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FEEDING HABITS OF COBIA IN PERNAMBUCO, NORTHEASTERN BRAZIL

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ABSTRACT

The feeding habits of cobia, *Rachycentron canadum*, was described along the coast of Pernambuco State, northeastern Brazil. One hundred ten specimens were caught between February 2004 and August 2006 with fork length ranging from 40.0 to 137.0 cm (mean and standard deviation: 85.8 ± 18.0 cm) and total weight between 0.4 and 29.8 kg (7.5 ± 4.4 kg). The importance of each food item in the diet was evaluated using the index of relative importance (IRI). Among the one hundred ten stomachs analyzed (52 females and 58 males), 92 (83.6%) had food items, while 18 (16.4%) were empty. Bony fish were the main food item (IRI = 98.7%), being squirrelfish (*Holocentrus adscensionis*) and porcupine fish (*Diodon* sp.) the most frequent prey items (30.7% and 8.2%, respectively). Elasmobranchs, crustaceans and cephalopods were also present in small proportions (IRI < 1% for each). No significant differences in diet were found between sexes or size classes (fork length: < or ≥ 69.8 cm; estimated L_{50} for the species). The present data demonstrate that cobia is a carnivorous predator along the coast of Pernambuco State, with a preference for demersal bony fish, independently of the size and sex of the individuals analyzed.

Key words: Rachycentridae; feeding strategy; diet composition; stomach contents; carnivorous predator.

HÁBITO ALIMENTAR DO BEIJUPIRÁ EM PERNAMBUCO, NORDESTE DO BRASIL

RESUMO

O hábito alimentar do beijupirá, *Rachycentron canadum*, foi descrito ao longo da costa do Estado de Pernambuco, Nordeste do Brasil. Foram capturados 110 exemplares entre fevereiro/2004 e agosto/2006, com comprimento furcal ou zoológico variando entre 40,0 e 137,0 cm (média e desvio padrão: 85,8±18,0 cm) e peso total entre 0,4 e 29,8 kg (7,5±4,4 kg). Foi avaliada a importância de cada item alimentar na dieta utilizando o índice de importância relativa (IIR). Dentre os 110 estômagos analisados (52 fêmeas e 58 machos), 92 (83,6%) com algum item alimentar e 18 (16,4%) vazios. Os peixes ósseos foram os principais itens consumidos na dieta alimentar (IIR = 98,7%), entre os quais a mariquita (*Holocentrus adscensionis*) e o baiacu (*Diodon* sp.) foram as presas mais consumidas (IIR = 30,7% e 8,2%, respectivamente). A dieta foi composta, ainda, por elasmobrânquios, crustáceos e cefalópodes (IIR <1% cada). Não foram encontradas diferenças na dieta entre os sexos e classes de tamanho (< ou ≥ 69,8 cm de comprimento furcal, L_{50} estimado para a espécie). Os dados analisados demonstram que, na costa de Pernambuco, o beijupirá é um predador carnívoro com preferência por peixes ósseos demersais, independente do tamanho e sexo dos indivíduos analisados.

Palavras-chave: Rachycentridae; estratégia alimentar; composição da dieta; conteúdo estomacal; predador carnívoro.

INTRODUCTION

The cobia, *Rachycentron canadum* (Linnaeus, 1766), is the only representative of the family Rachycentridae. This species is neritic and widely distributed in both tropical and subtropical waters in all oceans, except the eastern portion of the Pacific (Shaffer and Nakamura, 1989). In the Western Atlantic, the species occurs from the State of Massachusetts in the USA to Argentina (Figueiredo and Menezes, 1980).

The species forms small shoals of five to ten individuals (Carvalho Filho, 1999) and catches occur either incidentally or through spearfishing, with no specific fishery directed at the species. The global catch was 13,751 tons (t) in 2014, with Pakistan as the largest producer (3,257 t) and Brazil occupying the fourth place (974 t) (FAO, 2016). This species corresponds to approximately 0.2% of the total production of marine fish in Brazil, which is 553,670 t (Brasil, 2013). In Pernambuco State, northeastern Brazil, catches ranged from 0.5 to 1.5 t year^{-1} between 2002 and 2006 (Brasil, 2008).

Despite the small catch rates, the species has attracted attention due to its favorable characteristics with regard to aquaculture, such as fast growth (Arnold et al., 2002; Benetti et al., 2008; Barbieri and Doi, 2012), spawning in captivity (Franks et al., 2001; Arnold et al., 2002; Peregrino Junior et al., 2014) and established technology for the production of juveniles (Liao and Leaño, 2007; Benetti et al., 2008). The world production of cobia in aquaculture in 2014 was 40,329 t, with China, Vietnam, Panama and Taiwan being the main producing countries (FAO, 2016). In Brazil, the species currently presents low production (estimated between 50-100 t) in the north coast of São Paulo, and south of Rio de Janeiro.

However, little is known regarding its biology in Brazilian waters. Lopes et al. (2001) recorded the occurrence of the species in Baía de Todos-os-Santos in Bahia State, presenting meristic, morphometric and stomach content data for only three specimens caught in the region, with predominance of Crustacea Decapoda Brachyura in their diet (85%). In another study, Felix and Hackradt (2008) describe the interaction between cobia and Atlantic goliath grouper, *Epinephelus itajara* (Lichtenstein, 1822), as a common interspecific feeding association.

Cobia performs multiple spawning throughout the reproductive season, which extends from April to September in the Gulf of Mexico (Lotz et al., 1996). A similar pattern is found in the southern hemisphere, during spring and summer in Australia, with the spawning period from September to June. The mean size at first maturity is estimated to be 78.4 cm in fork length for females whereas mean fecundity is estimated at 2.8 x 10^6 eggs (Velde et al., 2010).

Studies conducted in the United States indicate that the diet of cobia is mainly composed of crustaceans (Knapp, 1951; Smith, 1995; Franks et al., 1996; Meyer and Franks, 1996), although smaller individuals (< 4.5 kg) prefer teleosteans (Smith, 1995). In Chesapeake Bay (USA), Arendt et al. (2001) found that more than 97% of prey items corresponded to two species of crab from the family Portunidae: *Callinectes sapidus* (Rathbun, 1896) and *Ovalipes ocellatus* (Herbst, 1799). Similarly, crustaceans occurred in 100% of stomachs analyzed in a study conducted in the Western Indian Ocean (Darracott, 1977).

In contrast, the cobia mainly feeds on fishes along the coast of Karnataka, India, and was defined as a non-selective generalist carnivorous predator that feeds on pelagic and benthic organisms (Rohit and Bhat, 2012). Juvenile cobia also exhibit an opportunistic feeding behavior (Franks et al., 1996) comparable to that reported for adults (Meyer and Franks, 1996).

Given the potential of cobia for aquaculture and the relative lack of information on its biology, the aim of the present study was to describe the diet and evaluate whether sex and size of fish specimens influence the dietary pattern of *R. canadum* in Pernambuco State, northeastern Brazil.

MATERIAL AND METHODS

The specimens of *R. canadum* were caught between February 2004 and August 2006 along the coast of Pernambuco State, mostly in Recife, Olinda and Porto de Galinhas, in isobaths from 20 to 45 m (Figure 1). The specimens were caught by artisanal and sport fishing (spearfishing). The location of capture, date and time was recorded for each specimen.

Total weight (TW) and fork length (FL) were determined for each individual. All specimens were eviscerated fresh and sex was identified. The stomachs were collected and kept in a freezer at -20º C until analysis. In the laboratory, the material was fixed in a 5% formalin solution for 48 hours and then transferred to 70% alcohol.

The material retained in a sieve with a 1-mm mesh was considered as stomach content. The food items were identified to the lowest possible taxonomic level using identification keys (Carpenter, 2002a; 2002b; 2002c; Humann and Deloach, 2002) and with the assistance of specialists. After blotting them dry with a paper towel, the food items, the number of prey items, as well as the length (cm) and wet weight (g) of the prey items were recorded for each individual.

The cumulative richness curve was used to evaluate the sufficiency of the number of stomachs analyzed (Ferry and Cailliet, 1996). The Primer 6 program (Primer-E Ltd., Plymouth, UK) was used to calculate the prey accumulation curve through the randomization of the samples (999 permutations) and the Student's t-test with a 5% significance level (Statistica8, StatSoft Inc., Tulsa, USA) was used to compare the regression slope (b) of the last four points on the curve with the horizontal asymptote (b = 0), following the method proposed by Bizarro et al. (2007).

The percentages of numeric abundance (%N), total weight (%W) and frequency of occurrence (%F) were determined to describe the importance of each food item in the diet of *R. canadum*. The index of relative importance (IRI) (Pinkas et al., 1971) was calculated by replacing prey volume with weight: $IRI_i = (\%N_i + \%W_i).\%F_i$, in which $\%N_i$ = number of prey items of species *i* divided by the total number of prey items x 100, $\%W_i$ = total weight of prey items of species *i* (in g) divided by the total weight of all prey items x 100, and $\%F_i$ = number of stomachs with at least one prey item of species *i* divided by the total number of stomachs with at least one food item x 100. The IRI percentage was calculated for each item based on Cortés (1997): $\%IRI_i = (IRI_i.\Sigma IRI^{-1}).\ 100$. The prey were classified by ecological groups according to prey habits, where demersal species were the prey associated with the botttom, pelagic species were those using the water column, and demersal-pelagic those species that inhabit both environments (Milmann et al., 2016). The prey association with reef environments was classified following Humann and Deloach (2002).

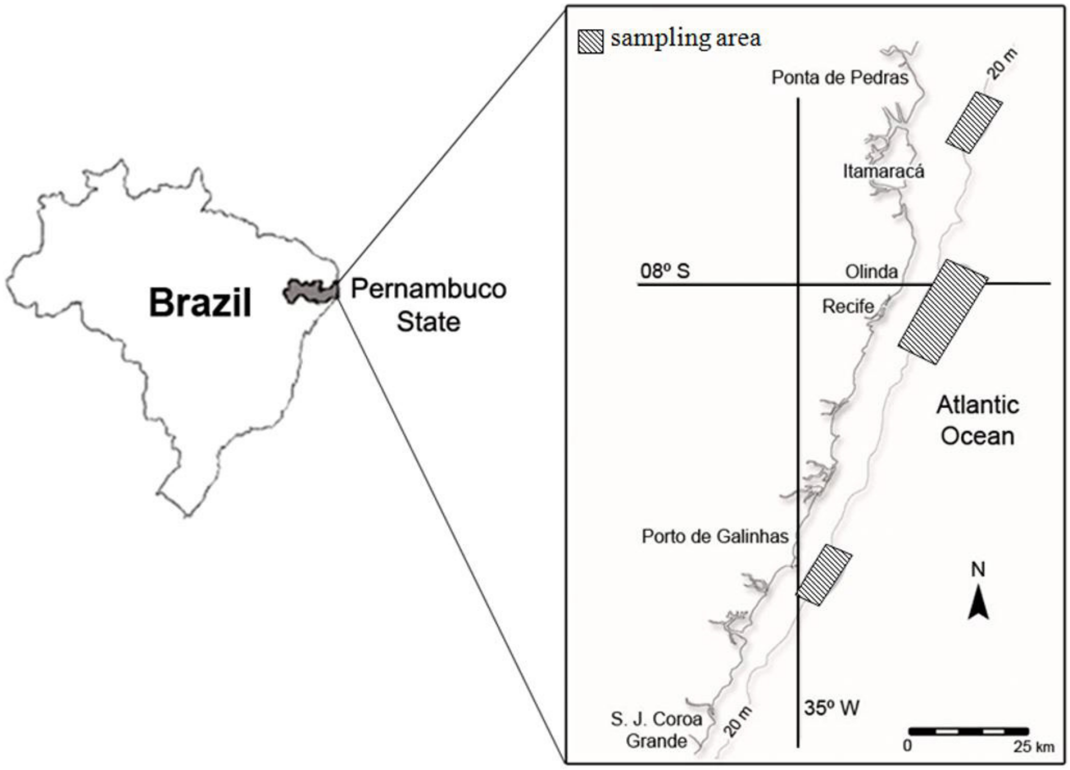

Figure 1. Sampling area of cobia *Rachycentron canadum* along the coast of Pernambuco State, Northeastern Brazil (mean depth 30 meters).

The fullness index (FI) was calculated using the formula proposed by Zavala-Camin (1996): FI = (SCW.TW^{-1}). 100, in which SCW = weight of the stomach content of the individual. This index was used to determine the time periods of greater feeding activity for the species, analyzing the index by three-hour time periods. As spearfishing, which was the main data source in the present study, was performed exclusively during daylight hours, the time periods were 6:00 to 9:00 h, 9:00 to 12:00 h, 12:00 to 15:00 h and 15:00 to 18:00 h, and only specimens caught at these periods were considered (n = 80). Considering the non-normality of data, Kruskal-Wallis test with a 5% significance level (Statistica8, StatSoft Inc., Tulsa, USA) was used to determine differences in the fullness index among time periods.

The relationship between the size of cobia and their prey was tested using Spearman rank correlation and the Student's t-test with a 5% significance level (Statistica8, StatSoft Inc., Tulsa, USA).

Diet overlap between females (n=46) and males (n=47) was analyzed using Schoener Index (SI) proposed by Schoener (1968): SI = 1 - 0.5 (Σ $|pi_A - pi_B|$), where pi_A and pi_B were the frequency of occurrence of item *i* in the diet of females and males, respectively. The index was calculated only for adults, since juveniles were scarce in the sample. Values of Schoener index vary from 0 (no food is shared) to 1 (maximum overlap), where values higher than 0.6 should be considered as biologically significant (Wallace and Ramsey, 1983).

Differences in feeding habits between sexes and size were analyzed using only stomachs with at least one identifiable prey item (n = 70). Two size classes were considered based on size at first maturity of females: class I: < 69.8 cm fork length; class II ≥ 69.8 cm fork length, based on L_{50} estimated for cobia in Pernambuco State (unpublished data). Cluster analysis and multidimensional scaling (MDS) based on the Bray-Curtis similarity index and abundance data (%N) were used to evaluate the behavior of different sexes and sizes. Significant differences in diet between sexes and size classes were determined using analysis of similarity (ANOSIM). All tests were performed with the Primer 6 program (Primer-E Ltd., Plymouth, UK).

RESULTS

One hundred ten specimens (52 females and 58 males, 15.5% juveniles) with fork length ranging from 40.0 to 137.0 cm (mean = 85.8; standard deviation = 18.0 cm) and total weight ranging from 0.4 to 29.8 kg (mean = 7.5; standard deviation = 4.4 kg) were collected (Figure 2). Among the stomachs analyzed, 92 (83.6%) had food items and 18 (16.4%) were empty.

The accumulative food item curve (Figure 3) demonstrated an asymptotic tendency, with no significant difference in the regression slope (b = 0.09) of the last four points (p = 0.2882) of the horizontal asymptote (b = 0), indicating that the number

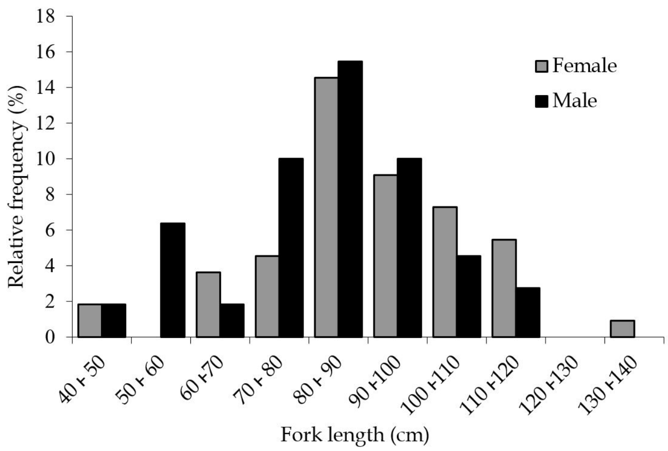

Figure 2. Fork length frequency of cobia *Rachycentron canadum* in Northeastern Brazil (sample number = 52 females and 58 males).

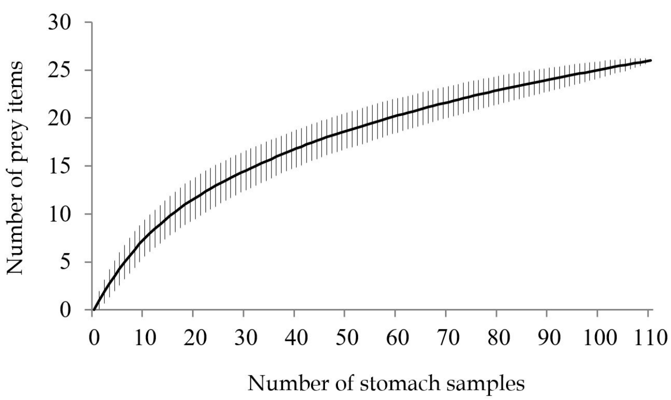

Figure 3. The cumulative number of prey items per stomach sample for cobia *Rachycentron canadum* in Northeastern Brazil (total stomachs analyzed = 110; total food items = 26; vertical bar = standard deviation).

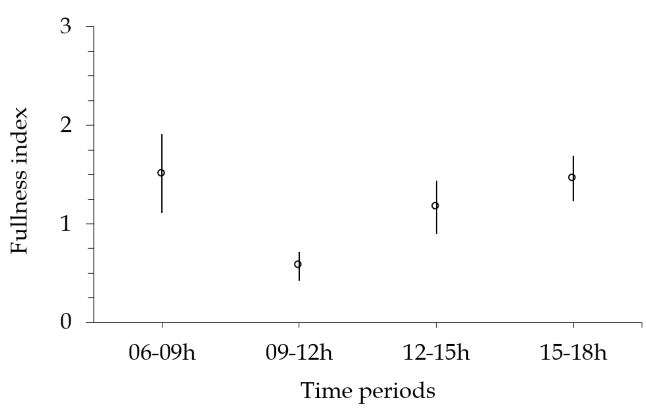

Figure 4. Fullness index by time period of day for cobia *Rachycentron canadum* in Northeastern Brazil (n=80). Vertical bar = standard error (total sample number = 80; n = 12 for 6:00-9:00 h period; n = 11 for 9:00-12:00 h period; n = 11 for 12:00-15:00 h period; and, n = 46 for 15:00-18:00 h period; vertical bar = standard error).

of stomachs analyzed was representative for an adequate diet analysis. The diet was composed of 26 prey items, including 19 families of teleost fishes, three families of crustaceans, two families of mollusks and two families of elasmobranchs (Table 1).

Actinopterygii was the dominant group in the diet of cobia, accounting for the ten major food items, with %N, %W and %IRI equal to 93.6%, 86.5% and 98.7%, respectively (Table 1). Other groups represented a small portion of the diet, with Chondrichthyes as the second most consumed group (%W and %IRI equal to 9.4% and 0.6%, respectively). Although crustaceans were the third most consumed group (%IRI = 0.4%), numerous prey items were found, making it the second most consumed group in terms of %N (3.4%). Mollusks were represented by cephalopods and had a %IRI of 0.3%.

Cobia showed a preference for demersal or demersal-pelagic prey, with only *Opisthonema oglinum* as a pelagic prey (Table 1). However, all species found in the stomach content are classified as reef-associated.

Considering %IRI, the squirrelfish *Holocentrus adscensionis* (Osbeck, 1765) was the main food item consumed by the cobia (30.7%), followed by the porcupine fish *Diodon* sp. (8.2%) and the eel *Myrichthys ocellatus* (Lesueur, 1825) (4.2%), whereas scraps of bony fish accounted for 42.3% (Table 1). However, it should be pointed out that the eel was the main item consumed concerning weight (10.4%). Among elasmobranchs, although the %IRI for the ray *Rhinobatos percellens* (Walbaum, 1792) was only 0.2%, this species had a high percentage in weight (5.4%) due to the ingestion of three specimens weighing from 40 to 266 g (total length: 37, 41 and 48 cm) found in a single stomach of a cobia measuring 114.5 cm fork length.

The fullness index ranged from 0.01 to 7.03 (mean ± SE: 1.41 ± 0.15). Although no significant differences were found among the time periods analyzed (Kruskal-Wallis test, $p = 0.2546$), higher fullness indices occurred in the 6:00 to 9:00 h (mean: 1.51 ± 0.40) and the 15:00 to 18:00 h (mean: 1.46 ± 0.23), whereas the lowest indices occurred in the 9:00 to 12:00 h (mean: 0.57 ± 0.15) (Figure 4).

The identifiable food items ingested by the cobia had TL values ranging from 1 cm (specimen of *H. adscensionis*) to 63 cm (specimen of *M. ocellatus*) (Table 2), with the greatest frequency of occurrence in the 10 to 20 cm range (40.2%), followed by the 0 to 10 cm range (31.3%). Small prey items were ingested by all length classes of the predator, whereas larger prey items were generally ingested by larger specimens (Figure 5). However, in a sample the prey was nearly the size of the predator (*e.g. M. ocellatus* measuring 42 cm found in the stomach of a cobia measuring 52.5 cm fork length).

The Schoener index value for frequency of occurrence percentage was higher than 0.6 (SI %F = 0.715) showing diet overlap between females (n=46) and males (n=47).

The cluster and MDS analyses using abundance (%N) as the basis demonstrated no pattern in the diet of cobia among the different factors analyzed (sex and size) for either raw data or data following log(%N+1) transformation. The global ANOSIM based on %N demonstrated no significant differences between sexes (R-statitic = -0.012; $p = 0.733$) or sizes (R-statitic = -0.007; $p = 0.562$), indicating that the groups are not distinguishable.

Table 1. Prey items presents in the stomach content of cobia (*Rachycentron canadum*), collected in Pernambuco State, northeastern Brazil. Abbreviations: EG = Ecological group of prey; D = demersal; P = pelagic; D/P = demersal/pelagic; %F = percentage of frequency of occurrence; %N = percentage of number; %W = percentage of weight; %IRI = percentage of index of relative importance; UID = Unidentified genus; Rank indicate the order of importance of prey by %IRI.

Prey item	EG	%F	%N	%W	%IRI	Rank
Muraenidae						
Gymnothorax sp.	D	7.6	2.0	5.4	1.9	7
Ophichthidae						
Myrichthys ocellatus (Lesueur, 1825)	D	8.7	4.2	10.4	4.2	3
Clupeidae						
Opisthonema oglinum (Lesueur, 1818)	P	1.1	0.3	1.1	0.1	15
Synodontidae						
Synodus foetens (Linnaeus, 1766)	D/P	2.2	0.8	3.2	0.3	11
Batrachoididae						
UID Batrachoididae	-	3.3	1.1	3.6	0.5	10
Holocentridae						
Holocentrus adscensionis (Osbeck, 1765)	D/P	17.4	45.5	7.6	30.7	1
Dactylopteridae						
Dactylopterus volitans (Linnaeus, 1758)	D	7.6	2.0	3.2	1.3	8
Scorpaenidae						
Scorpaena plumieri Bloch, 1789	D	5.4	2.0	9.6	2.1	6
Triglidae						
Prionotus sp.	D	1.1	0.3	0.3	< 0.1	22
Serranidae						
UID Serranidae	-	1.1	0.3	1.5	0.1	15
Haemulidae						
Haemulon sp.	D/P	1.1	0.3	3.0	0.1	15
Sparidae						
UID Sparidae	-	1.1	0.3	0.1	< 0.1	22
Mullidae						
Pseudupeneus maculatus (Bloch, 1793)	D	3.3	2.2	5.1	0.8	9
Paralichthyidae						
Syacium micrurum Ranzani, 1842	D/P	7.6	4.7	3.6	2.2	5
Bothidae						
Bothus ocellatus (Agassiz, 1831)	D/P	12.0	6.7	2.9	3.8	4
Balistidae						
Balistes capriscus Gmelin, 1789	D/P	1.1	0.3	0.5	< 0.1	22
Monacanthydae						
UID Monacanthydae	-	2.2	0.5	0.1	< 0.1	22
Ostraciidae						
UID Ostraciidae	-	2.2	0.6	1.4	0.1	15
Diodontidae						
Diodon sp.	D	17.4	6.1	8.0	8.2	2
Remains of teleost		43.5	13.4	15.9	42.3	
Actinopterygii		**95.7**	**93.6**	**86.5**	**98.7**	

Table 1. Continued...

Prey item	EG	%F	%N	%W	%IRI	Rank
Carcharhinidae						
Rhizoprionodon porosus (Poey, 1861)	D	1.1	0.3	1.7	0.1	15
Rhinobatidae						
Rhinobatos percellens (Walbaum,1792)	D	1.1	0.8	5.4	0.2	13
Remains of elasmobranchs		3.3	0.8	2.3	0.3	
Chondrichthyes		**5.4**	**1.9**	**9.4**	**0.6**	
Palinuridae						
Panulirus argus (Latreille, 1804)	D	2.2	0.8	1.2	0.1	15
Penaeidae						
Farfantepenaeus subtilis (Pérez Farfante, 1967)	D	4.3	2.0	0.1	0.3	11
Portunidae						
Cronius tumidulus (Stimpson, 1871)	D	1.1	0.3	< 0.1	< 0.1	22
Remains of crustaceans		1.1	0.3	< 0.1	< 0.1	
Crustacea		**8.7**	**3.4**	**1.3**	**0.4**	
Loliginidae						
UID Loliginidae	-	1.1	0.3	2.0	0.1	15
Octopodidae						
Octopus vulgaris Cuvier, 1797	D/P	3.3	0.8	0.8	0.2	13
Cephalopoda		**4.3**	**1.1**	**2.8**	**0.3**	

Table 2. Standard length of the ten main prey items in order of importance by %IRI of cobia (*Rachycentron canadum*) collected in Pernambuco State, northeastern Brazil. Abbreviations: N = number of measured prey; Min. = Minimum length; Max = Maximum length; SD = Standard deviation; UID = Unidentified genus.

Prey item	N	Standard length (cm)		
		Min.	Max.	Mean (SD)
Holocentrus adscensionis	18	1.0	12.5	7.5 (3.4)
Diodon sp.	14	6.5	20.0	10.6 (4.5)
Myrichthys ocellatus	9	22.5	63.0	40.7 (14.1)
Bothus ocellatus	16	6.0	18.0	10.4 (2.9)
Syacium micrurum	6	8.3	20.0	12.6 (4.8)
Scorpaena plumieri	7	13.0	23.0	17.0 (4.2)
Gymnothorax sp.	7	10.0	53.0	39.8 (15.5)
Dactylopterus volitans	6	8.0	22.5	13.9 (5.4)
UID Batrachoididae	4	11.0	21.5	16.6 (4.3)
Pseudupeneus maculatus	8	10.0	23.0	18.3 (4.4)

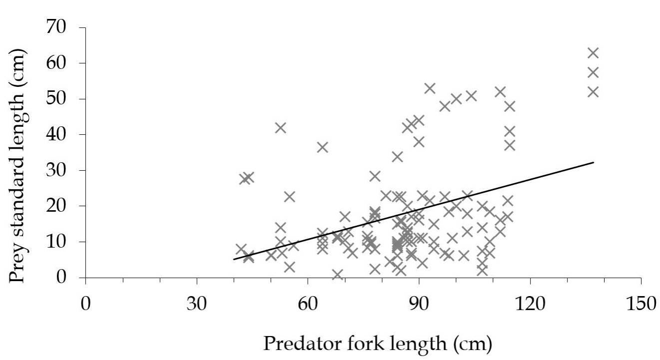

Figure 5. Predator-prey size relationship of cobia *Rachycentron canadum* in Northeastern Brazil (Spearman rank correlation=0.4148; df=121; $p<0.05$).

DISCUSSION

The cobia is a fast-growing fish, especially in the early years of life (Fry and Griffiths, 2010), reaching a maximum of 2 m in length and 68 kg in weight in nature (Shaffer and Nakamura, 1989). In Chesapeake Bay (USA), the fork length ranged from 37 to 141 cm (n = 114) (Arendt et al., 2001). In commercial and recreational fishing activities in Australia, specimens with a fork length ranging from 12.5 to 147 cm were caught (Fry and Griffiths, 2010). These data demonstrate that, although *R. canadum* is rarely caught on the coast of Pernambuco State, the sample in the present study corresponds to a size structure similar to that found in previous studies on this species in different regions of the world.

A total of 83.6% of the stomachs analyzed had at least one identifiable prey item. This percentage is close to that found in previous studies on the feeding habits of cobia in the USA (Knapp, 1951; Franks et al., 1996; Meyer and Franks, 1996; Arendt et al., 2001) and India (Rohit and Bhat, 2012), thus confirming the voracious nature of the species.

On the coast of Pernambuco, the diet of cobia is mainly composed of bony fish (98.7% IRI), which is similar to the behavior reported for juveniles in the northern portion of the Gulf of Mexico (USA) (Franks et al., 1996). However, different authors indicate crustaceans as the main food item in the diet of cobia. In Chesapeake Bay, the species feeds preferentially on crabs of the family Portunidae (IRI > 97%) (Arendt et al., 2001). On the coast of the State of North Carolina (USA), the blue crab (*C. sapidus*) dominates the diet (Smith, 1995). Although the cobia exhibits apparent selectivity, as indicated by Knapp (1951), the dominance of crabs in the diet of cobia in USA seems to be more related to the availability of prey items in the environment since crustaceans are abundant in that region (Stagg and Whilden, 1997).

Indeed, the authors of a study conducted on the coast of Karnataka (India) report that the cobia feeds on a wide variety of items and is defined as an opportunistic, non-selective predator that feeds on both benthic and pelagic organisms (Rohit and Bhat, 2012).

Demersal prey dominated the diet of cobia in Pernambuco State and all the prey taxa exhibit behavior associated with reef environments. The squirrelfish (*H. adscensionis*) was the main food item in the present study (IRI: 30.7%), whereas *Haemulon* sp. occurred in only one stomach examined (IRI: 0.1%). However, analyzing the ichthyofauna in vessel reefs in Pernambuco (Coxey, 2008) and around coral reefs and sunken ships in northeastern Brazil (Rocha et al., 1998) abundant shoals of the genus *Haemulon* were verified during the day, while during the night they were not observed in those environments. This may be related with the behavior of Haemulidae family that use the reefs for protection during the day, while the risk of being predated is lowest during diurnal periods (Danilowicz and Sale, 1999), and migrate to adjacent environments in search of food at night (Randall, 1967). On the other hand, the squirrelfish commonly hides during the day in crevices or below the edge of corals and feeds at night in the reefs (Greenfield, 1981). The difference between the behavior of these two preys associated with twilight foraging habit of cobia may explain the differentiated predation on such prey items, since the squirrelfish is susceptible to predation during the foraging hours of cobia.

Elasmobranchs were the most important dietary items (in terms of %IRI and %W) among the other groups of prey, despite only occurring in two stomachs analyzed. *Rhinobatos percellens* was the main species, with three specimens having been ingested by a single cobia. Similar behavior was found in a study conducted at Parcel Manoel Luís Marine State Park in the State of Maranhão (Brazil), where two specimens of the ray *Dasyatis marianae* (Gomes; Rosa; Gadig, 2000) were found in an adult cobia stomach (Gomes et al., 2000). Moreover, apart from being prey for cobia, Smith and Merriner (1982) report that an association can occur between the cobia and the ray *Rhinoptera bonasus* Mitchill 1815, in which the former benefits from the sediment suspended by the latter to feed on benthic organisms. This behavior has also been reported between cobia and *Epinephelus itajara* in Brazil (Felix and Hackradt, 2008), including cobia stimulation of grouper movement in order to benefit from the disturbing of the sandy seabed around artificial reef, similar environment to which the present study was developed.

Other items found in the stomach contents of cobia, such as calcareous algae, coral debris, small scraps of gastropod mollusks, shells of bivalves and algae of the genus *Halimeda*, were not considered prey items in the analyses due to the possibility of incidental ingestion during the capture of an effective prey item. The occurrence of other organisms not considered as food items is also reported in studies conducted in the USA. Leaves of seagrass (*Zostera marina* L.), small oyster shell fragments (*Crassostrea virginica* Gmelin 1791) and small gastropods have been found in the stomachs of specimens of *R. canadum* on the coast of the State of North Carolina (Smith, 1995), whereas small mollusk shells and crustacean larvae and post-larvae have been found in the stomachs of specimens in the Gulf of Mexico (Franks et al., 1996). Although these items supposedly do not compose the diet of cobia, the data indicate that this species feeds near the bottom.

Predators generally use vision to locate their prey and foraging is more common during twilight hours (dawn and dusk) (Zavala-Camin, 1996). The feeding of cobia seems to follow this pattern, as higher fullness indices occurred in the 6:00 to 9:00 h and 15:00 to 18:00 h time periods. The feeding pattern of the species is similar to that described for juveniles in the Gulf of Mexico (Franks et al., 1996), although the fullness indices were twofold higher in the study cited than the present investigation, which is likely related to differences in sample size in each study. The fact that the squirrelfish was the main food item in the present study must be associated with the nocturnal habits of this prey (Greenfield, 1981).

Although a large portion of the prey items were between 1 and 20 cm in length, the cobia on the coast of Pernambuco also ingested large prey items, such as specimens of *M. ocellatus* (63 cm) and *R. percellens* (48 cm) caught by individuals measuring 137 and 114.5 cm fork length, respectively. According to Costa-Bomfim et al. (2014), carnivorous fishes, such as the cobia, can ingest large organisms by distending their stomachs, thereby increasing their food storage capacity and allowing individuals to become satiated with a single large meal.

Albeit the pattern suggested for carnivorous predators is to consume larger prey items as a way to make energy intake more efficient (Zavala-Camin, 1996), approximately 70% of the organisms consumed by cobia were less than 20 cm in length. This apparent preference for smaller prey organisms may be related to their greater vulnerability to the attack of predators (Juanes and Conover, 1994; Lucena et al., 2000).

The lack of significant differences in feeding habits between males and females is similar to the habits reported in the northern Gulf of Mexico, where crustaceans were the dominant food in both sexes (Meyer and Franks, 1996). In the northern Gulf of Mexico larger cobia consumed fish with significantly greater frequency than did smaller cobia, that consumed more crustaceans. This may reflect an ontogenetic shift toward fish as prey in larger cobia

(Meyer and Franks, 1996). In Pernambuco, in terms of the two length classes analyzed, no significant differences were found, which may reflect the low availability of crustaceans as prey in the study area.

CONCLUSIONS

The broad variety of food items consumed by the cobia, associated with the high number of stomachs containing food, demonstrates that the cobia on the coast of Pernambuco, northeastern Brazil, is a non-selective voracious predator, whose feeding is apparently more related to the availability of food sources in the environment. Moreover, the fact that this species feeds preferentially on prey with demersal habits suggest that feeding occurs near the bottom, around coral reefs or shipwrecks.

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