classificados como "imaturos", 16,7% como "em maturação" e 7% como "maduros". Através das análises anatômicas e histológicas das gônadas e do tamanho da primeira maturação, verificamos que as espécies *Pomadasys corvinaeformes*, *Menticirrhus littoralis* e *Larimus breviceps* foram negativamente relacionadas à atividade pesqueira; Por outro lado, *Pellona harroweri* estava positivamente relacionada. Nossos achados indicam que a captura incidental de algumas espécies não-alvo pode afetar predominantemente indivíduos considerados imaturos, ou seja, sem potencial reprodutivo, um indicativo de pesca não sustentável na região.

Palavras-chave: diversidade, estágios reprodutivos, ictiofauna, maturidade sexual, zona costeira.

Introdução

Coastal areas are exposed to continental and marine processes capable of influencing the structural characteristics of ecosystems that may affect the distribution patterns of fish communities (NERO; SEALEY, 2006). The constitution of coastal environments is fundamental to the biological cycles of several fish species. These environments have high concentrations of nutrients and thermohaline gradients that provide breeding refuges and support the initial feeding of early-age specimens of a large number of species. These are relevant factors for the conservation of natural resources and biodiversity maintenance (LIVINGSTON, 2002).

Many multi-target small-scale fisheries operate in the west coast of Rio Grande do Norte (RN); small boats operate mainly in coastal waters using fishing gear such as gill nets and bottom trawls. The trawl fisheries target fish and shrimp; however, a large number of fish are accidentally captured (BOMFIM, 2014). These fish are often small-sized juveniles, and therefore, of low economical value (SOUZA; CHAVES, 2007), rejected on board or discarded on sandy beaches, characterizing bycatch (HELFMAN et al., 2009). High mortality rates of juvenile fish may contribute to the decline of recreational and commercial species populations (HELFMAN et al., 2009), leading to a collapse of the current environmental balance and, consequently, generating ecological and economical impacts.

Understanding the reproductive stages of Brazilian fish, including of non-commercial species, as well as the depletion of natural stocks is paramount to administer, manage and create conservation measures to mitigate the impacts generated by trawling (VAZZOLER, 1996). Studies on the diversity and reproduction of fish species in ecosystems with intense human activity, including fishing, are crucial and bring knowledgment to improve conservation plans. Thus, our study focused on evaluating the composition, distribution and reproductive aspects of the ichthyofauna in the Potiguar Basin, northeastern Brazil, subject to different levels of fishing activity in order to elucidate the impact of bycatch on fish reproduction.

Material and Methods

Study area

This research was carried out in the northeastern Brazil, between Caiçara do Norte (5°4'1.15"S, 36°4'36.41"W) in Rio Grande do Norte State (RN) and Icapuí (4°38'48.28"S, 37°32'52.08"W) in Ceará State (CE), region known as Potiguar Basin; an area of approximately extension of 300 km.

Since 2010, the Projeto Cetáceos da Costa Branca - Universidade do Estado do Rio Grande do Norte (PCCB-UERN) in Brazil has conducted the Beach Monitoring Program in the Potiguar Basin (*Programa de Monitoramento de Praias da Bacia Potiguar* – PMP-BP). The PMP-BP is part of an environmental constraint compliance enforced by the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) over oil exploitation operated by PETROBRAS (Petróleo Brasileiro S.A.) (agreement number 2500.005657510.2).

Due to geomorphological features and enviromental characteristics, the monitoring area was divided into four stretches: (A) Grossos/RN - Icapuí/CE, (B) Areia Branca/RN - Porto do Mangue/RN, (C) Guamaré/RN - Macau/RN, and (D) Galinhos/RN - Caiçara do Norte/RN (Figure 1).

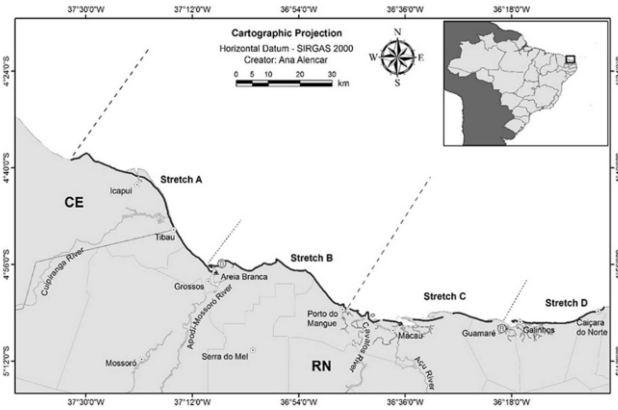

Figure 1. Location of the studied area, Potiguar Basin, northeastern Brazil.

Sample collection

Samples were obtained monthly for 12 months (January - December 2012) at the time of the drag. Trawl nets varied from 6 to 40 m long X 3 m wide, and were usually made of mono or braided nylon (also named "trammel"). Fishermen often use this type of trawl net to capture shrimp during the day, at an average depth of 1.5 m; however, other animals may also get caught, such as catfish, sauna, anchovy and other small fishes.

The studied specimens were stored in isothermal bags until arriving at the support base, where the fishes were photographed, fixed in 10% formalin, and preserved in 70% alcohol for further anatomical identification by experts and according to previous studies (MENEZES; FIGUEIREDO, 2000; SZPILMAN, 2000; JÚNIOR et al., 2010;). Biometric data (total length - TL, standard length - SL, total weight - TW, and gonadal weight - GW), sex, and stage of gonadal maturation were recorded.

The stages of gonadal maturation were classified as: immature, maturing and mature, considering the macro and microstructural aspects of the gonads and the mean values of the Gonadosomatic Index (IGS).

The gonadosomatic index (GSI) is an indicator of gonadal functional status represented by the percentage of the gonads in relationship to the body mass (GSI = GW/TW × 100) (WOOTTON et al., 1978). Maturation of germinative cells occurs simultaneously with the increase of GW (LE CREN, 1951), therefore, the GSI is a good reference of the reproductive activity of fish, and can be used to determine the stages of gonadal maturation (MADDOCK; BURTON, 1999).

Formalin-fixed gonadal tissue were routinely processed, sectioned at 5 μm, stained with hematoxylin and eosin, and examined under light microscopy in order to confirm the sex and stage of gonadal maturation by histological analysis. This procedure was carried out at the Laboratory of Vertebrate Morphophysiology, Morphology Department, Rio Grande do Norte Federal University (UFRN).

All procedures for the sample collection were approved by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) - Ministry of the Environment through the Biodiversity Information and Authorization System (SISBIO) number 13694-6, and Authorization and Information in Biodiversity (ABIO) number 615/2015.

Data analysis

The abundance in number of individuals and total biomass were analyzed according to the identified taxonomic groups. In addition, we calculated the seasonal distribution of species and their occurrence constancy during the studied year, according to the expression proposed by Dajoz (1978): C= n/N*100 (C= occurrence constancy; n= number of collections containing the species studied; N= total number of collections). The rainfall data for the study period was obtained from Proclima (Real-Time Climate Monitoring Program for the Northeast) (http://www6.cptec.inpe.br/proclima/ accessed 31 Jan 2013).

We analyzed the following community attributes according to the monitored stretches: abundance in number of specimens, total biomass, Shannon-Wiener diversity (H') (KREBS, 1989), Pielou's evenness (J) (PIELOU, 1989), and Margalef richness (d) (LUDWIG; REYNOLDS, 1988). The Chi-square test was performed to compare the stretches of studied area. In order to analyze faunal similarity among the four areas we performed a cluster analysis using the Jaccard coefficient.

The ratio of captured specimens according to their different reproductive phases (mature, maturing and immature), and the temporal distribution of gonadal maturation stages were also analyzed. The ANOVA variance was performed in order to evaluate the relationship between the GSI and the stage of gonadal maturation. The Levene's test revealed non-homogeneity among the groups, so a Welch F test followed by the Tukey test was employed. Significance level (alpha) was 0.05 for all tests. PAST version 2.14 and Statistica version 9.0 were used to process all data.

RESULTS

Ichthyofauna composition

A total of 1,426 individuals classified into 10 orders, 23 families, and 49 species of fish were captured (Table 1), with a total biomass of 33 kg.

Table 1. Seasonal distribution of the species and their Families, constancies of Occurrence (% C) and abundances in Percentage (PA).

Family	Especie	Numbers of voucher specimens	Months												%C	PA
			J	F	M	A	M	J	J	A	S	O	N	D		
Haemulidae	*Pomadasys corvinaeformis* (Steindachner, 1868)	UFRN 2440			X	X	X	X	X	X	X	X		X	81.8	29.66
Sciaenidae	*Menticirrhus littoralis* (Holbrook, 1847)	UFRN 2447	X		X	X	X	X	X	X	X	X			81.8	6.87
Carangidae	*Selene brownii* (Cuvier, 1816)	UFRN 2456	X		X	X	X	X	X	X	X	X			81.8	3.57
Sciaenidae	*Menticirrhus americanus* (Linnaeus, 1758)	UFRN 2452	X		X	X	X	X	X	X	X	X			81.8	1.26
Sciaenidae	*Larimus breviceps* (Cuvier, 1830)	UFRN 2469	X		X	X		X	X	X	X	X			72.7	9.04
Haemulidae	*Conodon nobilis* (Linnaeus, 1758)	UFRN 2451	X		X	X	X		X	X	X	X			72.7	6.52
Engraulidae	*Lycengraulis grossidens* (Spix & Agassiz, 1829)	UFRN 2435	X		X			X	X	X	X	X		X	72.7	3.64
Clupeidae	*Opisthonema oglinum* (Lesueur, 1818)	UFRN 2450			X		X	X	X	X	X	X			63.6	9.53
Ariidae	*Aspistor luniscutis* (Valenciennes, 1840)	UFRN 2434		X	X	X		X	X		X	X			63.6	3.56
Polynemidae	*Polydactylus virginicus* (Linnaeus, 1758)	UFRN 2453	X		X	X		X		X	X	X			63.6	1.96
Ariidae	*Bagre marinus* (Mitchill, 1815)	UFRN 2442				X	X		X	X	X	X			54.5	2.85
Tetraodontidae	*Sphoeroides testudineus* (Linnaeus, 1758)	UFRN 2473	X		X	X	X		X	X					54.5	2.38
Sciaenidae	*Macrodon ancylodon* (Bloch & Schneider, 1801)	UFRN 2437	X		X			X		X	X	X			54.5	1.68
Pristigasteridae	*Pellona harroweri* (Fowler, 1917)	UFRN 2439	X		X			X			X	X			45.4	4.90
Sciaenidae	*Stellifer stellifer* (Bloch, 1790)	UFRN 2474			X	X		X	X	X					45.4	1.19
Carangidae	*Chloroscombrus chrysurus* (Linnaeus, 1766)	UFRN 2457				X	X	X			X	X			45.4	0.49
Paralichthyidae	*Etropus crossotus* (Jordan & Gilbert, 1882)	UFRN 2438					X		X	X		X			36.4	0.56
Gerreidae	*Diapterus rhombeus* (Cuvier, 1829)	UFRN 2466	X		X			X		X					36.4	0.35
Carangidae	*Selene vomer* (Linnaeus, 1758)	UFRN 2463			X					X		X			27.3	0.91
Ephippidae	*Chaetodipterus faber* (Broussonet, 1782)	UFRN 2471	X		X							X			27.3	0.49
Gerreidae	*Eucinostomus argenteus* (Baird & Girard, 1855)	UFRN 2468							X			X		X	27.3	0.42
Tetraodontidae	*Lagocephalus laevigatus* (Linnaeus, 1766)	UFRN 2433			X					X		X			27.3	0.35

Cont.

Cont. **Table 1.** Seasonal distribution of the species and their Families, constancies of Occurrence (% C) and abundances in Percentage (PA).

Family	Especie	Numbers of voucher specimens	J	F	M	A	M	J	J	A	S	O	N	D	%C	PA
Cynoglossidae	*Symphurus plagusia* (Bloch & Schneider, 1801)	UFRN 2454					X		X	X					27.3	0.35
Ariidae	*Bagre bagre* (Linnaeus, 1766)	UFRN 2462			X	X									18.2	0.77
Gymnuridae	*Gymnura micrura* (Bloch & Scheneider, 1801)	UFRN 2458			X				X						18.2	0.56
Paralichthyidae	*Syacium micrurum* (Ranzani, 1842)	UFRN 2448								X				X	18.2	0.56
Clupeidae	*Chirocentrodon bleekerianus* (Poey, 1867)	UFRN 2475								X		X			18.2	0.49
Hemiramphidae	*Hemiramphus brasiliensis* (Linnaeus, 1758)	UFRN 2459	X											X	18.2	0.42
Triglidae	*Prionotus punctatus* (Bloch, 1793)	UFRN 2449								X		X			18.2	0.42
Scombridae	*Scomberomorus brasiliensis* (Collette, Russo & Zavala-Camin, 1978)	UFRN 2465							X	X					18.2	0.42
Dasyatidae	*Hypanus guttatus* (Bloch & Schneider, 1801)	UFRN 2472			X					X					18.2	0.28
Narcinidae	*Narcine* sp.	UFRN 2461						X							18.2	0.28
Paralichthyidae	*Syacium papillosum* (Linnaeus, 1758)	UFRN 2476			X							X			18.2	0.21
Haemulidae	*Genyatremus luteus* (Bloch, 1790)	UFRN 2464			X	X									18.2	0.14
Carangidae	*Trachinotus carolinus* (Linnaeus, 1766)	UFRN 2443								X		X			18.2	0.14
Sparidae	*Archosargus rhomboidalis* (Linnaeus, 1758)	UFRN 2477										X		X	18.2	0.07
Gerreidae	*Eucinostomus gula* (Quoy & Gaimard, 1824)	UFRN 2481												X	9.1	0.91
Haemulidae	*Haemulon steindachneri* (Jordan & Gilbert, 1882)	UFRN 2483	X												9.1	0.21
Carangidae	*Trachinotus falcatus* (Linnaeus, 1758)	UFRN 2478			X										9.1	0.21
Lutjanidae	*Ocyurus chrysurus* (Bloch, 1791)	UFRN 2445										X			9.1	0.14
Achiridae	*Trinectes paulistanus* (Miranda Ribeiro, 1915)	UFRN 2460					X								9.1	0.14
Gerreidae	*Eucinostomus melanopterus* (Bleeker, 1863)	UFRN 2468									X				9.1	0.14
Narcinidae	*Narcine bancrofti* (Griffith & Smith, 1834)	UFRN 2436				X									9.1	0.07
Lutjanidae	*Lutjanus alexandrei* (Moura & Lindeman, 2007)	UFRN 2441	X												9.1	0.07
Sciaenidae	*Micropogonias furnieri* (Desmarest, 1823)	UFRN 2480			X										9.1	0.07
Dasyatidae	*Hypanus marianae* (Gomes, Rosa & Gadig, 2000)	UFRN 2484								X					9.1	0.07
Rhinobatidae	*Pseudobatos percellens* (Walbaum, 1792)	UFRN 2455										X			9.1	0.07
Carangidae	*Caranx latus* (Agassiz, 1831)	UFRN 2482							X						9.1	0.07
Haemulidae	*Haemulon plumieri* (Lacepède, 1801)	UFRN 2479	X												9.1	0.07

The orders Perciformes (N=27) and Pleuronectiformes (N=5) represented 65% of the sampled species (Figure 2A), followed by Clupeiformes (N=4), Rajiformes (N=3), Siluriformes (N=3), Tetraodontiformes (N=2), Torpediniformes (N=2), Myliobatiformes (N=1), Scorpaeniformes (N=1) and Beloniformes (N=1).

The families Carangidae, Sciaenidae, Haemulidae, Gerreidae, Ariidae and Paralichthyidae were the most commonly observed; a total of 54% of the sampled species (Figure 2B).

The analysis of total abundance indicated that 67.6% of the sampled individuals were classified into Order Perciformes, including two of the most abundant species: *Larimus breviceps* (Cuvier, 1830) and *Pomadasys corvinaeformis* (Steindachner, 1868). Together, these two species represented 38.9% of all captured specimens (Figure 2C). In regards to biomass, the order Perciformes was the most prevalent (54.7%) (Figure 2D).

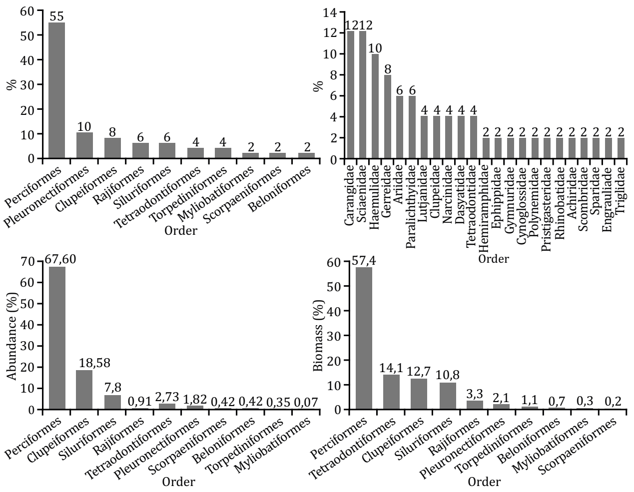

Figure 2. Animals caught in the Potiguar Basin, northeastern Brazil: (A) proportion of species (%) by taxonomic order; (B) proportion of species (%) by families; (C) numerical abundance, (D) total biomass.

The occurrence of the species discarded by shrimp trawling was distributed as accidental (54%), constant (27%) and accessory (19%), according to Dajoz (1978). Twelve species were captured only during the rainy season (January - July): *Caranx latus* (Agassiz, 1831), *Trachinotus falcatus* (Linnaeus, 1758), *Micropogonias furnieri* (Desmarest, 1823), *Genyatremus luteus* (Bloch, 1790), *Haemulon plumieri* (Lacepède, 1801), *Haemulon steindachneri* (Jordan & Gilbert, 1882), *Bagre bagre* (Linnaeus, 1766), *Lutjanus alexandrei* (Moura & Lindeman, 2007), *Narcine bancrofti* (Griffith & Smith, 1834), *Narcine* sp., *Gymnura micrura* (Bloch & Scheneider, 1801), and *Trinectes paulistanus* (Miranda Ribeiro, 1915); while ten species were captured solely during dry season (August - December): *Trachinotus carolinus* (Linnaeus, 1766), *Eucinostomus melanopterus* (Bleeker, 1863), *Eucinostomus gula* (Quoy & Gaimard, 1824), *Syacium micrurum* (Ranzani, 1842), *Ocyurus chrysurus* (Bloch, 1791), *Chirocentrodon bleekerianus* (Poey, 1867), *Hypanus marianae* (Gomes, Rosa & Gadig, 2000), *Pseudobatos percellens* (Walbaum, 1792), *Archosargus rhomboidalis* (Linnaeus, 1758), *Prionotus punctatus* (Bloch, 1793). In regards to species occurrence during rainy and dry season, the most prevalent were, respectively, *Opisthonema oglinum* (Lesueur, 1818), *P. corvinaeformis*, *L. breviceps* and *Pellona harroweri* (Fowler, 1917), and *P. corvinaeformis* and *Lycengraulis grossidens* (Spix & Agassiz, 1829) (Table 1).

The species occurrence was higher at Mel de Baixo, Porto do Mangue, Minhoto, and Caiçara do Norte beaches (Figure 3).

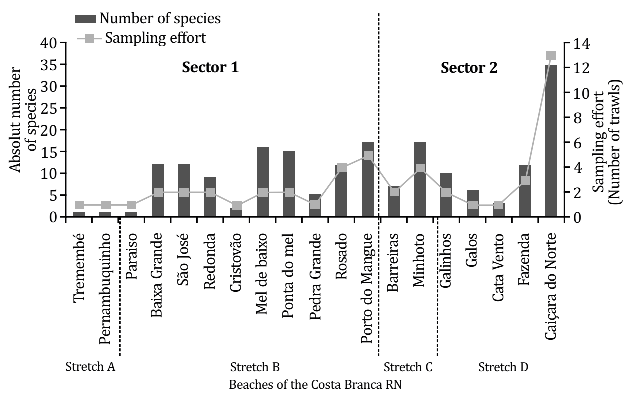

Figure 3. Distribution of occurrence of fish species in the Potiguar Basin, northeastern Brazil.

Analysis of the community attributes indicated that stretch "A" had the lowest values of abundance, biomass, diversity and richness, and the highest values of evenness and dominance among all four monitored area. Stretches "B" and "D" presented the highest abundance, biomass and richness values and "C" presented intermediate values in comparison to "B" and "D". Regarding Shannon diversity, the highest values were observed for stretches "B" and "C", followed by "D". The dominance variable values were higher for "A" and "D" due to the dominance of species *Aspistor luniscutis* (Valenciennes, 1840) and *P. corvinaeformis*, respectively. Variations were more discreet in terms of evenness, with the highest and lowest values for "A" and "D" stretches, respectively (Figure 4).

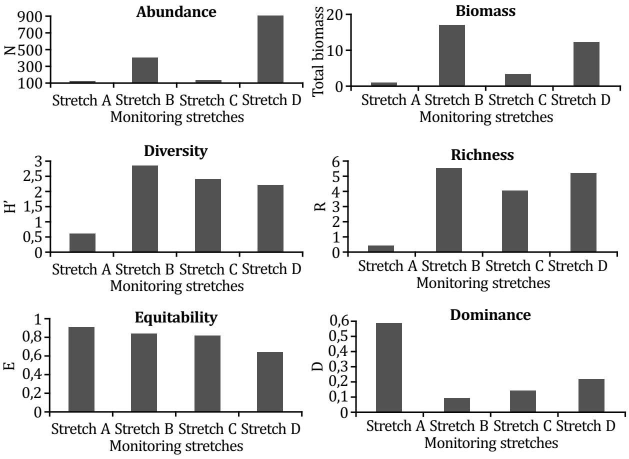

Figure 4. Total values (rainy and dry) of abundance, biomass, Shannon diversity, richness, evenness, and dominance in different stretches of monitoring in the Potiguar Basin, northeastern Brazil.

Faunal similarity along the monitored area could be divided into three groups: (I) found in stretches "B" and "D" and characterized by the presence of a greater number of species and abundance uniformity; (II) found in stretch "C", with an intermediate pattern between groups I and III, and greater similarity to group I; (III) found in stretch "A" and represented by two species (*A. luniscutis* and *Hemiramphus brasiliensis* Linnaeus, 1758); the former being the most abundant (Figure 5).

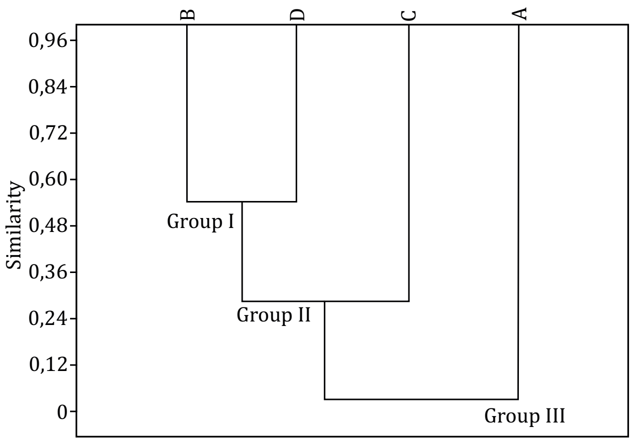

Figure 5. Dendogram of faunal similarity among four stretches of monitored area with presence and absence of species using the Jaccard coefficient.

Reproductive phase

The classification of sexual maturity was based on the macro and microstructural aspects of the gonads. We observed that 76.3% of the sampled specimens were classified as "immature". On the other hand, "maturing" and "mature" stages represented 16.7% and 7%, respectively. Species *Pellona harroweri*, *Larimus breviceps*, *Menticirrhus littoralis* (Holbrook, 1847) and *Pomadasys corvinaeformis* were the most captured. Considering these four species, we also observed a higher percentage of "immature" individuals (76.3%), followed by "maturing" and "mature" (18.9% and 4.8%, respectively). These results indicate that trawling captures predominantly "immature" individuals.

We observed an increase in the GSI values from "immature" to "mature" stage, and a significant difference between "mature" stage and "maturing" and "immature" stages. Levene's test indicated non-homogeneity among the groups (*P. harroweri*, p = 0.002391; *L. breviceps*, p = 0.719; *M. littoralis*, p = 1.029 × 10^{-5}; and *P. corvinaeformis*, p = 1.782 × 10^{-6}); however, the Welch F test demonstrated differences for *P. harroweri* (p = 0.02019), *L. breviceps* (p = 0.002744), and *P. corvinaeformis* (p = 0.0191). The Tukey test detected differences between immature and mature stages for *P. harroweri*: (p = 0.003922), *L. breviceps* (p = 0.007636), and *P. corvinaeformis* (p = 2.175 × 10^{-5}). These same species also presented differences between maturing and mature stages (p = 0.0186, p = 0.01, and p = 2.175 × 10^{-5}, respectively). Variations on these values were consistent with the stages of gonadal maturation (Figure 6).

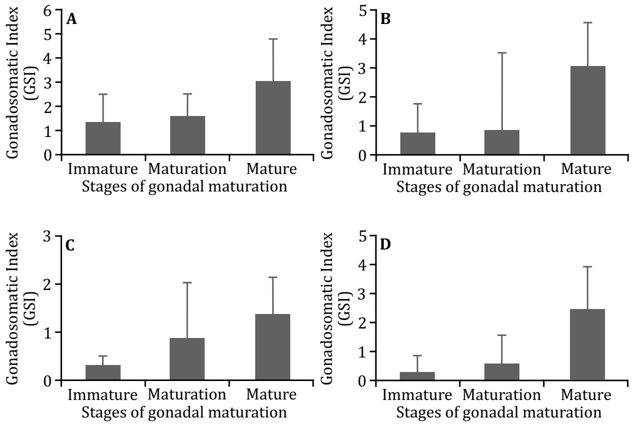

Figure 6. Gonadosomatic index (GSI) of stages of gonadal maturation: (A) *Pellona harroweri*; (B) *Larimus breviceps*; (C) *Menticirrhus littoralis*, (D) *Pomadasys corvinaeformis*.

Analysis of the sampled species and the period in which the study was conducted demonstrated that *P. harroweri* had the highest relative frequency of "mature" individuals (60%) in January. After this period, the occurrence of mature individuals decreased, and there was a simultaneous increase in the proportion of "maturing" and "immature" individuals, reaching 100% of "immature" individuals in September and October. Specimens identified as *L. breviceps* and *M. littoralis* were classified predominantly as "maturing" and "immature", and the highest relative frequency of "maturing" individuals was observed in the rainy season. For *P. corvinaeformis*, the relative frequency of "immature" individuals remained high throughout the studied period (Figure 7).

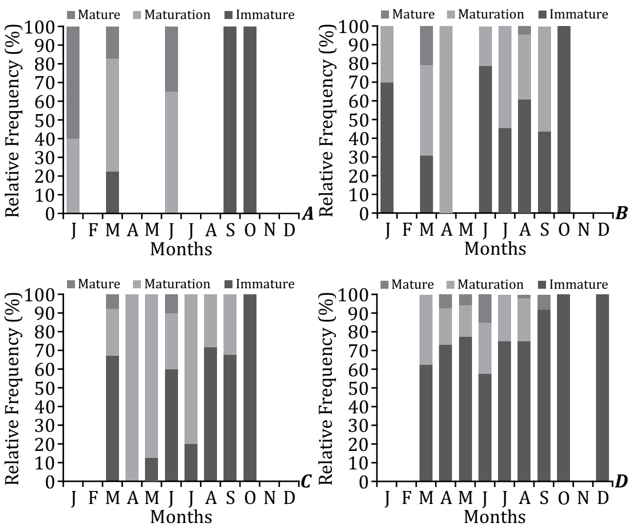

Figure 7. Temporal variation in the stages of gonadal maturation, from January to December 2012: (A) *Pellona harroweri*; (B) *Larimus breviceps*; (C) *Menticirrhus littoralis*, (D) *Pomadasys corvinaeformis*.

The average size at first maturity for each studied species was based on literature data (Table 2).

Table 2. Average size of first maturation for *Pellona harroweri*, *Larimus breviceps, Menticirrhus littoralis* and *Pomadasys corvinaeformis* captured as bycatch at Potiguar Basin beaches, northeastern, Brazil.

Species	L (50) (cm) according with references
Pellona harroweri	7 (SILVA-JÚNIOR et al., 2013)
Larimus breviceps	14 (SILVA-JÚNIOR et al., 2013)
Menticirrhus littoralis	23 (BRAUN; FONTOURA, 2004)
Pomadasys corvinaeformis	15,8 (SILVA-JÚNIOR et al., 2013)

In the discharges analyzed in this study, a higher proportion of *M. littoralis*, *P. corvinaeformis* and *L. breviceps* specimens, were captured before reach the average size and gonadal stage associated to the first maturity, presenting negative relation with fishing activity. On the other hand, the evaluation of size and gonadal tissue revealed that the most specimens of *Pellona harroweri* had already spawned at least once, and were positively related with fishing activity (Figure 8).

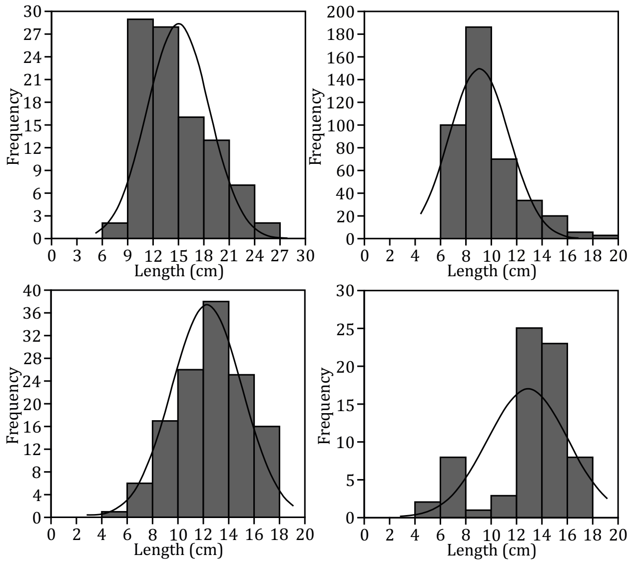

Figure 8. Proportion of specimens per class of total length (cm): (A) *Menticirrhus littoralis*; (B) *Pomadasys corvinaeformis*; (C) *Larimus brevicps*; (D) *Pellona harroweri*.

Discussion

Ichthyofauna composition

The diversity of fish species bycaught in the Potiguar Basin was higher than that found by Silva e Fonteles-Filho (2009) (18 species) for the same fishing category and region. Our data indicated that the sample size was adequate to represent the species occurring in the discarding of fish from trawl nets on the northwest coast of RN. Ninety-six species of fish were reported in this region (GARCIA, 2006). The number of species described in this study differed from an ichthyofaunistic survey conducted by Garcia (2006), possibly because various means of fishing devices (gill nets, seines, handlines, dip nets, cast nets, and trammel) and different sampled environments (estuaries and sandy beaches) were analyzed.

In regards to species composition, order Peciformes was the most commonly observed. Such finding may be due to the fact that this order represents half of the demersal teleostei occurring in Brazil, that along with Pleuronectiformes, Anguilliformes and Tetraodontiformes represent over 70% of the brazilian species (HAIMOVICI; KLIPPEL, 1999).

The most abundant families in terms of number of individuals were Haemulidae, Scianidae, Clupeidae and Ariidae. On the other hand, the most abundant families in number of species were Carangidae, Scianidae, Haemulidae, and Gerreidae.

Studies of the bio-ecological analysis of fish production in the northern coast of RN, recorded the families Haemulidae, Carangidae, Lutjanidae, Scianidae, Scombridae and Serranidae as the most abundant in number of species (31), of which 18 were considered discarded fish (bycatch) (SILVA; FONTELES-FILHO, 2009). Families registered in our study are in accordance with other studies carried out in different subtropical and tropical regions. Dantas et al., (2012) also found a similar pattern of composition and structure of demersal fish at the São Cristóvão Beach, Areia Branca, RN: families Scianidae, Ariidae, Carangidae, Engraulidae, Haemulidae and Pristigasteridae were the most representative in number of species and individuals.

It is difficult to compare species diversity and relative abundance in different areas due to habitat heterogeneity, changes in environmental variables, and fishing effort; however, it is evident that this coastal area is important in these species' life cycle. On the other hand, Guedes et al., (2005) reported a uniform ichthyofauna along the Brazilian coast in regards of families. Our results demonstrated that the number of species per family differed among previous studies due to variations among different samples and years. However, the most common families are often the same, especially in regards of family Scianidae.

The vast majority of species captured in this study presented low constancy, which has been observed in previous studies in the Potiguar Basin, as well as in other regions with similar characteristics. On the other hand, we verified a high constancy of occurrence and abundance for *Larimus breviceps*, *Pomadasys corvinaeformis*, *Opisthonema oglinum*, *Pellona harroweri*, *Conodon nobilis*, *Menticirrhus littoralis*, *Menticirrhus americanus*, *Lycengraulis grossidens* and *Selene brownii,* suggesting that their life cycles are connected to sandy beach ecosystems. The same pattern was previously described for *P. corvinaeformis*, *Cathorops spixii*, *Stellifer rastrifer*, *P. harroweri*, *Stellifer stellifer*, *Chirocentrodon bleekerianus*, *L. breviceps*, *M. americanus* and *C. nobilis* at the São Cristóvão Beach, Areia Branca, RN (DANTAS et al., 2012). In regards to seasonality, the rainy season (January-July) presented higher levels of species occurrence, which indicates major inputs of fish in coastal areas. During the rainy season, nutrient concentrations increase and there is a reduction of salinity, favoring primary productivity and higher trophic levels (THURMAN; TRUJILLO, 2008; FRÉDOU et al., 2009).

Fish assemblage differed among monitoring stretches (A, B, C, and D), with the highest value of abundance, biomass and indexes of richness and diversity in stretches "B", "C", and "D". Stretch "A" showed higher values for dominance and evenness. The most abundant species for stretches "B", "C", and "D" were *L. breviceps*, *P. harroweri*, *O. oglinum*, *P. corvinaeformis*, *M. littoralis*, and *C. nobilis*. According to Bomfim (2014), the analysis of gut content demonstrated that all these species are carnivorous, and feed especially on shrimp; except the last one, which presented a fish preference. These results indicate an abundance of such food items in the monitored stretches.

Unequal access to resources, such as food or space, or different levels of predation may lead to differences in fish species composition (HYNDES et al., 2003). Therefore, food availability promotes the distribution of the observed species in the three stretches (B, C, and D), which comprise a region where trawling is more common, and the geographical areas have the highest percentages of shrimp production by trawl nets. Total production accounts for 36.8%, 30.8%, and 28.8% respectively, according to the Operating Unit of Exploration and Production of Rio Grande do Norte and Ceará - UO-RNCE (2012).

In stretch "A", trawl net shrimp fishing is not as frequent as in other segments, and represented only 3.5% of shrimp production according to the Operating Unit of Exploration and Production of Rio Grande do Norte and Ceará - UO - RNCE (2012). Lobster and shellfish fishing is predominant in this monitored stretch.

The fishing panorama of stretch "A" seems to indicate a lower availability of shrimp in the region, leading to lower fish diversity, richness, abundance, and biomass. Thus, the fishing panorama could be an indicator of the availability of the main food source of fish accidentally caught by nets, which is reflects on community attributes and, consequently, in the distribution of fish species in the Potiguar Basin.

Reproductive phase

The factors that define the exploitation of a species relate directly to abundance and catchability, but also to life cycle characteristics. Researchers still question whether it is more harmful removing young specimens or adults in reproductive age from a population (SOUZA; CHAVES, 2007; DANTAS et al., 2012; FORREST et al., 2013). Regardless of the analyzed period and season, shrimp trawling will always affect some percentage of the reproductive individuals of a fish population. Studies that analyzed the accompanying ichthyofauna of shrimp fishing in the north coast of Santa Catarina state indicated that both situations occur with the same intensity (SOUZA; CHAVES, 2007). Our results showed that, throughout the study period, shrimping drag focused predominantly on immature individuals.

Species with late-maturation are highly vulnerable to extinction (JENNINGS et al., 2001; HUTCHINGS; REYNOLDS, 2004). Many specimens of *Menticirrhus littoralis*, *Pomadasys corvinaeformes* and *Larimus breviceps* were still juveniles when captured, before reaching the appropriate size and gonadal development associated with reproductive maturity, thus these species may possibly be considered negatively related with fishing activity. According to Silva-Junior et al., (2013), captured individuals that spawned at least once may be positively correlated with fishing activity, which was also observed in our results (e.g. *Pellona harroweri*), since a great proportion of the captured individuals were larger than they would be at first maturity. Studies at the São Cristóvão Beach, Areia Branca, RN reported similar results for *P. harroweri* and *P. corvinaeformis* (SILVA-JUNIOR et al., 2013).

Overfishing is defined by a greater number of captured organisms in comparison to the number of produced organisms (CORDUE, 2012). It is difficult fishery to reach equilibrium when the fishing effort is reduced during a short period after overexploitation (KING, 2007). A population may decline if the natural mortality rate, combined with the mortality caused by fishing, reduces inventory levels. This phenomenon could continue even after cessation of fishing (WOOTTON, 1989).

Commercial drag is typically performed in deep waters and farther offshore. However, in the Potiguar Basin, drag is performed in shallow waters and very close to the coast. Furthermore, the incidental capture of non-target species in this are in not sustainable because many organisms are caught before reaching their first maturity size. Among the species that had their reproductive stage studied, *P. corvinaeformes*, *M. littoralis* and *L. breviceps* were found to be negatively related to fishing activity, being therefore, even more vulnerable to shrimping trawl nets.

The removal of species from an ecosystem may lead to diversity loss and local extinction. According to Silva-Junior et al., (2013), non-target species that are accidentally caught during fishing can be classified as vulnerable. Therefore, shrimp fishing in the studied area threatens the ichthyofauna, especially estuarine species from families Carangidae and Scianidae.

Finally, the exploitation of this target resource (shrimp) has caused environmental and economical impact in the northwest coast of Rio Grande do Norte.

Conclusion

Our results indicate that the incidental capture of some non-target species can affects predominantly individuals considered immature, i.e. without reproductive potencial, an indicative of non-sustainable fishing in region. So, we highlight the need for collective efforts, including co-management among government, production sector and research institutes to find ways to solve this problem.

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