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Scientific Article

Long-term changes in a tropical coastal recreational fishery

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ABSTRACT

There is no functional reporting system for Brazilian recreational fisheries. This study aimed at identifying which species were caught during competitive fishing events promoted by the Pâmpano Esporte Clube in Rio Grande do Norte (northeastern Brazil) in 2009 to set a baseline for assessing future changes. Additionally, catch data for 1974–1994 were used to test two hypotheses: species composition changed over time; and the mean weight of each main species decreased over time. Seventy species or taxonomic units were caught in 2009. The highest numerical proportion was for *Haemulopsis corvinaeformis* (44.6%) and catfishes *Aspistor* sp. and *Sciades* sp. (14.3%). The highest proportion in weight was for *Aspistor* sp. and *Sciades* sp. (19.4%), followed by *H. corvinaeformis* (16.6%). *Haemulopsis corvinaeformis*'s abundance increased from the 1970s to 2009, which may be associated with the increasing number of trammel nets leading to decreasing abundance of other species except for *H. corvinaeformis* due to its burying behavior. Additionally, sharks were caught in the 1970s–1990s, but not in 2009. Mean weight decreased for the great pompano and pufferfishes during the same period and increased only for threadfins. Estuaries should not be used for competitive fishing events due to the high potential for juvenile capture.

Keywords: Sport fishery; Northeastern Brazil; Unregulated catch; Championship; Tournament; Rio Grande do Norte.

Mudanças de longo prazo em uma pesca amadora costeira tropical

RESUMO

Não há um sistema de registro funcional para pescarias amadoras brasileiras. Este estudo teve como objetivo identificar as espécies que foram capturadas durante os eventos de pesca competitiva promovidos pelo Pâmpano Esporte Clube no Rio Grande do Norte (nordeste do Brasil) em 2009 a fim de definir uma linha de base para avaliar futuras mudanças. Adicionalmente, dados de captura para 1974–1994 foram usados para testar duas hipóteses: a composição das espécies mudou ao longo do tempo; e o peso médio de cada espécie principal se alterou com o tempo. Setenta espécies ou grupos taxonômicos foram capturados em 2009. A mais elevada proporção numérica foi de *Haemulopsis corvinaeformis* (44,6%) e de bagres *Aspistor* sp. e *Sciades* sp. (14,3%). A maior proporção em peso foi de *Aspistor* sp. e *Sciades* sp. (19,4%), seguida de *H. corvinaeformis* (16,6%). A abundância de *H. corvinaeformis* aumentou da década de 1970 até 2009, o que pode estar associado ao aumento do número de redes de beira de praia, levando à diminuição de outras espécies, exceto de *H. corvinaeformis*, por causa do seu comportamento de enterrar-se. Além disso, tubarões foram capturados nas décadas de 1970–1990, mas não em 2009. O peso médio diminuiu para o pampo e os baiacus no mesmo período e aumentou apenas para os barbudos. Os estuários não devem ser utilizados para eventos competitivos em razão do elevado potencial para a captura de juvenis.

Palavras-chave: Pesca esportiva; Nordeste do Brasil; Captura não regulada; Campeonato; Torneio; Rio Grande do Norte.

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INTRODUCTION

Recreational fisheries have become one of the most popular leisure activities in the world. However, the participation rate varies among regions, with the highest being observed in northern Europe, Asia, United States of America, and Oceania (Arlinghaus et al., 2021). Recreational fisheries have been responsible for extracting about 0.9 million tonnes from marine waters worldwide (Freire et al., 2020a). However, we are still far from getting accurate estimates of total global extractions, as many countries do not have mandates for recording recreational fishery statistics. Indeed, the Food and Agriculture Organization of the United Nations recognizes this information deficit in poorly documented areas, mainly in developing countries (FAO, 2020).

Brazil is one of the countries that does not collect catch statistics from recreational fisheries. Isolated initiatives have been implemented (Freire et al., 2016), but they do not cover all habitats (fresh, estuarine, and marine waters), categories (underwater, boat-based, and shore-based), and types of activities (competitive events and daily activities). In northern Brazil, marine recreational fisheries are not very prevalent, but some information on species and catch in championships for the state of Pará has been obtained (Frédou et al., 2008). In southeastern Brazil, interest in understanding marine recreational fisheries is growing (Ramires et al., 2023), and some attempts have been made to quantify total extractions (Barcellini et al., 2013; Chiappani, 2006; Dal Negro et al., 2021; Motta et al., 2016). One of the major features of recreational fisheries in this region is its oceanic component, which has been studied since the 1990s (Amorim et al., 2009; Amorim & Silva, 2005; Arfelli et al., 1994; Mourato et al., 2016). In southern Brazil, studies on recreational fisheries started in the 1990s and have included boat-based and shore-based activities (Basaglia & Vieira, 2005; Lewis et al., 1999; Schork et al., 2010).

In northeastern Brazil, recreational fisheries are important in almost all nine states, but information is still scarce and restricted to the states of Maranhão, Rio Grande do Norte, Paraíba, Sergipe, and Bahia (Costa Nunes et al., 2012; Freire et al., 2017; Freire et al., 2018; Freire et al., 2020b; Santos et al., 2021). The state of Rio Grande do Norte has one of the oldest fishing clubs in Brazil (Pâmpano Esporte Clube, established in 1954) (Freire, 2010). This club has kept records of competitive fishing events since the 1970s. Freire (2005) analyzed these data for the first time and documented a decreasing trend in the size of the largest fish caught. Results of these fishing events were usually registered as total number and weight of fishes caught per recreational fisher in each event, as well as the common name and weight of the largest fish. However, there was no register of the species caught for most of the years. Competitive events represent opportunities to collect data on recreational fisheries (Boucek et al., 2023; Schramm Jr. et al., 1991), but differences in fishing activities related or not to competitive events should be considered in all analyses of recreational fisheries (Freire & Rocha, 2021; Wilde et al., 1998).

This study aimed at identifying the species caught in competitive fishing events promoted by the Pâmpano Esporte Clube, in the state of Rio Grande do Norte, and at assessing the main factors influencing species composition, to set a baseline for future studies. Additionally, we tested two hypotheses: that species composition changed over time; and that the mean weight of each main species decreased over time.

MATERIAL AND METHODS

The identification of the species caught by recreational fishers along the coast of the state of Rio Grande do Norte was performed after attending 16 competitive fishing events promoted by the Pâmpano Esporte Clube (PEC) in 2009 (Table 1). Two of these events were not considered here, Torneio das Crianças (participants were only children) and Torneio do Mamarrei (only one species targeted), due to their peculiar characteristics. Each event was classified into heavy (*barra pesada*), in which only specimens heavier than 100 g were counted and weighed to compose the score of each fisher or team, or light (*barra leve*), in which all specimens were valid. Each event occurred on a different estuary or beach in Rio Grande of Norte (Fig. 1).

After each event, our team counted and weighed all specimens of each species together, which were reported under the common name informed. We selected a random sample from each species and took it to the Laboratório de Biologia Pesqueira (LABIPE) at the Universidade Federal do Rio Grande do Norte (UFRN), where we identified each specimen into the lowest possible taxonomic level. The family organization followed Nelson et al. (2016). Whenever the same common name was used for different species, this set was considered a taxonomic unit (T.U.). Total length (TL; cm) was measured in each specimen using an ichthyometer (precision = 1 mm) and total weight (TW; g) using an electronic scale (precision = 0.01 g). The sex and maturity were defined through a macroscopic analysis of the gonads (Vazzoler, 1996). The size at first maturity (L_m) was estimated for the species with the highest abundance using a logistic equation (Eq. 1):

$$p = 100 / [1 + \exp(a + bTL)] \quad (1)$$

Where: p: percentage of mature individuals at each length class; TL: total length (cm); a and b: parameters of the curve (Sparre & Venema, 1998).

Table 1. Competitive fishing events promoted along the coast of the state of Rio Grande do Norte, Brazil, by the Pâmpano Esporte Clube (PEC) in 2009.

Event	Date	Hour	Local	C/S/Ha
1. Barra Pesada do PEC (1st.R)	03/08/2009	6:00–10:00	Avenida Circular	H/Ra/RB
2. Barra Leve do PEC (1st.R)	03/22/2009	7:00–10:30	Guia Corrente	L/Ra/Est
3. Barra Leve do PEC (2nd.R)	04/05/2009	7:00–10:30	Passarela do Forte	L/Ra/Est
4. Barra Leve do PEC (3rd.R)	04/19/2009	7:30–11:00	Praia de Muriú	L/Ra/SB
5. Barra Leve do PEC (4th.R)	05/01/2009	13:30–17:00	Galinhos	L/Ra/SB
6. Barra Pesada do PEC (2nd.R)	05/02/2009	7:00–11:00	Galinhos	H/Ra/SB
7. Aniversário do PEC (55 anos)	05/17/2009	7:00–11:00	Mar e Sol/Natal	H/Ra/RB[1]
8. Barra Pesada do PEC (3rd.R)	06/07/2009	8:30–12:30	Barra de Cunhaú	H/Ra/MSR
9. Casais do PEC	06/11/2009	8:00–11:30	Genipabu	L/Ra/SB
10. Barra Leve do PEC (5th.R)	07/19/2009	8:00–11:30	Barra de Maxaranguape	L/Ra/MSR
11. Barra Pesada do PEC (4th.R)	08/16/2009	9:00–13:00	Praia de Sagi	H/Dr/SB
12. Barra Pesada do PEC (5th.R)	09/20/2009	8:30–12:30	Tibau do Sul	H/Dr/SB
Crianças[2] (Children)	10/11/2009	8:30–10:00	Redinha Velha	Pindaúba
Mamarrei[2]	10/25/2009	7:00–11:00	Redinha Velha	Pindaúba
13. Encerramento	11/15/2009	7:00–11:00	Avenida Circular	H/Dr/RB
14. Padroeira	11/21/2009	7:00–11:00	Pedra do Rosário	H/Dr/Est

[1]Locally known as "fiel de balança"; [2]not considered in the analyses here; R: round (first to fifth); C: categories [H: heavy (*pesada*) and L: light (*leve*)]; S: season: Ra: rainy; Dr: dry; Ha: habitat; RB: rocky beach; Est: estuary; SB: sandy beach; MSR: muddy, sandy, and rocky beach.

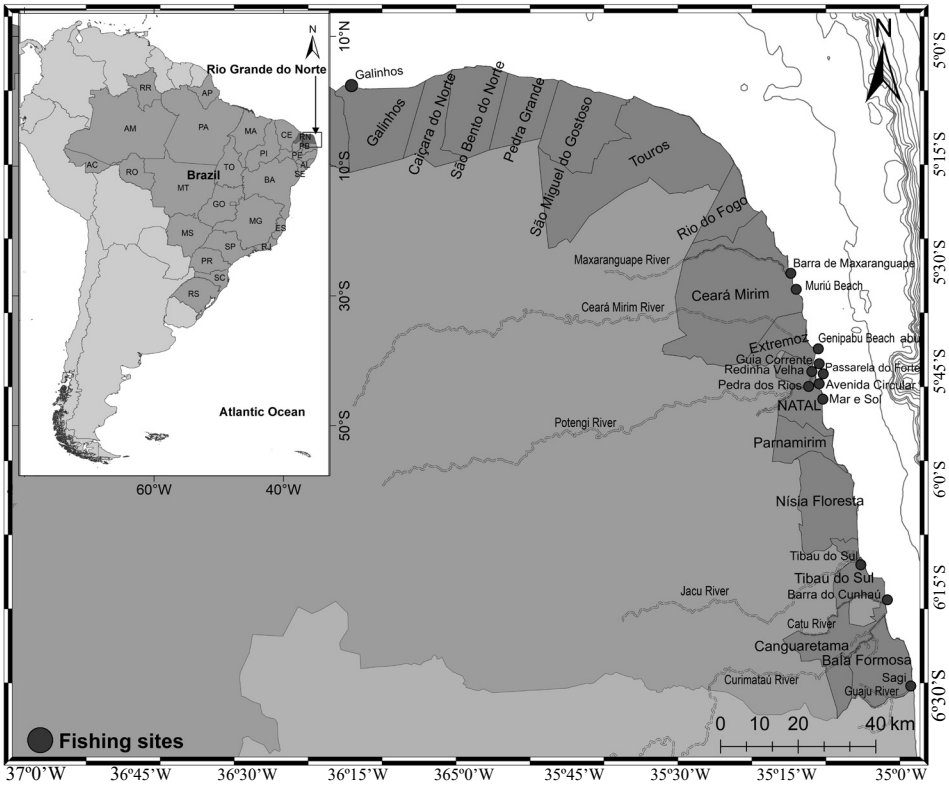

Figure 1. Map of the state of Rio Grande do Norte, Brazil, indicating all localities where competitive fishing events were promoted by Pâmpano Esporte Clube in 2009.

Abundance and weight data were assessed in relation to the following factors: fishing category (heavy and light), season (rainy and dry), and habitat (rocky beach, sandy beach, estuary, and muddy, sandy and rocky beach). The definition of seasons (rainy and dry) was based on monthly rainfall data from the National Oceanic and Atmospheric Administration (NOAA) for 1978 to 2020. Abundance and weight data were standardized in relation to the total for each factor used in this analysis by the proportion of the total. For the estimation of individual mean weight, the total weight and number of specimens caught for each competitive event were used. Data normality and homoscedasticity were tested using the Shapiro-Wilk and Levene tests, respectively. Whenever these hypotheses were rejected, non-parametric tests were used to test for significant differences: Mann-Whitney for differences in mean individual weight between fishing category and season, and Kruskal-Wallis for differences among habitats. The representativeness of abundance and weight of each species or taxonomic unit per fishing category or season was assessed using the Wilcoxon test. For habitats, the Friedman test was used, followed by a *post-hoc* Wilcoxon test with the Bonferroni correction whenever a statistical difference was detected. Non-hierarchical clustering analyses were conducted using the between-group average linkage function (UPGMA) and the Chord distance (Conde & Domínguez, 2018; Grimm, 1987; Khachumov, 2012; Legendre & Borcard, 2018; Romesburg, 1984).

The similarity in composition was evaluated using the Jaccard index (Chung et al., 2019; Jaccard, 1912; Koeneman & Cavanaugh, 2022). A canonical correspondence analysis (CCA) was performed using the original abundance data for each species/T.U. by fishing category, season, and habitat. The definition of the groups was carried out based on a cluster analysis, using the score values of the two main CCA axes.

For the analysis of long-term trends, catch data per recreational fisher were used, provided by the Pâmpano Esporte Clube from 1974 to 1994. Only events for which catch per species (registered by common name) was available were included (more recent events did not register catch per species, but only the total weight and the number of fishes caught per fisher). It is worth pointing out that this is the only club in northeastern Brazil that kept results per species for coastal events, but this ended in 1994. Due to the incompleteness of the data coverage (the result of each event was not available in all years), all data for the 1970s were combined, as well as the 1980s and 1990s. A cluster analysis was performed with the standardized abundance for these three decades and for the different habitat types: estuary, muddy, sandy and rocky beach, rocky beach, and sandy beach. The weight caught for each species was registered for the total number of specimens caught for each species. In order to obtain the individual weight of each species and to test the hypothesis of temporal changes, we had to select those cases for which only one specimen per species was caught by fisher. For this analysis, we used the *lineplot.CI* function of the library 'sciplot' in R. All analyses were performed using an $\alpha = 5\%$ in PAST 4.0 (Hammer et al., 2001) or R 4.1.1. (R Core Team, 2021).

RESULTS

General characteristics of the 2009 competitive fishing events

Most of the competitive events (71.4%) promoted by the Pâmpano Esporte Clube along the coast of Rio Grande do Norte in 2009 occurred during the rainy season (January to July) and in sandy beaches (42.9%), belonging mainly to the heavy category (57.1%) (Table 1). A total of 6,373 fish specimens was caught in all 14 events considered in this analysis, totaling about 317 kg. The mean number of specimens caught per event was 455.2 (22.7 kg). As the mean number of recreational fishers per event was 34.1, the mean number of fishes caught per fisher in each event was 12.9 (700.4 g; Table 2). The mean richness per event was 19.7 species/T.U. (Table 2). The mean number of fishers was 36.6 during the rainy season (January to August) and 27.8 during the dry season (September to December) (Table 2). The mean abundance during the rainy season was 576.5 fishes/event (23.4 kg), and 152.0 fishes/event (20.9 kg) during the dry season. Mean catch per fisher during the rainy season was 15.7 (669.5 g) and 5.8 (777.5 g) fishes/event during the dry season (Table 2).

A total of 76 common names was registered, associated with 53 species and 14 T.U. (17 species), totaling at least 70 species of 33 families (Table 3). The highest numerical proportion was for coró-branco, *Haemulopsis corvinaeformis* (44.6%), and the taxonomic unit bagre-branco (14.3%), represented by *Aspistor* sp. and *Sciades* sp. On the other hand, the highest proportion of weight was for *Aspistor* sp. and *Sciades* sp. (19.4%), and *H. corvinaeformis* (16.6%) (Table 3). There were enough specimens to estimate the size at first maturity (L_m) only for females of *H. corvinaeformis*: 13.5 cm TL (Fig. 2). Thus, 81% of all females were below the L_m of 13.5 cm estimated here, or 60% if a L_m of 10.4 cm TL, also estimated for the state of Rio Grande do Norte, was considered (Medeiros e Silva et al., 2012).

The highest mean individual weight was represented by *Hypanus* spp. (arraia; 906.3 g), followed by *Lagocephalus laevigatus*

Table 2. Competitive fishing events (1–14; see also Table 1) taking place in the state of Rio Grande do Norte, Brazil, in 2009, number of species or taxonomic units (T.U.) caught, abundance and weight of fishes, mean weight/fish, number of recreational fishers, abundance/fisher (A/F), and weight/fisher (W/F).

Event	Number of species/T.U.	Abundance (A)	Weight (W; kg)	Mean weight/ fish (g)	Number of fishers	A/F	W/F (g)
1	29	185	21.8	117.8	44	4.20	495.3
2	12	1762	24.2	13.8	41	42.98	591.0
3	25	900	14.3	15.9	38	23.68	376.4
4	16	907	23.7	26.1	37	24.51	640.3
5	13	849	32.2	37.9	32	26.53	1,006.5
6	24	293	63.9	218.0	32	9.16	1,995.8
7	21	212	11.4	53.8	49	4.33	232.8
8	19	151	15.1	99.9	34	4.44	443.9
9	18	348	19.2	55.1	30	11.60	638.8
10	13	158	8.0	50.4	29	5.45	274.3
11	11	69	6.3	92.0	29	2.38	218.9
12	25	291	31.7	109.1	24	12.12	1,322.8
13	27	93	13.2	142.1	29	3.21	455.8
14	23	155	32.3	208.1	29	5.34	1,112.5

Table 3. Common name (*taxonomic unit–T.U.), family, scientific name/T.U., acronomy of species/T.U. (Acr.), abundance (A%), weight (W%), average weight (mean ± standard deviation), and number of fishes (n). Organized by alphabetical order of families.

Common name	Family Scientific name/T.U.	Acr.	A%	W%	Average weight (g)	N
	Albulidae/Elopidae					
Ubarana*	*Albula* spp. and *Elops* sp.	AE	0.188	0.518	142.6 ± 111.2	13
	Ariidae					
Bagre-branco*	*Aspistor* sp. and *Sciades* sp.	AS	14.295	19.361	67.1 ± 81.9	910
Bagre-fita	*Bagre filamentosus*	Bf	0.690	1.897	136.8 ± 106.7	44
Bagre-amarelo*	*Cathorops* spp.	Ca	2.495	4.384	87.5 ± 80.5	159
Bagre*	*Notarius* sp. and *Sciades* sp.	NS	0.063	0.066	52.0 ± 24.2	4
	Atherinopsidae					
Peixe-rei	*Atherinella brasiliensis*	Ab	0.235	0.040	8.4 ± 2.9	15
	Batrachoididae					
Pacamon	*Amphichthys cryptocentrus*	Ac	0.016	0.177	563	1
	Blenniidae					
Moré-cachorro	*Scartella cristata*	Sc	0.047	0.004	4.1 ± 1.1	3
	Carangidae					
Garacimbora	*Caranx crysos*	Cc	0.157	0.320	101.5 ± 2.3	10
Xaréu/Guarajuba	*Caranx hippos*	Ch	0.455	1.153	126.1 ± 95.4	29
Xarelete	*Caranx latus*	Cl	0.126	0.079	31.5 ± 21.2	8
Palombeta/Garapau	*Chloroscombrus chrysurus*	Cy	0.220	0.331	75.0 ± 36.7	14
Tibiro*	*Oligoplites* spp.	OS	0.126	0.146	57.9 ± 57.7	8
Peixe-galo	*Selene vomer*	Sv	0.047	0.289	306.0 ± 31.2	3
Pampo/Garabebéu	*Trachinotus carolinus*	Tc	0.659	1.728	130.5 ± 167.4	42
Pampo-sernambiquara	*Trachinotus falcatus*	Tf	0.031	0.006	9.5 ± 4.8	2
Aracanguira/Aratobaia	*Trachinotus goodei*	Tg	3.154	1.843	29.1 ± 22.4	201

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Common name	Family Scientific name/T.U.	Acr.	A%	W%	Average weight (g)	N
	Centropomidae					
Camurim/Robalo*	*Centropomus* spp.	Ce	0.063	0.350	277.8 ± 162.6	4
	Dorosomatidae					
Sardinha	*Harengula clupeola*	Hd	0.016	0.003	8	1
	Dasyatidae					
Arraia*	*Hypanus* spp.	Hy	0.502	9.141	906.3 ± 322.2	32
	Echeneidae					
Piolho-de-cação	*Echeneis naucrates*	Ec	0.063	0.076	60.5 ± 28.2	4
	Engraulidae					
Arenque*	Engraulidae spp.	AA	7.202	1.751	12.0 ± 2.0	459
	Ephippidae					
Paru/Enxada	*Chaetodipterus faber*	Cf	0.267	2.768	516.6 ± 142.1	17
	Gerreidae					
Carapeba	*Diapterus auratus*	Da	0.502	1.915	189.9 ± 158.4	32
Carapicu-preto*	*Eucinostomus* spp.	ES	2.997	1.277	21.2 ± 3.9	191
Carapicu-branco	*Eucinostomus melanopterus*	Em	1.459	0,630	21.5 ± 5.2	93
	Haemulidae					
Pirambu	*Anisotremus surinamensis*	Au	1.663	2.328	69.6 ± 44.1	106
Mercador	*Anisotremus virginicus*	Av	0.031	0.017	27.5 ± 19.1	2
Coró amarelo/Roncador	*Conodon nobilis*	Cn	3.515	2.425	34.4 ± 9.3	224
Sanhoá	*Genyatremus luteus*	Gl	0.267	1.243	231.9 ± 51.6	17
Cambuba*	*Haemulon* spp.	HS	0.486	0.190	19.5 ± 52.2	31
Biquara	*Haemulon plumierii*	Hp	0.031	0.010	16.5 ± 9.2	2
Coró-branco	*Haemulopsis corvinaeformis*	Ho	44.563	16.601	18.6 ± 10.2	2840
Xira/Sapuruna	*Orthopristis scapularis*	Or	0.220	0.207	46.9 ± 45.6	14
Zumbi	*Paranisotremus moricandi*	Pm	0.220	0.424	96.1 ± 32.3	14
	Holocentridae					
Mariquita	*Holocentrus adscensionis*	Ha	0.016	0.022	69	1
	Labridae					
Budião-arara	*Bodianus pulchellus*	Bp	0.031	0.074	117.0 ± 60.8	2
	Labrisomidae					
Moré-de-pedra*	*Labrisomus* spp.	LS	0.439	0.136	15.5 ± 7.9	28
	Lutjanidae					
Cioba	*Lutjanus analis*	La	0.455	0.614	67.2 ± 88.8	29
Caranha	*Lutjanus cyanopterus*	Lc	0.031	0.043	67.5 ± 62.9	2
Dentão	*Lutjanus jocu*	Lj	0.063	0.244	193.8 ± 137.5	4
Ariocó	*Lutjanus synagris*	Ly	0.816	0.109	6.6 ± 8.1	52
Guaiúba	*Ocyurus chrysurus*	Ou	0.016	0.001	40	1
	Megalopidae					
Camurupim	*Megalops atlanticus*	Ma	0.016	0.922	2926	1
	Muraenidae					
Moreia*	*Gymnothorax* spp.	GS	0.267	1.711	319.4 ± 422.9	17
	Ophichthidae					
Muriongo	*Ophichthus cylindroideus*	Oc	0.063	0.213	169.0 ± 214.0	4
	Paralichthyidae					
Linguado	*Citharichthys arenaceus*	Ct	0.016	0.010	31	1
	Polynemidae					
Barbudo*	*Polydactylus* spp.	PS	3.656	4.759	64.8 ± 36.4	233
	Pomacentridae					
Saberé	*Abudefduf saxatilis*	Ax	0.016	0.002	6.0	1
Maria-preta	*Stegastes fuscus*	Su	0.016	0.009	29.0	1

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Common name	Family Scientific name/T.U.	Acr.	A%	W%	Average weight (g)	N
	Scaridae					
Budião	*Sparisoma axillare*	Sx	0.016	0.025	79.0	1
	Sciaenidae					
Espinho-duro	*Bairdiella goeldi*	Bg	0.063	0.123	97.2 ± 0.2	4
Cururuca	*Micropogonias furnieri*	Mf	0.063	0.115	91.2 ± 45.6	4
Judeu*	*Menticirrhus* spp.	MS	3.593	5.829	80.8 ± 25.4	229
Corvina-preta	*Stellifer brasiliensis*	Sb	0.016	0.020	64	1
Pescada-branca	*Stellifer gomezi*	Sg	0.031	0.013	21.1 ± 9.9	2
Corvina	*Stellifer punctatissimus*	Sp	0.377	0.100	13.2 ± 2.2	24
	Scorpaenidae					
Beatriz	*Scorpaena plumieri*	Sl	0.016	0.043	138.0	1
	Epinephelidae					
Garoupa	*Alphestes afer*	Aa	0.016	0.073	231.0	1
	Serranidae					
Sirigado	*Serranus flaviventris*	Sf	0.016	0.004	14.0	1
	Sparidae					
Pena	*Archosargus probatocephalus*	Ap	0.031	0.072	230.0 ± 0.01	2
Salema	*Archosargus rhomboidalis*	Ar	0.204	0.986	240.7 ± 238.5	13
	Synodontidae					
Traíra-de-água-salgada	*Trachinocephalus myops*	Tm	0.031	0.003	4.5 ± 2.2	2
	Tetraodontidae					
Baiacu-arara	*Lagocephalus laevigatus*	Ll	0.063	0.745	591.2 ± 865.2	4
Baiacu-garajuba	*Sphoeroides psittacus*	Sps	0.314	4.678	742.2 ± 164.3	20
Baiacu	*Sphoeroides testudineus*	St	2.056	4.459	108.0 ± 72.5	131
	Triglidae					
Voador-de-rio	*Prionotus punctatus*	Pp	0.110	0.144	65.1 ± 34.4	7

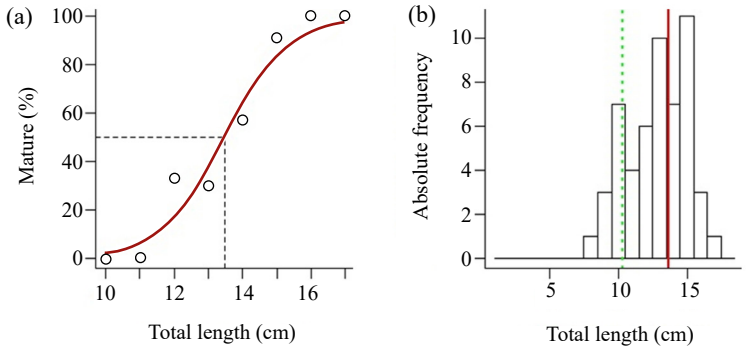

Figure 2. Populational structure for females of *Haemulopsis corvinaeformis* estimated based on competitive fishing events taking place in the state of Rio Grande do Norte, Brazil, in 2009: (a) size at first maturity (L_m) and (b) length distribution. Vertical colored lines indicate L_m values = 10.4 cm total length for Medeiros e Silva et al. (2012) (green dotted) and 13.7 cm total length for this study (red continuous).

(baiacu-arara; 591.2 g) (Table 3). For light events, the mean individual weight was 33.2 g, which was significantly lower than in heavy events (130.6 g) (Fig. 3; Mann-Whitney: U = 1; z = - 2.905; p = 0.004). Results by season showed higher mean individual weight during the dry season (137.8 g) than the rainy season (68.9 g), even though the Mann-Whitney test was not able to detect statistical difference (Fig. 3; Mann-Whitney: U = 7; z = - 1.768; p = 0.077). The highest mean individual weight was observed in rocky beaches (104.6 g), followed by sandy beaches (89.7 g), estuary (79.3 g), and muddy, sandy, and rocky beach (75.1 g), but no statistically significant difference was found (Fig. 3; Kruskal-Wallis: χ^2 = 1.648; p = 0.649).

The mean number of fishers per fishing event was similar between categories: 34.5 and 33.8 fishers in light and heavy events, respectively (Table 2). Heavy events had higher mean richness of species/T.U. (22.4) than light events (16.2). The mean abundance was 820.7 fishes (20.3 kg) per light event and 181.1 fishes (24.5 kg) per heavy event (Fig. 3). Mean catch per fisher was 22.5 fishes (587.9 g) per light event and 5.6 fishes (784.7 kg) per heavy event. In light events, 33 species and 12 T.U. were identified, while in heavy events 43 species and 13 T.U. were identified, with high similarity in taxonomic composition (50.8%).

The species/T.U. with the highest abundance in light events were *H. corvinaeformis* (53.3%), and *Aspistor* sp. and *Sciades* sp. (15.0%). In heavy events, the most abundant species/T.U. were: *H. corvinaeformis* (15.0%), *Aspistor* sp. and *Sciades* sp. (11.9%), *Trachinotus goodei* (11.9%), and *Polydactylus* spp. (8.1%), with the abundance of species/T.U. statistically different between categories (W = 1,759; z = 3.874; $p < 0.001$). In terms of weight, *H. corvinaeformis* (33.4%), and *Aspistor* sp. and *Sciades* sp. (22.2%) were the most represented in light events, whereas *Aspistor* sp. and *Sciades* sp. (17.6%), *Hypanus* spp. (14.8%), and *Cathorops* spp. (7.6%) were more common in heavy events, with statistical difference between categories (W = 1552; z = 2.5799; $p = 0.010$).

The most abundant species/T.U. during the rainy season were *H. corvinaeformis*, *Aspistor* sp., *Sciades* sp., and *Cathorops* spp., and, during the dry season, *T. goodei*, *Aspistor* sp., *Sciades* sp. and *Polydactylus* spp. However, the Wilcoxon test did not detect significant difference (W = 1,369; z = 1.437; $p = 0.151$). In terms of weight, the most important species/T.U. during the rainy season were *Aspistor* sp., *Sciades* sp., *H. corvinaeformis,* and *Hypanus* spp., and, during the dry season, *Sphoeroides psittacus*, *Cathorops* spp., *Aspistor* sp., *Sciades* sp., and *Sphoeroides testudineus*. Similarly, no statistical difference was found (W = 1154; z = 0.0937; $p = 0.926$).

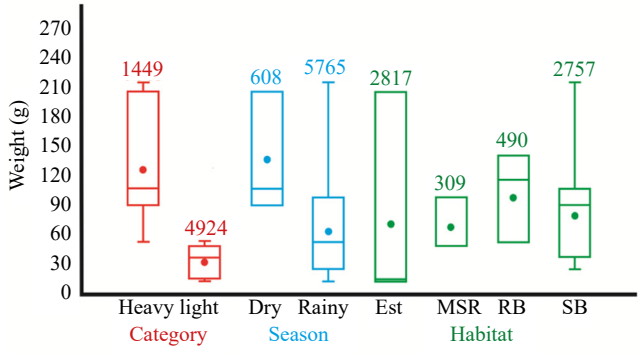

Figure 3. Mean individual weight by fishing category (heavy and light), season (dry and rainy), and habitat (Est: estuary; MSR: muddy, sandy, and rocky beach; RB: rocky beach; SB: sandy beach). Dots are mean values and numbers on the boxes are number of fishes.

Rocky beaches presented the highest mean richness per competitive event (25.7 species/T.U.), followed by estuary (20.0), sandy beaches (17.8), and muddy, sandy, and rocky beach (MSR) (16.0) (Table 2). The total number of species/T.U. caught in estuaries was 43, followed by 42 in sandy beaches, 40 in rocky beaches, and 25 in MSR. The similarity in taxonomic composition was low (< 50.0%), with the highest value observed between sandy beach and estuary (49.1%), and the lowest between estuary and MSR (36.0%). The highest catch in number for all events combined was observed in estuaries, followed by sandy beaches, rocky beaches, and MSR (Table 2). The highest mean catch in number per fisher in each event was higher in estuaries (24.0 fishes; 0.7 kg) than in sandy beaches (14.4 fishes; 1.0 kg), MSR (4.9 fishes; 0.4 kg), and rocky beaches (3.9 fishes; 0.4 kg) (Table 2). The highest abundance was for *H. corvinaeformis* and Engraulidae in estuaries, *H. corvinaeformis*, *Aspistor* sp., and *Sciades* sp. in sandy beaches, *H. corvinaeformis*, *Anisotremus surinamensis*, and *Polydactylus* spp. in rocky beaches, and *Polydactylus* spp., *T. goodei*, and *Cathorops* spp. in MSR. The abundance among habitats was statistically different (Friedman: $\chi^2 = 7.137$; $p = 0.036$), with the difference identified using the Wilcoxon test with the Bonferroni correction between rocky beaches and estuaries ($p = 0.001$) and rocky and sandy beaches ($p = 0.005$). The cluster analysis identified higher similarity between rocky beaches and estuaries, and lower similarity between MSR and the other habitats (Fig. 4a). The cluster analysis identified the highest similarity of taxonomic composition between rocky beaches and MSR, and the lowest between estuaries and other habitats (Fig. 4b).

Long-term changes in results of competitive events

Based on all historical results of competitive fishing events available at the Pâmpano Esporte Clube, 57 taxonomic units (T.U.) were caught in 1974–1994. From 1995 onwards, no result was reported by species by the Pâmpano Esporte Clube until 2023 (at least). The number of T.U. per year ranged from six to 37, with a mean value of 23. Due to the highest sampling representativeness during the 1980s (nine years), followed by the 1990s (five years), and the 1970s (four years), the richness of T.U. was higher in the 1980s (49 T.U.), followed by the 1990s (43 T.U.) and the 1970s (38 T.U.). The same pattern was observed for abundance, with the highest value observed in the 1980s (2,734 fishes), followed by the 1990s (1,092 fishes) and the 1970s (687 specimens).

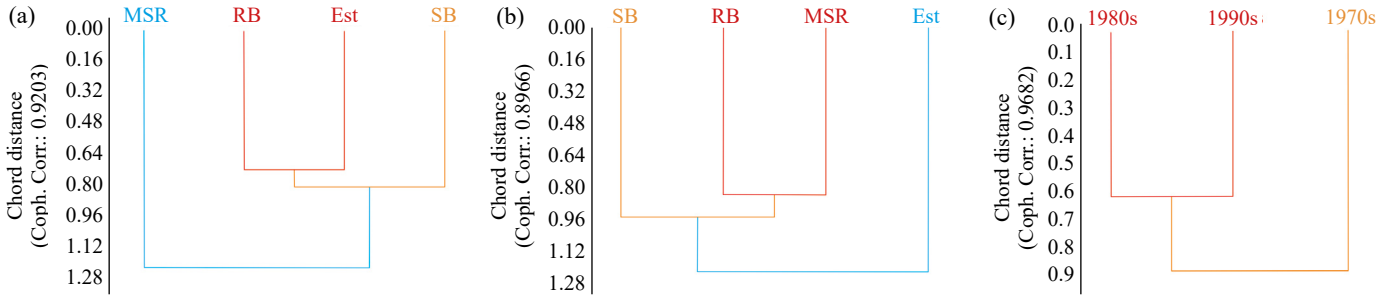

Figure 4. Cluster analysis showing the groups formed based on the proportion of species and taxonomic units (T.U.) in (a) number and (b) weight by type of habitat (Est: estuary, MSR: muddy, sandy, and rocky beach, RB: rocky beach, SB: sandy beach), and (c) based on numerical representativeness of T.U. in the 1970s, 1980s, and 1990s (no weight data available by T.U. for these decades).

The T.U. with the highest abundance (> 1%) during the three decades were: coró (15.0%), bagre (8.3%), moreia (7.9%), barbudo (7.4%), garajuba/xaréu (6.8%), garapau/palombeta (6.0%), aracanguira/aratobaia (5.9%), garabebéu/pampo (4.8%), judeu (4.7%), baiacu (3.2%), pirambu (3.1%), zumbi (3.1%), ubarana (2.7%), arraia (2.3%), moré (1.5%), and carapicu (1.3%). The representativeness of the T.U. did not present statistical difference among the three decades according to the Friedman test ($\chi^2 = 1.1667$; $p = 0.5392$). However, the cluster analysis using standardized abundance among decades indicated higher similarity between the 1980s and the 1990s (Fig. 4c). Indeed, there is some difference in rank of the species with the highest abundance among the decades: barbudo (18.9%), bagre (12.8%), judeu (8.2%), moreia (7.1%), and garapau/palombeta (6.3%) in the 1970s; coró (13.6%), garajuba/xaréu (9.8%), garapau/palombeta (7.8%), moreia (7.7%), and aracanguira/aratobaia (6.3%) in the 1980s; and coró (26.3%), bagre (11.4%), moreia (8.9%), and garabebéu/pampo (8.5%) in the 1990s.

Considering all 57 T.U. caught over the three decades, the abundance of 28.1% of them (16 T.U.) decreased (bagre-amarelo, bagre-branco, baiacu, barbudo, cação, cação-lixa, cação-martelo, camurim/robalo, corvina, cururuca, dentão, judeu, mero, paru/enxada, sirigado, and zumbi) and 19.3% (11 T.U.) increased (coró, galo, galo-do-alto, garabebéu/pampo, garacimbora, linguado, mariquita, moreia, salema, vermelho, and xira). The most significant changes noticed from the 1970s to the 1990s were the decreasing participation of *Polydactylus* spp. (barbudo), the increasing participation of coró (probably mostly *H. corvinaeformis*, as it corresponded to 44% of the total abundance in 2009), and a decreasing abundance of garajuba/xaréu (*Caranx hippos*) in the 1990s. Moreover, at least 105 rays were caught from the 1970s to the 1990s (6.5 ± 6.4 per year), with an additional 32 rays caught in 2009. Finally, sharks were also caught between 1975 (11 individuals) and 1991 (three individuals), most of them reported by the generic name cação. The other shark species were *Ginglymostoma cirratum* (cação-lixa; 87.6% of the sharks), *Sphyrna* spp. (cação-martelo; 6.2%), and *Rhizoprionodon* spp. (cação-rabo-seco; 6.2%). In 2009, no sharks were caught.

The mean individual weight decreased for great pompano (aracanguira/aratobaia) and pufferfish (baiacu) from the 1970s to the 1990s (Fig. 5). On the other hand, the mean weight increased only for the threadfin (barbudo) during the same period (Fig. 5). The reporting system of the largest fish is rather poor. Most of the largest specimens in each event had their weight reported, but not their common name (49 individuals). Most of the identified largest species were baiacu (18 individuals), garabebéu/pampo (three individuals), aracanguira/aratobaia, arenque, arraia, moreia, xarelete (two individuals each), and cação, cação-lixa, dentão, and espinho-duro (one individual each).

Canonical correspondence analysis

The results of the cluster analysis using the score values of the first two axes from the CCA indicated the presence of four groups of species related to different features (Fig. 6a):

- Group 1 (orange), mainly associated with MSR beaches;
- Group 2 (green) was associated with rocky beaches;
- Group 3 (red) was correlated with estuaries;
- Group 4 (blue) was related to sand beaches.

The first two axes in the CCA explained 81.1% of the variability in the correlation of abundance by category, season, and habitat, with 54.3% related to axis 1 and 26.8% to axis 2 (Fig. 6b). Axis 1 presented positive correlation with the heavy category and rainy season, in which the sandy beach (group 4–blue) and MSR (group 1–orange) habitats are completely located, and the rocky beach (group 2–green) is partially located, and the

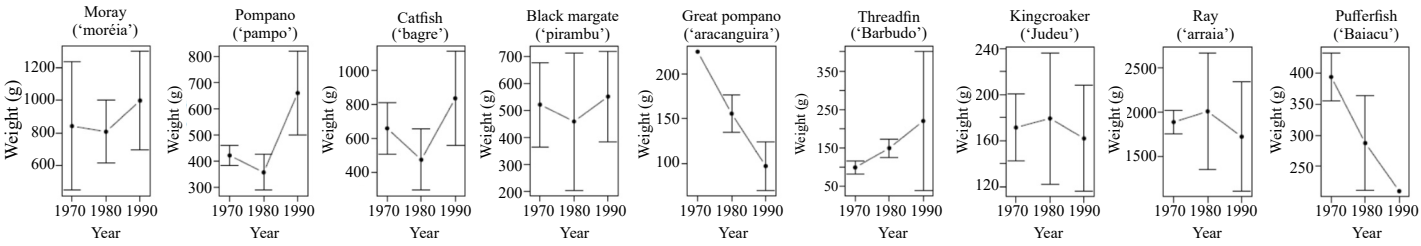

Figure 5. Mean weight and confidence interval (95%) for all taxonomic units for which there were more than 20 individuals caught in competitive fishing events taking place in the state of Rio Grande do Norte, Brazil (1974–1994).

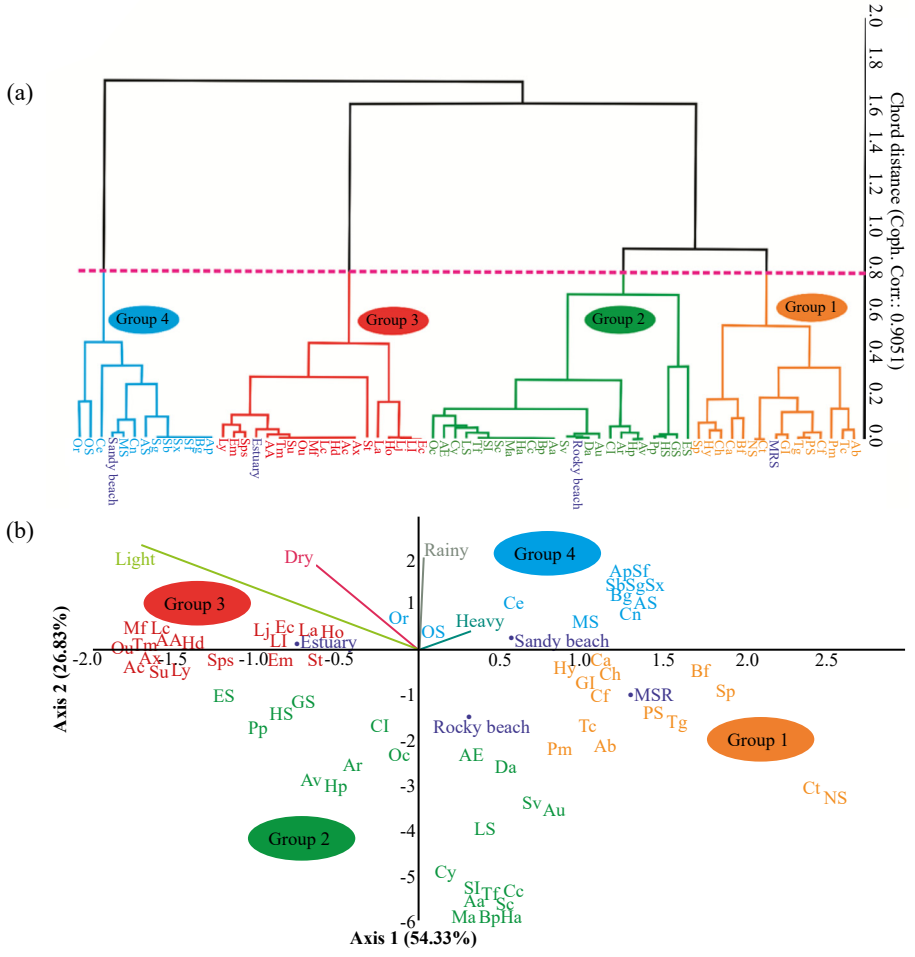

Figure 6. Results from the multivariate analysis for competitive fishing events taking place in the state of Rio Grande do Norte, Brazil: (a) Cluster analysis using the score values (from the canonical correspondence analysis) of the first two axis; (b) canonical correspondence analysis using the numerical abundance of species by habitat (estuary, sandy beach, rock beach and muddy, sandy, and rocky beach–MSR), season (dry and rainy) and fishing category (light and heavy). The corresponding abbreviations for species and taxonomic units are in Table 3.

rocky beach (group 2–green) is partially located. Conversely, axis 1 presented a negative correlation with the light category and dry season, in which the estuary is completely located (group 3–red). Axis 2 presented a positive correlation with both categories (light and heavy) and seasons (dry and rainy), in which the sandy beach (group 4–blue) was completely located and the estuary (group 3–red) was partially located. The remaining species of group 3 were in the negative portion of axis 2, together with MSR

(group 1–orange) and the rocky beach (group 2–green). In terms of species, group 1 was represented mainly by *Polydactylus* spp., *Chaetodipterus faber*, *T. goodei*, and *Stellifer punctatissimus*; group 2 included mainly *Eucinostomus* spp., *A. surinamensis*, and *Diapterus auratus*; group 3 was associated mainly with *H. corvinaeformis*, *S. testudineus*, *Eucinostomus melanopterus*, *Lutjanus synagris*, *Lutjanus analis*, and *S. psittacus*; and group 4 included mainly *Menticirrhus* spp. and *Centropomus* spp.

DISCUSSION

Competitive fishing events in the state of Rio Grande do Norte present some similarities in relation to other states in northeastern Brazil, mainly their multi-specific and catch-and-keep features (Freire et al., 2017; Freire et al., 2020b). The total of 70 species caught here was higher in relation to the states of Sergipe and Bahia (represented by Ilhéus) (Freire et al., 2017; Freire et al., 2020b). Another similarity is the occurrence of catfishes (Ariidae), *Polydactylus* spp. (threadfins), and *Menticirrhus* spp. (kingcroakers) among the top five species caught by recreational fishers in the state, which is expected due to the coastal habitat of these species. Catfishes vary among states and include around ten species along the coast of Rio Grande do Norte (Garcia Júnior et al., 2015). Due to the impossibility of analyzing all specimens caught by recreational fishers in competitive events, we decided to work with taxonomic units to avoid misidentifications.

Polydactylus spp. is usually represented by *Polydactylus virginicus*, which is found at a maximum depth of 20 m along the northern coast of Rio Grande do Norte (Nóbrega et al., 2019). This species is very common in the surf zone in some beaches of Rio Grande do Norte (see, e.g., Nascimento et al., 2021), an area used as a nursery by many species. Even though *P. virginicus* is usually caught in sandy/muddy areas, it may also be recorded in rocky reefs (Adelir-Alves et al., 2018), as well as in MSR beaches in Rio Grande do Norte. According to Adelir-Alves et al. (2018), this behavior could be related to protection and feeding. Everaldo "Dinho" Lima (Clube Dentão de Pesca e Lançamento, personal communication) pointed out that *Polydactylus* spp. is mainly found along the coast of Rio Grande do Norte during the summer (dry season), when the coastal water is clearer. It was not possible to assess this hypothesis, as no event occurred during the summer (December–February), which corresponds to the longest vacation period in the region. During the rainy season, they migrate offshore, where they are consumed by *Coryphaena hippurus* (dolphinfish). Even though threadfishes are found by recreational fishers in the stomach of dolphinfishes (Everaldo "Dinho" Lima, personal communication), Vaske Júnior and Lessa (2004) did not register them in the stomach of dolphinfishes found in northeastern Brazil. The decreasing participation of *Polydactylus* spp. in competitive events from the 1970s to the 1990s led to a very low abundance of specimens in 2009 (3.7%), although their size increased and became more variable. *Menticirrhus* spp. includes mainly *Menticirrhus cuiaranensis*, formely *Menticirrhus littoralis*, which occurs in shallower waters in relation to *Menticirrhus martinicensis*, formely *Menticirrhus americanus* (Marceniuk et al., 2020), and, thus, are more prone to be caught by recreational fishers. In fact, Barreto et al. (2018) found a higher abundance of *M. martinicensis* than *M. cuiaranensis* in the shrimp by-catch off Sergipe, as shrimp trawling occurs in deeper waters in relation to shore-based recreational fishing. Recreational catches may signal changes in the health of local stocks. This is very important, mainly considering the current absence of a proper collection system for statistics from artisanal and industrial fisheries in Brazil, except for a few states (Freire et al., 2021a). *Trachinotus goodei* (aracanguira/aratobaia) and pufferfishes, e.g., decreased in size from the 1970s to the 1990s.

The remaining two, out of the top five species, differ among the states analyzed up to now in northeastern Brazil. In Rio Grande do Norte, the most abundant species was *H. corvinaeformis*. This species occurs from the United States of America's coast to southeastern Brazil, in estuaries and in waters with soft and hard bottoms (Carvalho et al., 2020), such as those found in the state of Rio Grande do Norte. Increasing recreational catches of coró were observed from the 1970s to the 1990s, and in 2009. Even though earlier events registered catches only by common name, coró probably corresponded to the roughneck grunt, *H. corvinaeformis* (or coró-branco), as 93% of the specimens caught in competitive events along the coast of Rio Grande do Norte were represented by this species in 2009, and the remaining 7% by *C. nobilis* or coró-amarelo. *Haemulopsis corvinaeformis* was found in three of the four states for which coastal recreational fisheries have been analyzed up to now, including Sergipe and Bahia (Freire et al., 2017; Freire et al., 2020b). One possible explanation for the increasing abundance of this species was provided by Erivaldo "Dinho" Lima (Clube Dentão de Pesca e Lançamento, personal communication): the increasing use of trammel nets in coastal areas of the state of Rio Grande do Norte. Recreational fishers usually keep roughneck grunts in holes filled with water while fishing, to use as live baits. Thus, they could notice their habit of burying themselves. Thus, a hypothesis was raised that their abundance has not decreased due to its burying habit. This is also associated

with the zoobenthivore habit of *H. corvinaeformis*, which was found mainly feeding on *Anomalocardia flexuosa* in an area southwards from our study area (Silva, J. D. B. et al., 2018).

The proportion of juveniles of *H. corvinaeformis* caught by recreational fishers along the coast of Rio Grande do Norte is high, and fishers should consider the use of larger hooks or any other changes in gear towards the capture of larger specimens. Some clubs in other states have already been adopting minimum size rules in their competitive events (Freire et al., 2017; Freire et al., 2020b). As sandy beaches are nursery areas for many fish species (Basaglia & Vieira, 2005; McLachlan, 1980; Vaske Júnior et al., 2019), juveniles are commonly found in the surf zone and caught by recreational fishers. Dal Negro et al. (2021) observed that 50% of all specimens of *Menticirrhus gracilis* caught by recreational fishers along the central coast of the state of São Paulo (southeastern Brazil) were juveniles. Fishing clubs in this state have been also adopting a minimum size (15 cm), besides the minimum legal-size limits existing for some species.

In relation to Chondrichthyes, rays were caught throughout the 1970s, 1980s, and 1990s along the coast of Rio Grande do Norte, and 32 individuals were caught in 2009 in competitive events. Rays are commonly caught in this type of coastal event, usually making the fishers champions due to the rays' higher weight (big trophies). The exception was Ilhéus, in southern Bahia, where no ray was caught (Freire et al., 2020b). Sharks were caught from the 1970s to the 1990s, but none were caught in 2009. They were not caught by recreational fishers in Ilhéus (2007-2008), and only one specimen was captured in an event in Sergipe (2014) (Freire et al., 2017; Freire et al., 2020b). There is no competitive event in Brazil where recreational fishers target sharks. Barbini et al. (2015) were able to document, for the same period, declines of shark populations in northern Argentina, using information extracted from magazines specialized in recreational fisheries. There is no detailed information available to affirm that decreasing catches of sharks may be associated to decreasing abundance along the coast of Rio Grande do Norte. The feasibility of improving the reporting system for this group should be discussed to avoid the capture of threatened species and/or moving towards catch-and-release, due to its slow growth and low fecundity (Helfman et al., 2009).

The CCA indicated greater numerical abundance for the *barra leve* category, the estuarine habitat, and the dry period. This relationship can be explained by the smaller size of the hooks used in this category, which provides higher capture rates, but of smaller specimens, as demonstrated in the present study (Çebin et al., 2024; Hidayati & Mohamad, 2024; Mehanna et al., 2021; Uysal & Öztekin, 2021). Greater abundance and smaller size are also intrinsic characteristics of the estuarine fish community, mostly composed of populations in early stages that find protection against predation and high abundance of food in these habitats (Gaines et al., 2024; Silva-Lima et al., 2020; Whitfield et al., 2024). Rainfall represents an important feature of estuarine dynamics, being responsible for changes in salinity, temperature, turbidity, physical space, etc. (Harrison & Whitfield, 2024; Whitfield et al., 2022). As evidenced in other studies, during the dry period, when the water volume is lower, the catch in number is higher due to the high density and low connectivity between continental and marine environments (Harrison & Whitfield, 2024; James et al., 2018; Oliveira & Pessanha, 2014; Silva, J. D. B. et al., 2018; Silva, R. S., 2018; Thomson et al., 2010; Van Der Veer et al., 2015). It is important to note that four species included in the group associated with the estuarine habitat (*Trachinocephalus myops*, *Abudefduf saxatilis*, *Ocyurus chrysurus*, and *Stegastes fuscus*) exhibited behavior that differed from expectations based on Froese and Pauly (2024). This happened because some of the fishers were placed in adjacent coastal marine areas during some competitions classified as estuarine, capturing these unexpected species. Similarly, *Ophichthus cylindroideus* was recorded in a rocky beach, even though it is expected only in sandy areas, possibly because hook and bait are cast in adjacent areas of soft sediment.

CONCLUSION

The first steps into a better understanding of the recreational fisheries in Rio Grande do Norte were taken in this study, in which the richness of species caught was high, and the heavy category and events that took place during the dry season (September to November) led to higher catch in weight. Thus, a baseline was established to assess future changes. However, there is still a need for a better understanding of the profile of local recreational fishers and a more precise analysis of the possible increased importance of other sectors such as oceanic, boat-based estuarine, and kayak recreational fisheries, which have been increasing in other Brazilian states.

The information collected here should be expanded further, as there is no data on coastal recreational fisheries for the states of Ceará, Paraíba, Pernambuco, and Alagoas, except for the scarce information from Freire (2010). An improved collection system of catch data should be implemented to allow for timely analyses of Brazilian recreational fisheries.

Finally, we propose that Pâmpano Esporte Clube remove estuaries from the list of possible places to hold fishing events due to the high proportion of juveniles of *H. corvinaeformis*.

CONFLICT OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

All data sets were generated or analyzed in the current study.

AUTHORS' CONTRIBUTIONS

Conceptualization: Freire, K.M.F.; **Formal Analysis:** Freire, K.M.F., Alves, G.A.; **Investigation:** Freire, K.M.F., Alves, G.A.; **Resources:** Freire, K.M.F.; **Supervision:** Freire, K.M.F., Lins-Oliveira, J.E., Garcia Júnior, J.; **Data curation:** Freire, K.M.F.; **Writing – original draft:** Freire, K.M.F., Alves, G.A., Rotundo, M.M.; **Writing – Review and editing:** Lins-Oliveira, J.E., Garcia Júnior, J., Dal Negro, T.; **Investigation:** Dal Negro, T., Rotundo, M.M.; **Final approval:** Freire, K.M.F.

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