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REPRODUCTION ASPECTS OF COBIA CAUGHT IN PERNAMBUCO COAST, NORTHEASTERN BRAZIL*

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† *In memoriam* of Fábio Hissa Vieira HAZIN.

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ABSTRACT

Aspects of the reproduction of cobia (*Rachycentron canadum*) population from the coast of Pernambuco State, Northeastern Brazil, were studied from February 2004 to August 2006. One hundred eleven individuals were analyzed: 54 females with fork length (FL) ranging from 40 to 137 cm (mean ± standard deviation: 90.7 ± 18.1 cm) and 57 males with FL from 43 to 114.5 cm (82.4 ± 17.0 cm). Histological analysis was used to identify maturational phases. Spawning capable females were found from August to May, except in December, while mature males were present throughout the year, except in July. Size at first maturity (L_{50}) obtained by Bayesian analysis was 72.51 cm FL for females and 60.69 cm FL for males. Overall batch fecundity ranged from 192,063 to 1,600,513 oocytes (722,398 ± 430,911) and mean relative batch fecundity ranged from 32.9 to 104.8 (71.1 ± 29.8) oocytes *per* gram of female body weight. The data indicate that the reproduction of cobia off the coast of Pernambuco occurs throughout the year, but with peaks between February and April, period in which gonadosomatic indices reach the maximum values and then decrease until May for females and males.

Keywords: batch fecundity; marine fish; sexual maturity; spawning season; fish reproduction.

ASPECTOS DA REPRODUÇÃO DO BEIJUPIRÁ CAPTURADO NA COSTA DE PERNAMBUCO, NORDESTE DO BRASIL

RESUMO

Aspectos da reprodução do beijupirá (*Rachycentron canadum*) na população da costa do Estado de Pernambuco, Nordeste do Brasil, foram estudados de fevereiro de 2004 a agosto de 2006. Cento e onze indivíduos foram analisados, 54 fêmeas com comprimento zoológico (CZ) variando de 40 a 137 cm (média ± DP: 90,7 ± 18,1 cm), e 57 machos com CZ de 43 a 114,5 cm (82,4 ± 17,0 cm). Foi utilizada a análise histológica para identificar as fases de maturação. Foram encontradas fêmeas maduras de agosto a maio, exceto em dezembro, enquanto machos maduros foram presentes ao longo de todo o ano, exceto em julho. O tamanho de primeira maturação (L_{50}), obtido por análise Bayesiana, foi de 72,51 cm CZ para fêmeas e 60,69 cm CZ para machos. A fecundidade total do lote variou de 192.063 a 1.600.513 oócitos (722.398 ± 430.911) e a fecundidade média relativa do lote variou de 32,9 a 104,8 (71,1 ± 29,8) oócitos por grama de peso corporal de fêmeas. Os dados indicam que a reprodução do beijupirá na costa de Pernambuco ocorre ao longo do ano, com picos entre fevereiro e abril, período em que os índices gonadossomáticos alcançam os valores máximos e depois decrescem até maio para fêmeas e machos.

Palavras-chave: fecundidade em lote; peixe marinho; maturidade sexual; período reprodutivo; reprodução de peixe.

INTRODUCTION

The cobia, *Rachycentron canadum* (Family Rachycentridae), is widely distributed in tropical and subtropical waters, except the eastern portion of the Pacific (Shaffer and Nakamura, 1989), and can achieve 165.1 cm of fork length and 62.2 kg of total weight (Franks et al., 1999). The world fishery production of the species was 16,228 tonnes (t) in 2017, with Iran being the major producer (5,252 t). In Brazil, catches are rare and are estimated at 880 t (FAO, 2020), mainly related to sport fishing (spearfishing) and, on a smaller scale, artisanal fishing (IBAMA, 2008).

The cobia has been indicated for aquaculture due to its rapid growth (Arnold et al., 2002; Chou et al., 2004; Benetti et al., 2008), excellent meat quality (Craig et al., 2006; Liao and Leaño 2007), and successful spawning in captivity (Franks et al., 2001; Arnold et al., 2002; Peregrino Junior et al., 2014). Owing to these characteristics, the aquaculture production of cobia reached 49,572 t in 2017, the major producers of which were China, Taiwan, Panama, and Vietnam (FAO, 2020).

Studies conducted in the USA indicate that the species spawns preferentially at the spring and summer seasons (Biesiot et al., 1994; Brown-Peterson et al., 2001), performing multiple spawning throughout the reproductive season, which extends from April to September in the northern hemisphere (Lotz et al., 1996). In the Gulf of Mexico, spawning occurs in areas distant from the shore (30 to 40 miles), where larvae (13 to 15 mm in standard length - SL) are found, whereas larger individuals (45 to 140 mm SL) are found close to the coast (Dawson, 1971). However, the presence of eggs in the area surrounding Chesapeake Bay in the USA (Joseph et al., 1964) as well as eggs and larvae in estuarine waters in the state of South Carolina (USA) (Lefebvre and Denson, 2012) indicate that reproduction also occurs in areas close to the coast or even in estuaries with high salinity. A similar pattern is found in the southern hemisphere, with a spawning period spanning from September to June in Australia, which are the warmest months of the year (Van der Velde et al., 2010).

Mean size at first maturity is estimated to be 78.4 cm in fork length (FL) for females in Australia (Van der Velde et al., 2010), whereas males in Chesapeake Bay (USA) reach maturity in the second year of life at 51.8 cm FL and females become mature at three years of life at 69.6 cm FL (Richards, 1967). Mean fecundity in females weighing 10 kg is 1.8 x 10^6 eggs *per* spawn in the USA (Brown-Peterson et al., 2001; Arnold et al., 2002; Weirich et al., 2007), while mean fecundity in Australia was estimated to be 2.8 x 10^6 eggs (Van der Velde et al., 2010).

Although the cobia has been indicated for marine aquaculture activities in Brazil, information on the biology of this species is scarce (Hamilton et al., 2013). The deficiency or lack of scientific data on biology (specifically reproductive biology) is a limiting factor for the development of aquaculture (Godinho, 2007). Considering the scarcity of information on the reproduction of cobia in Brazilian waters, the aim of the present study was to evaluate some aspects of the reproduction (*e.g.*, spawning season, size at first maturity, type of spawning and batch fecundity) of the species from the Pernambuco coast, Northeastern of Brazil.

MATERIAL AND METHODS

The individuals analyzed in the present study were caught off the coast of the state of Pernambuco, Brazil (07°35'S - 034°49'W and 08°54'S - 035°09'W) at isobaths of 20 to 45 m between February 2004 and August 2006 by artisanal handline operations and sport fishing (spearfishing). The samples were transported on ice to the laboratory for analysis.

In the laboratory, the specimens were measured for the determination of total weight (TW, in g) and fork length (FL, in cm). The specimens were then eviscerated. The gonads were weighed (GW, in g), fixed in a 10% formalin solution for 48 hours, and stored in 70% ethanol.

The proportion of males and females in relation to length classes was compared using the chi-square test (χ^2) at a 5% level of significance considering an estimated proportion of 1:1 (Zar, 2010). The weight-length relationship (WLR) of the species was calculated using the exponential model ($TW = aFL^b$) and the confidence interval (CI_{95}%) of the intercept (a) and slope (b) were calculated (Froese, 2006). The effect of sex on the WLR was tested by ANCOVA (Statistica 8 program, StatSoft Inc., Tulsa, USA).

Size at first maturity (L_{50}) for females and males was defined as the FL at which 50% of the population is mature (Doll and Lauer, 2013) and was estimated using Bayesian inference, assuming binomial distribution. For such, the runjags package (Denwood, 2016) was implemented in R version 3.5.1 (R Core Team, 2018). The interval of credibility ($ICr_{95\%}$) for θ is the interval delimited by 2.5 and 97.5% of the posterior distribution.

The microscopic analysis was performed in females (n = 42) and males (n = 55) using cuts from the middle portion of the gonads, since no differences are found between the anterior, middle, and posterior portions in *R. canadum* (Lotz et al., 1996; Van der Velde et al., 2010). The fragments were dehydrated in increasing concentrations of ethanol (80%, 90%, 100% I, and 100% II), cleared in xylol I/II, and finally impregnated and embedded in liquid paraffin at 60°C. The blocks were cut to a thickness of 5 µm using a microtome (LEICA®) and stained with hematoxylin-eosin (Junqueira and Carneiro, 2013). The slides were analyzed under a light microscope (Trinocular NIKON 50i). The gonads of males were classified as immature (without spermatozoa stored in the seminiferous tubules) or mature (with spermatozoa stored in the seminiferous tubules), according to Shinozaki-Mendes et al. (2007). The scale proposed by Brown-Peterson et al. (2011) was used for the maturation phases of the females, which were classified as:

. Immature – only presence of oogonia and primary growth oocytes - PG;

. Developing – presence of PG, cortical alveolar oocytes – CA; primary and secondary vitellogenic oocytes - Vtg1 and Vtg2, respectively;

. Spawning capable - presence of tertiary vitellogenic oocyte - Vtg3; late germinal vesicle breakdown – GVBD; hydration, ovulation, or newly collapsed postovulatory follicle complex – POF;

. Regressing – atresia and POFs present, some CA and/or Vtg1 and Vtg2 oocytes present;

. Regenerating – only oogonia and PG oocytes present and thick ovarian wall.

After the classification of the maturation phases of females and males, the results were grouped monthly, independently of the year of the capture, for the identification of the spawning period. The gonadosomatic index (GSI) of females and males (without immature individuals) was determined according to Vazzoler (1996), as follows:

$$GSI = (GW / TW) \times 100$$

The GSI data were grouped in monthly periods by the year of capture for the identification of annual reproductive peaks. Statistical analysis was not performed for this parameter due to the small sample number (n) and the imbalance in the number of specimens over the period analyzed.

For the analysis of spawning type, the maximum diameter of 120 oocytes were measured in stereoscopic microscope from each of four spawning capable females and the frequency distribution *per* oocyte diameter class was determined. Spawning type was classified based on Murua and Saborido-Rey (2003).

The gravimetric method was used for the analysis of batch fecundity (Fb) (Murua et al., 2003). For this purpose, three subsamples (w_i, mean weight: 0.52 ± 0.02 g) were removed from seven spawning capable ovaries (females with TW between 6.0 and 16.1 kg). The material was immersed in Gilson's fluid for the complete dissociation of the oocytes. The number of mature oocytes (diameter: >700 µm) were counted (Brown-Peterson et al., 2001). The subsample data were extrapolated to the total gonad weight (GW) using the following equation:

$$Fb = [(\sum_i o_i / w_i) / 3] \, x \, GW,$$

in which o_i is the number of mature oocytes contained in the subsample with weight w_i. The relative fecundity of the batch was expressed as the number of mature oocytes *per* gram of female weight (without the ovary).

RESULTS

During the study, 111 cobia specimens were collected: 54 females with FL ranging from 40.0 to 137.0 cm (mean ± standard deviation: 90.7 ± 18.1 cm) and TW ranging from 400 to 29,800 g (8,576 ± 4,933 g); 57 males with FL ranging from 43.0 to 114.5 cm (82.4 ± 17.0 cm) and TW ranging from 700 to 13,500 g (6,605 ± 3,455 g). The overall proportion of females to males was 1:1.05, with no significant difference found in the sex ratio ($\chi^2 = 0.59$, df = 1, $p = 0.442$).

The analysis of the regression coefficients of the WLR for females and males were not significantly different (ANCOVA; df = 110, F = 0.672, $p = 0.414$). Therefore, the model was determined for both sexes pooled and represented by the function $TW = 5.6 \times 10^{-3} FL^{3.137}$ ($R^2 = 0.971$, $p < 0.001$). A summary containing the regression coefficients for females and males is given in Table 1.

Size at first maturity (L_{50}) was 72.5 cm FL for females ($ICr_{95\%}$ = 63.2 - 78.5 cm) and 60.7 cm FL for males ($ICr_{95\%}$ = 56.4 - 65.5 cm). The smallest adult female in the samples measured 70.0 cm FL and was in the regeneration phase. The smallest adult male was 61.0 cm FL.

Histological analyses were performed on 42 females. Females in all phases of development were found throughout the period analyzed. In immature females it was possible to observe the primordial cells (oogonia and primary growth oocytes - PG) and a thin ovarian wall (Figure 1a). Primary growth oocytes were also observed at developing phase, but together with primary and secondary vitellogenic oocytes (Figure 1b). The spawning capable females showed mature ovary with presence of vitellogenic oocytes (Vtg3), germinal vesicle breakdown (GVBD) and atresic oocytes (Figure 1c). The regenerating phase presented oogonia and PG oocytes, with wider lamellae space (Figure 1d). The main difference between the regenerating and immature phase were the thick ovarian wall and more space between the lamellae in the regenerating phase. Duet to the scale used for males (immature and mature), the maturational phase of males was presented in Table 2.

The pattern evidenced by the three different batches of oocytes (around 200, 400 and 800 µm) presented by the spawning capable females (Figure 2) as well as the presence of oocytes in several stages in the histological slides of females in the developing and spawning capable phases demonstrate that the species has gonads with asynchronous oocyte development, which characterizes the cobia as a batch spawner.

Females in the spawning capable phase were found in all months of the year, except June, July, and December (Table 2). However, the higher female GSI values in February-March (3.62 and 4.01, respectively) and their following decrease until April-May suggest the occurrence of a spawning peak in the early part of the year (Figure 3a). Mature males were present throughout the year, except in July, when the males collected (n = 3) were immature (Table 2). The highest GSI values for males were found in the same period (February and March, 3.07 and 3.79, respectively) as those of females (Figure 3b).

Absolute batch fecundity among females ranged from 192,063 to 1,600,513 oocytes (733,386 ± 464,224 oocytes), demonstrating a positive linear relationship between the number of oocytes in the batch and weight of the female (in g), represented by the function Fb = 133.8 TW – 568,347 ($R^2 = 0.749$, $P = 0.012$). Relative batch fecundity ranged from 32.9 to 104.8 oocytes *per* gram of weight of the female (71.1 ± 29.8 oocytes g^{-1}).

Table 1. Parameters estimates for weight-length relationship ($TW = a FL^b$; TW = total weight; FL = fork length) of *Rachycentron canadum* caught off Pernambuco coast, Northeastern Brazil, for females, males, and pooled sexes and respective confidence intervals ($CI_{95\%}$).

Sex	n	R^2	*a*	*b*
Females	54	0.971	0.0042 (0.0021 - 0.0084)	3.196 (3.043 - 3.349)
Males	57	0.970	0.0061 (0.0032 - 0.0117)	3.121 (2.973 - 3.269)
Pooled sexes	111	0.971	0.0056 (0.0035 - 0.0088)	3.137 (3.034 - 3.241)

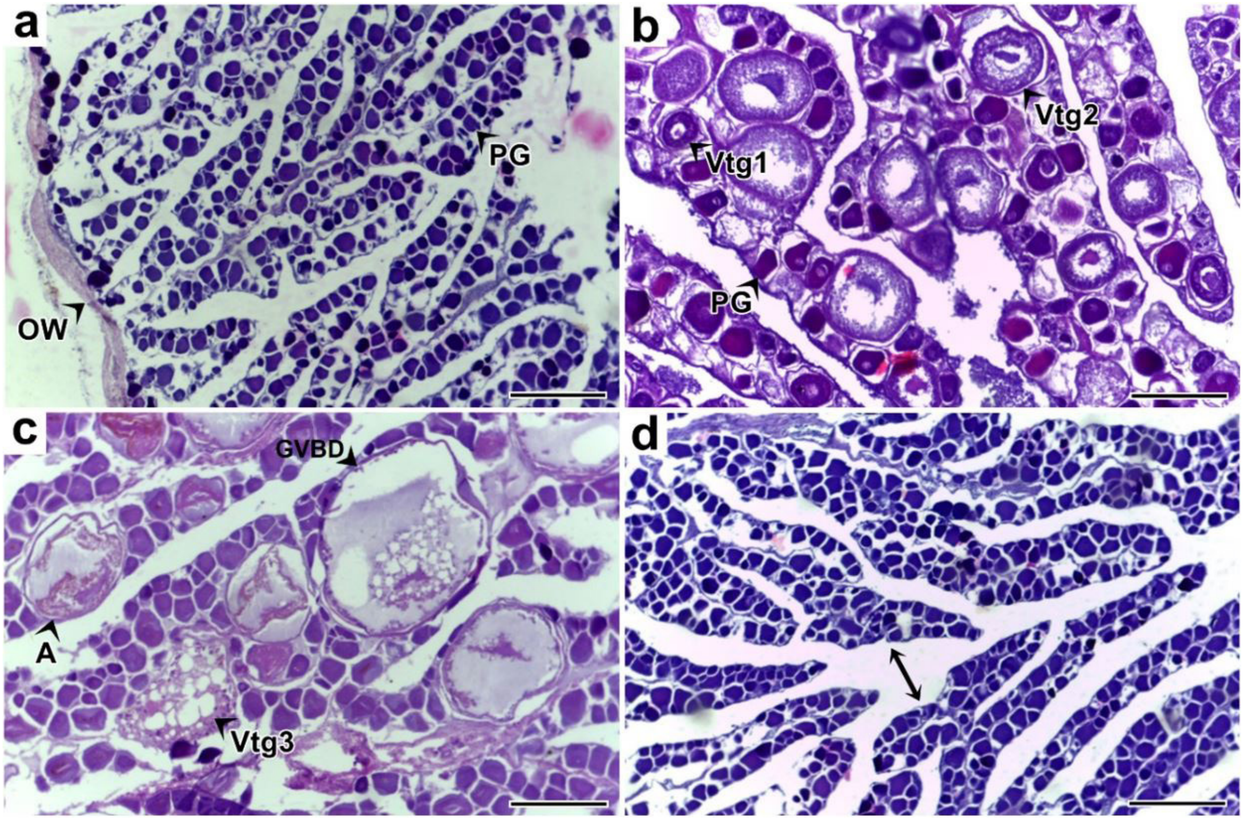

Figure 1. Photomicrographs of ovarian histology illustrating the reproductive phases of *Rachycentron canadum* caught off Pernambuco coast, Northeastern Brazil.: a) Immature phase with primary growth oocytes (PG), showing ovarian wall (OW); b) Developing phase, with oocytes in PG stage, primary vitellogenic oocytes (Vtg1), synchrony of secondary vitellogenic oocytes (Vtg2); c) Spawning capable phase presenting synchrony of tertiary vitellogenic oocytes (Vtg3), atresic oocyte (A), and germinal vesicle breakdown (GVBD); d) Regenerating phase, with oogonia and PG oocytes present; arrow indicates thickening of lamellae. Hematoxylin and eosin (HE) staining. Scale bar: 200 µm.

Table 2. Monthly distribution of *Rachycentron canadum* caught off Pernambuco coast, Northeastern Brazil. Data grouped independently of year of sample. Maturation phases based on histological analysis of females and males (I – Immature; II - Developing; III – Spawning capable; IV – Regressing; V – Regenerating; NC - not classified).

	Maturation phases									Total
	Females (n = 54)						Males (n = 57)			
	I	II	III	IV	V	NC	Immature	Mature	NC	
Jan	-	1	1	-	-	-	2	1	-	**5**
Feb	-	-	4	-	1	1	-	4	1	**11**
Mar	2	2	2	-	1	3	-	14	-	**24**
Apr	-	-	2	-	-	-	-	6	1	**9**
May	-	-	1	-	1	4	-	1	-	**7**
Jun	-	-	-	-	-	-	2	2	-	**4**
Jul	2	-	-	-	-	1	3	-	-	**6**
Aug	-	-	2	-	-	1	-	4	-	**7**
Sep	1	1	1	-	-	-	-	3	-	**6**
Oct	1	-	2	1	2	1	-	1	-	**8**
Nov	1	2	2	-	1	1	-	9	-	**16**
Dec	-	5	-	-	-	-	1	2	-	**8**
Total	**7**	**11**	**17**	**1**	**6**	**12**	**8**	**47**	**2**	**111**

DISCUSSION

The sex proportion of cobia is generally favorable to females in studies conducted in Northeastern Australia (Van der Velde et al., 2010), and Gulf of Mexico, USA (Lotz et al., 1996; Franks et al., 1999; Brown-Peterson et al., 2001), but the dominance of males can also occur in other areas of the Gulf of Mexico, USA (Thompson et al., 1992). In the state of North Carolina (USA), a sex ratio of 1:1 was reported for the species (Smith, 1995), which is similar to that found in the present study. A 1:1 sex proportion in the reproductive period could increase the odds of successful spawning (Pinheiro et al., 2011). Some species could exhibit changes in the sex proportion due to reproductive behaviors in particular periods of the year (Vazzoler, 1996). However, this type of analysis could not be performed in the present study due to the low catch rates of the species during the winter. Female dominance can also occur due to the predominance of this sex in larger length classes, as cobia females are larger than males of the same age (Smith, 1995; Franks et al., 1999). Although the length-weight relationships between the sexes did not differ significantly, studies have reported that females are typically larger than males, as described for *R. canadum* populations from the USA (Thompson et al., 1992; Smith, 1995; Franks et al., 1999).

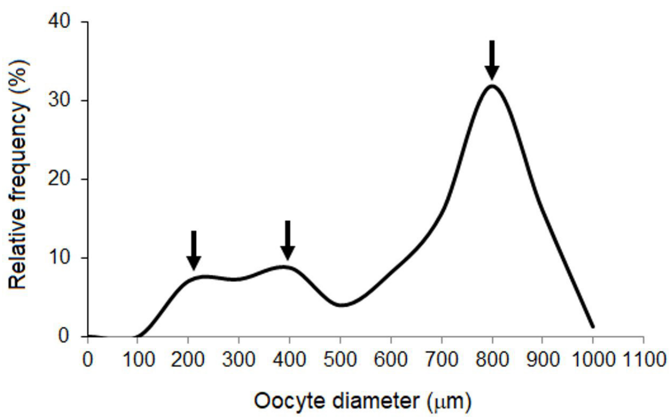

Figure 2. Frequency distribution of oocyte diameter of *Rachycentron canadum* females at spawning capable phase caught off Pernambuco coast, Northeastern Brazil. Arrows indicate the different batches of oocytes.

The low number of individuals smaller than 70 cm FL (14.4%) may be explained by the origin of the samples, since sport fishing (spearfishing) is more selective and directed at larger individuals. The distribution of length classes was similar to that described in previous studies on the species conducted in the USA (Richards, 1967; Smith, 1995; Arendt et al., 2001), Australia (Fry and Griffiths, 2010), and the Indian Ocean (Darracott, 1977). However, regulations in the USA and Australia establish a minimum catch size of 84 and 75 cm FL, respectively, which favors the sampling of larger individuals, especially females, as the samples in these countries come from sport fishing or commercial vessels (Franks et al. 1999, Fry and Griffiths, 2010).

Size at first maturity for females on the coast of Pernambuco (72.5 cm FL) was lower than that reported by Van der Velde et al. (2010) on the northeastern coast of Australia (78.4 cm FL). In the Gulf of Mexico (USA), it was not possible to define size at first maturity for the species due to the rarity of immature specimens in the samples as a result of the minimum catch size of 84 cm FL (Brown-Peterson et al., 2001). The smallest reproductively active female on the coast of Pernambuco was 70 cm FL, which is very close to the 67.1 cm FL reported for the northeastern coast of Australia (Van der Velde et al., 2010). In Chesapeake Bay, USA, male cobias reach maturity in the second year of life at 51.8 cm FL, whereas females reach maturity in the third year of life at 69.6 cm FL (Richards, 1967). In the Gulf of Mexico, maturity in females is reached at a size 13.8 cm larger than that found for females in Chesapeake Bay. This discrepancy may reflect the slower growth rate in the colder waters of Chesapeake Bay,

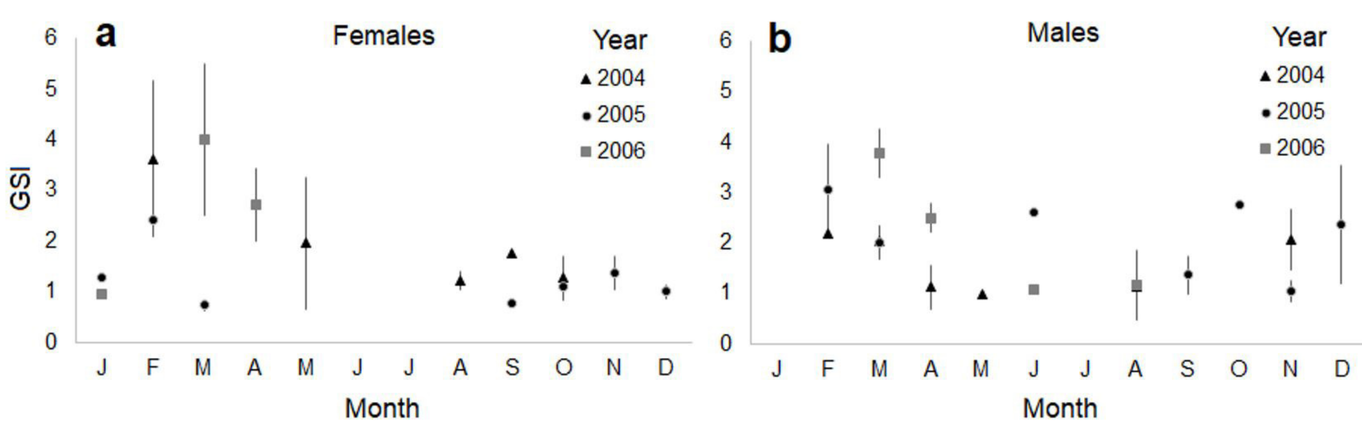

Figure 3. Monthly mean gonadosomatic index (GSI) of *Rachycentron canadum* caught off Pernambuco coast, Northeastern Brazil: a) GSI of female (n = 35); b) GSI of male (n = 47). Vertical bars indicate the standard error (values without a bar, indicate a single value in the sampled month).

where females measuring 70 cm FL are two years of age, whereas those at this age in the Gulf of Mexico are 85 cm FL (Lotz et al., 1996). However, despite the higher temperature on the coast of Pernambuco, Brazil, the size at first maturity was similar to that found in Chesapeake Bay (Richards, 1967), which contradicts the hypothesis of the effect of temperature on growth. This finding may be related to the existence of two distinct populations, as suggested by Darden et al. (2014), or due to the fishing pressure on the rare cobia population. However, we have no data available to confirm this hypothesis.

The occurrence of spawning capable females throughout the entire year indicates that the species has prolonged reproduction in Northeastern Brazil. In the USA, reproduction occurs between April and September (Shaffer and Nakamura, 1989; Brown-Peterson et al., 2001), which corresponds to the warmer months in the northern hemisphere. In Australia, spawning extends from September to June, based on histological analyses and the variation in the GSI, with less reproductive activity in July and August (Van der Velde et al., 2010). The presence of males with sperm in the seminiferous tubules throughout the entire year indicates that males are capable for reproduction throughout the year, which is similar to the pattern found in the Gulf of Mexico (Brown-Peterson et al., 2001).

Mean GSI values for females and males on the coast of the state of Pernambuco were higher in February and March and then decreased until May, which indicates peak spawning between March and April. A similar pattern is found in the USA, where higher GSI values are reported for May and August, corresponding to late spring and summer in the northern hemisphere (Brown-Peterson et al., 2001). Temperature seems to be an important factor for spawning in tropical and subtropical pelagic species. Although different species of tunids exhibit different spawning patterns, a common characteristic is the relationship between reproductive activity and sea surface temperature above 24ºC (Schaefer, 2001). The prolonged spawning season of cobia on the northern coast of Australia seems to be influenced by this environmental factor, as the surface temperature of the region remains above 24ºC throughout the entire year (Van der Velde et al., 2010).

Indeed, the strategy of raising water temperature in the tanks of breeders in captivity to extend the spawning period is a common practice. In a study conducted in the state of Pernambuco, Brazil, the authors were able to prolong the reproduction of cobia from October to June by maintaining the water temperature at 28.3ºC. However, it is believed that this occurs not only through the maintenance of favorable environmental conditions, but also due to the abundant provision of food sources of high nutritional quality (Peregrino Junior et al., 2014). In the USA, reproduction in captivity was achieved at temperatures between 26 and 28ºC (Arnold et al., 2002). In the coastal region of Pernambuco, the sea surface temperature ranges from 27.5 to 28.8ºC in summer and 26.3 to 27.2ºC in winter (Domingues et al., 2017). Thus, conditions are favorable to reproduction throughout the year. In contrast, cobia reproduction occurs in a more restricted period (June to August) in Chesapeake Bay, USA, where the water temperature has a wider range (Joseph et al., 1964). Temperature also seems to be an important factor for the reproduction of the common dolphinfish (*Coryphaena hippurus*), which is a species of the family Coryphaenidae that has phylogenetic similarity to the cobia (Johnson, 1984) and also exhibits increased reproductive activity in the warm months of the summer (Santos et al., 2014).

Although the post-ovulatory follicles (POFs) were absent at the samples collected on the coast of Pernambuco, after spawning, the POFs have no endocrine function and are quickly reabsorbed, which involves programmed cell death or apoptosis of the follicular cells (Drummond et al., 2000). Given this information and considering that this developmental stage occurs within a very short span of time (Van der Velde et al., 2010), this could explain the absence of POFs in the female slides in the present study. In the Gulf of Mexico (USA), no hydrated oocytes were found, but this may have occurred because the catches were performed with lines and hooks and females do not feed during the reproduction period or due to the fact that the catches were performed during the day, whereas spawning is believed to occur at night (Lotz et al., 1996). However, observing the reproduction of the species in captivity, Peregrino Junior et al. (2014) found an increase in the belly volume of females throughout the day, which was believed to be related to the hydration of oocytes.

The spawning site of the species differs among different studies. The collection of eggs and larvae at the entrance to Chesapeake Bay (Joseph et al., 1964) and in coves in the state of North Carolina (Smith, 1995) suggest spawning near the coast. The presence of females with high mean GSI values, recently fertilized eggs and larvae also demonstrate spawning in estuaries in the state of South Carolina (Lefebvre and Denson, 2012). On the other hand, the presence of eggs and larvae from the species on the continental shelf of the Gulf of Mexico suggests spawning at 50 to 90 km from the coast (Ditty and Shaw, 1992). This difference may be explained by genetic studies, which demonstrate a genetically homogeneous group in the open sea and two groups in sheltered areas in the state of Virginia and South Carolina, USA, which are genetically distinct from one another and from the group analyzed in the open sea (Darden et al., 2014).

The gonads of spawning capable cobia females had oocytes in several stages, which characterized asynchronous development (Murua and Saborido-Rey, 2003). This pattern has been reported for the species in other regions of the world, such as the Gulf of Mexico (Biesiot et al., 1994; Lotz et al., 1996; Brown-Peterson et al., 2001), Australia (Van der Velde et al., 2010), and India (Sajeevan and Kurup, 2016), as well as for other species of migrating pelagic fish (Hunter et al., 1985). Many species with multiple spawning throughout the year in warm regions exhibit the continuous recruitment of oocytes as a strategy to increase fecundity and spawning capacity over an extended period (Lowerre-Barbieri et al., 2011). Multiple spawning may be a strategy to release eggs for a long period of time, thereby increasing the probability of the survival of descendants (Lambert and Ware, 1984; Hunter et al., 1985). It may also be a need in species with high fecundity, in which the coelomic cavity may become a limiting factor due to the accentuated increase in gonad volume during oocyte hydration (Chaves, 1989).

In a study conducted in the Gulf of Mexico, batch fecundity (oocytes larger than 700 µm) ranged from 3.7×10^5 to $1.9 \times$

10^6 (Brown-Peterson et al., 2001), which is close to the range found in the present study (1.9 x 10^5 to 1.6 x 10^6), in which only oocytes larger than 700 µm were also considered. In contrast, batch fecundity in other studies conducted in the USA ranged from 1.9 to 5.4 x 10^6 in Chesapeake Bay (Richards, 1967) and 2.6 x 10^6 to 1.9 x 10^8 in the Gulf of Mexico (Lotz et al., 1996). However, oocytes with a diameter >500 µm and 550 µm, respectively, were considered mature. According to these authors, this cutoff point may have led to an overestimation of the oocytes in the batch to be spawned. In a study conducted in Australia, batch fecundity ranged from 5.7 x 10^5 to 7.3 x 10^6 eggs, with a mean of 7.6 days between spawns (Van der Velde et al., 2010). Faulk and Holt (2008) obtained an average of 1.3 and 2.3 x 10^6 eggs from captive-spawned cobia and highlighted that batch fecundity was increased with broodstock size. Other study evaluating the reproductive performance of female cobias in captivity with a water temperature of 28.3 ± 0.7ºC, achieved 21 spontaneous spawns, mainly at dusk, with a mean of 2.4 x 10^6 oocytes *per* spawn (Peregrino Junior et al., 2014), which is a higher fecundity in comparison to the present study conducted with specimens of a similar size. However, the more stable environmental conditions and frequent offer of quality food sources may explain the greater fecundity of the captive females.

CONCLUSIONS

Although the results should be considered with carefulness, due to the low number of samples, the present study is the first to address the reproduction of the cobia in the natural environment in Brazil and brings important information about the population of the species on the coast of the state of Pernambuco. The present findings indicate that the reproduction of cobia on the coast of the state of Pernambuco, Brazil, occurs in a prolonged manner throughout the year, with peaks in months in which the sea temperature is warmer (March to April). The size at first maturity of females (72.5 cm FL) and males (60.7 cm FL) indicates the minimum catch size for the formation of broodstock and the high batch fecundity (mean = 722,398 oocytes) suggests that the species has high potential to produce juveniles in captivity, which constitutes the first and most complex step in the establishment of aquaculture activities.

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