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Maturity, spawning and feeding intensity of cobia *Rachycentron canadum* (Linnaeus, 1766) in northwest coast of India

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Abstract

An attempt was made to provide some vital aspects of reproductive biology of cobia *Rachycentron canadum* (Linnaeus, 1766). Samples for a period of two years from an exploratory vessel and from the landing centers of Mumbai were used for the study. The average sex ratio between males and females observed was 1:0.80. Dominance of the number of females above the size of 100 cm was noticed. The size at first maturity of males and females was 72 and 83 cm, respectively. Similarly, age at first maturity of males and female was estimated at 1.77 and 2.17 years, respectively. Spawning season was based the on occurrence of five maturity stages and Gonadosomatic index (GSI) values indicated a throughout the year spawning behavior with peak spawning activity during July-August and November-January. Percentages of feeding condition of various maturity stages indicated that cobia take very less food during their spawning period.

Keywords: *Rachycentron canadum*, Maturity, Feeding intensity, Sex ratio

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Introduction

Cobia, *Rachycentron canadum* is a coastal pelagic, fast growing fish, distributed worldwide in tropical and subtropical seas except for the eastern pacific (Sajeevan, 2011). The adult fish inhabits coastal waters and occasionally enters estuaries. In India, they occur along the coastal waters of both the west and east coast (Sajeevan and Kurup, 2014b).

Pioneer study on the reproductive biology of cobia *R. canadum* (Linnaeus, 1766) is that of Day (1878). However, the study of Goode (1884) is considered as a milestone in this field. Hildebrand and Schroeder (1928), Joseph *et al*. (1964), Richards, (1967), Erdman (1968), Dawson (1971), Swingle (1971), Schwartz (1972, 1981), Finucane *et al.* (1978), Franks *et al*. (1991), Ditty and Shaw (1992), Biesiot *et al.* (1994), Smith (1995), Lotz *et al.* (1996), Franks *et al*. (1999), Brown-Peterson *et al.* (2001), Arnold *et al*. (2002), Kaiser and Holt (2004, 2005) and Tonya *et al*. (2010) reported some information on the maturation, spawning, reproductive behavior and dynamics of cobia. Most of the studies on spawning biology of cobia are based on either very less number of samples collected or for a shorter duration, hence the results have some limitation.

Sajeevan and Kurup (2013, 2014 a, b) provided information on feeding intensity, systematic, distribution and abundance of cobia inhabiting Indian waters. However, information on spawning, maturity, and reproductive behavior of cobia in the Indian waters are scanty. Rajan *et al.* (1968) Somvanshi *et al*. (2000), Pillai *et al.* (2009) and Ganga *et al.* (2012) provided some preliminary information on reproductive biology of cobia inhabiting in Indian waters. Gopakumar *et al.* (2011) and Sakthivel *et al.* (2012) provided information on controlled breeding and embryonic development. The present study is an attempt to provide some vital aspects of reproductive biology of cobia and thereby bridging the knowledge gaps in this field.

Materials and methods

Samples collected from the vessel M.V. *Matsya Nireekshani*, a survey vessel belonging to the Mumbai Base of Fishery Survey of India, Mumbai, and from the local landing centers at Mumbai were used for the present study. 34 m fish trawl, 45.6 m expo model fish trawl and 27 m fish trawl were the fishing gears used for the resource survey. A total of 292 specimens (162 male and 130 female) collected during the period January 2008 to December 2009 were analysed for the study. The total length of fish was measured to the nearest 1 cm and total weight to the nearest 1.0 g. The weight of ovary was recorded to the nearest 0.1g. Data recorded during the same months for the 24 months period were pooled together to understand the month wise variations.

Sex of individual specimens was determined by observing the gonads after dissecting the specimens, whereas the sex of juveniles was identified by microscopic examination of gonads. Stages of maturity of gonads were

determined based on morphological appearance. Five stages were identified through macroscopic observations following Qasim (1973).

The relative ovary weight or Gonadosomatic Index (GSI) was calculated following Yuen (1955). GSI was calculated on a monthly basis. Distribution of different maturity stages during different months were also used for determining the spawning season. The spawning season of the fish was inferred by using values of GSI and the month-wise percentage of mature specimen. Fish were grouped in different length classes of 10cm length groups following Arendt *et al.* (2001). The percentage of the mature fish and immature fish in different size groups was analyzed. The length at which 50 % of fish were mature was considered as length at first maturity (Lm50) of both sexes (Hodgkiss and Man, 1978). To determine Lm50%, fish belonging to maturity stage III, IV, and V were considered as mature fish. Raw maturity data was generally summarized with a logistic regression with required logit transformation. The logistic regression is fit in R with the general linear model (glm) procedure. The glm function is quite general but it is forced to fit a logistic regression by including the family=binomial argument. A general formula for computing this metric was

$X=(\log(p/ 1-p)- \alpha)/\beta 1$

Where, X=Total length, p is the probability of being mature; 1− p is the probability of being immature, α is intercept) and β1=slope. A plot showing the fitted logistic regression line with the individual data and the proportion that are mature for several categories of length and a fitted line plot with the Lm50 was constructed. Lm50 value was substituted in von Bertalanffy growth equation (Von Bertalanffy, 1957) of fish and the age at maturity was estimated. Growth parameters were taken as L_∞ in cm=194.25; K value in L/yr =0.24; t_o in yr = -0.1567 (Sajeevan, 2011).

Month-wise and length wise sex ratio (M:F) was calculated following Philip (1994). Fishes were further grouped into juveniles (below the size at first maturity class) and adults to determine the sex ratio of fish in these life history stages. Sex ratio values were further tested for equality following Chi-square test (Snedecor, 1961; Snedechor and Cochran, 1967).

Variations in feeding intensity during different maturity stages were assessed by recording fullness of stomach of the specimens in different maturity stages. Physical appearance of the fullness of stomach was the criteria used for this categorization. All fishes were then categorized into four groups namely 1.Empty, 2.Poor feeding (traces and ¼ full stomach), 3.Moderate feeding (1/2 full stomach) and 4. Active feeding (3/4 full stomach, full stomach and gorged stomach). Values in percentages of feeding condition were plotted against maturity stages to understand the differential feeding habits of the fish in various maturity stages.

Results

Classification of maturity stages

Five stages identified through the macroscopic observations on external appearance following Qasim (1973) are furnished in Table 1.

Table 1: Macroscopic characteristics of stages of gonadal maturation of female and male of *Rachycentron canadum* following Qasim (1973).

Gonad maturity Stage	Female	Testis
Stage I: Immature	Gonads Usually translucent; occupy nearly one-fourth length of abdominal cavity. Ovaries thin, pinkish with innumerable tiny ova, which are invisible to the naked eye. The surface of the ovary smooth with no sign of blood vessels.	Testis small and occupy nearly 20% of the length of body cavity. They are filamentous and white in color.
Stage II: Maturing virgin/recovered spent	Gonads are either yet to develop or already been discharged. Occupy more than one third length of abdominal cavity, Ovary pinkish, translucent; eggs not visible to naked eye, but can be seen with the help of magnifying glass.	Testis becomes little more thicker and creamy white in color.
Stage III: Ripening-	Gonads about two third length of body cavity, Eggs visible to naked eye. Ovary becomes bright yellow, blood vessels conspicuous with numerous blood capillaries.	Testes enlarged, fleshy and whitish to creamy in color.
Stage IV: Ripe –	Gonads occupy about full length of body cavity. Ovaries orange red in color, blood vessels prominent on the surface and contains large translucent eggs.	Testis whitish- creamy, occupy nearly three fourth length of body cavity. On exerting slight pressure on the testis, milt oozes out.
Stage V: Spent-	Gonads shrunken, having loose walls. Ovaries contain few ripe darkened or translucent eggs.	Testes usually dull white in color and flabby.

Sex ratio

Lengthwise sex ratio of cobia (M:F) obtained during the study showed dominance of males over females in all the size classes up to 100 cm, except 40-50 cm size group (Table 2). The average sex ratio between males and females observed during the period was 1:0.80, showing dominance of males over the females. Month wise sex ratio of cobia (M:F) showed the dominance of males over females in numbers during all the months, except during September.

Table 2: Month-wise, Length-wise sex ratio of *Rachycentron canadum*.

Month	M: F	X^2 value	Mid length of length class in cm	M: F	X^2 value
Jan	0.81	0.31	25	0.32	8.76*
Feb	0.75	1.43	35	0.92	0.09
Mar	0.83	0.18	45	1.24	0.98
Apr	0.92	0.04	55	0.86	0.22

Table 2 continued:

May	0.78	0.25	65	0.53	2.79
June	0.65	1.29	75	0.47	2.91
July	0.71	0.33	85	0.63	0.69
Aug	0.88	0.13	95	0.40	1.29
Sept	1.00	0.00	105	2.00	0.67
Oct	0.71	0.33	115	2.00	0.33
Nov	0.83	0.09	125	1.50	0.20
Dec	0.83	0.09	135	1.00	0.00
Total	0.80	3.51	145	1.00	0.00

* Sex ratio significantly different from 1:1 at 1% confidence level. 1% (5%)

Size at first maturity

Length at first maturity (Lm50) of males was estimated at 72 cm, while in the case of females, it was 83 cm (Figs. 1, 2). By fitting these lengths to the VBGF equation, the age at first maturity of males and females was estimated as1.77 and 2.17 years, respectively.

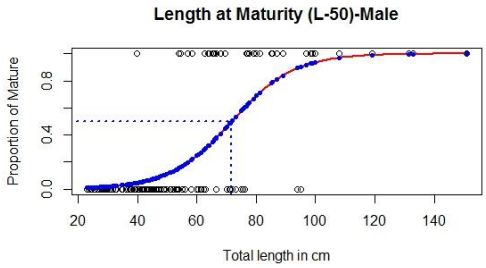

Figure 1: Length at first maturity (Lm50) of male *Rachycentron canadum.*

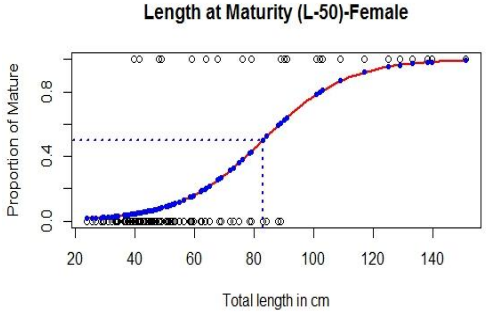

Figure 2: Length at first maturity (Lm50) of female *Rachycentron canadum.*

Spawning season

Month-wise occurrence of maturity stages of Cobia is furnished in Figure 3. As showed in Fig. 3, mature specimens (Maturity stages III to V) were reported throughout the year with varying percentages. Pooled data on percentage of occurrence of mature specimens on a monthly basis for the year 2008 and 2009 and GSI values were plotted against each month (Fig. 4). Mature specimens were observed throughout the year with maximum percentage of occurrence during July, followed by March, December, February and November. This indicates a protracted spawning behavior of the species.

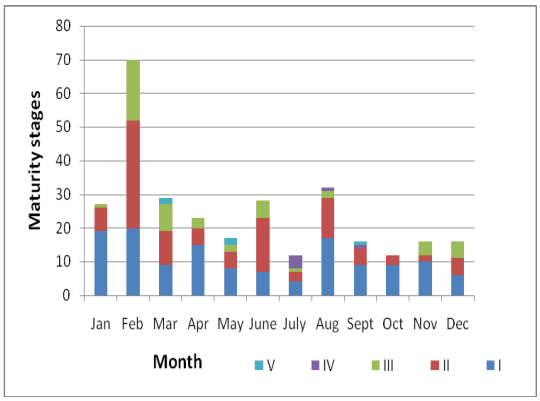

Figure 3: Month wise occurrence of maturity stages of *Rachycentron canadum.*

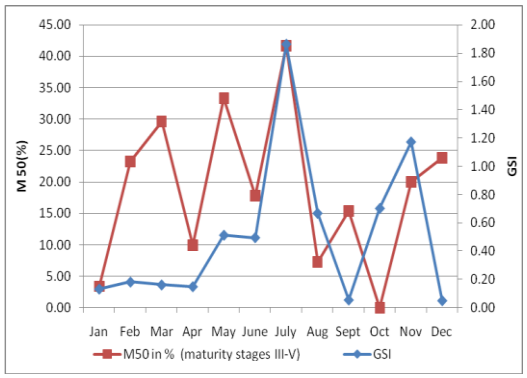

Figure 4: Month-wise occurrence of mature specimens and Gonadosomatic index values of *Rachycentron canadum*.

Variation in GSI values during the period from January 2008 to December 2009 are shown in Fig. 5. The mean monthly G.S.I. fluctuated between 0.05 (September and December) to 1.86 (July). Maximum mean GSI value was recorded during July, followed by November, October and August. From May onwards, GSI values showed an increasing trend with two peaks during July and November. Fluctuations in the GSI values were almost synchronous with the fluctuation of month wise percentage of mature specimens (maturity stages III- V). Moreover, the peak value in GSI. coincided with the peak spawning period**.**

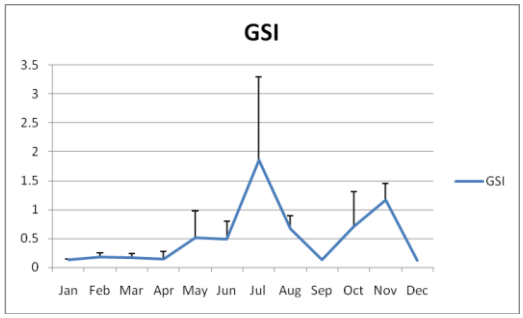

Figure 5: Month-wise Gonadosomatic index values of *Rachycentron canadum*.

Maturity stages and feeding condition

Cobia inhabiting the northwest coast of India mainly feed on fishes (72%), and crustaceans (22%). Percentages of feeding condition based on fullness of stomach of specimens at various maturity stages are given in Fig.6. Feeding intensity of immature fishes was comparatively poor. In contrast to this, the majority of maturing/recovered spent and ripening fishes were found in well fed conditions. Among fully matured fishes (IV stage of maturity), percentage of fishes with empty stomach and poorly fed fishes were 16% and 50% respectively. Meantime, 75% of fishes in spent stage (V stage of maturity) were either moderate or actively fed. This variation in feeding intensity shows that cobia takes very less food during their spawning period.

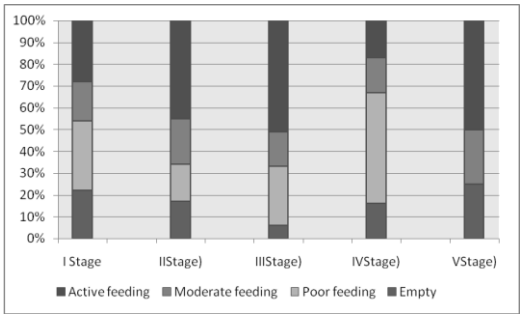

Figure 6: Maturity stages vs feeding condition in *Rachycentron canadum*.

Discussion

Classification of maturity stages

The present study classified maturity stages of cobia into five. Tonya *et al.* (2010) carried out histological analysis of gonads, and observed that cobia follows asynchronous reproduction and results of histological analysis supported the five maturity stage classification of cobia. Moreover, according to Qasim (1973) a five stage maturation classification is more

appropriate for fishes inhabiting tropical waters.

Sex ratio

Sex ratios of *R. canadum* reported from different localities of the cobia habitat are furnished in Table 3. As showed in Table 3, results are at variance. Sex ratio of cobia inhabiting the waters of the northwest cost of India reported by Somvanshi *et al.* (2000) matches with the results of the present study. Here the study area is identical to the present study and results are in concurrence.

Richards (1967), Daghogi *et al.* (2006) and Somvanshi *et al.* (2000) recorded a dominance of males over females. In contrast Richards (1967), Thompson *et al.* (1991), Lotz *et al.* (1996), Franks *et al.* (1999) and Tonya *et al.* (2010) reported a dominance of females over male cobia. Richards (1967) studied sex ratio of cobia along the eastern and western Chesapeake Bay, USA and reported dominance of males over females along the eastern Chesapeake Bay and observed an opposite trend along the western Chesapeake Bay. Results of the above study along the waters of Chesapeake Bay clearly indicate that, sex ratio of cobia may vary in different habitats.

Table 3: Sex ratio, Size at first maturity, Peak spawning season and fecundity of *Rachycentron canadum* reported by various authors from different localities.

Author/s	Area of study	Sex ratio (F:M)	Size at first maturity in cm (TL/FL) Female	Male	Peak Spawning season
Joseph *et al.* (1964)	Chesapeake Bay, USA	NA	NA	NA	Mid June–mid August
Richards (1967)	Chesapeake Bay -East, USA	26:74	69.6(FL)	51.8(FL)	Late June–mid August
	Chesapeake Bay- West, USA	72:28			
Erdman (1968)	Puerto Rican waters	NA	NA	NA	August
Dawson (1971)	Northern Gulf of Mexico	NA	NA	NA	Spring
Finucane *et al*. (1978)	Texas, USA	NA	NA	NA	July-September
Tortonese (1986)	Gulf of Mexico	NA	NA	NA	April-September
Rajan *et al.* (1968)	Chilka lake, India	NA	42.6(TL)	NA	NA
Thompson *et al.* (1991)	Louisiana, USA	2.1:1	NA	NA	May- July
Biesiot *et al.* (1994)	Northern Gulf of Mexico	NA	NA	NA	Spring and summer
Smith (1995)	North Carolina, USA	1:1	70(FL)	-	May- July
Lotz *et al.* (1996)	North central Gulf of Mexico	1:0.36	83.4(FL)	64.0(FL)	April-October
Franks *et al.* (1999)	Northeastern Gulf of Mexico	2.7:1	NA	NA	NA
Somvanshi *et al.* (2000)	North west coast of India	1:1.5	NA	NA	NA
Brown-Peterson *et al*. (2001)	Southern United States of America	NA	NA	NA	April - September
Williams (2001)	Gulf of Mexico	NA	84.5	64	NA
Franks and Brown-Peterson (2002)	Gulf of Mexico, Mexico	NA	NA	NA	April - October
Kaiser and Holt (2005)	Texas, USA	NA	83.4(FL)	64.0(FL)	NA

Table 3 continued:

Daghogi *et al.* (2006)	Northern water of Persian Gulf	1:1.49	NA	NA	NA
Valinasaab *et al.*(2008)	Persian Gulf	1:1.3	-	-	July - September
Tonya *et al.* (2010)	Northeastern Australia	2.18:1	78.4(FL)	77(FL)	September-June
Present study	North west coast of India	0.8: 1	83(TL)	72(TL)	July-August and November - December

Size at first maturity

The present study estimated the size at first maturity of male and female cobia at 72 cm and 83 cm, respectively. 13 mature specimens in the length group of 40-50 cm recorded during the present study indicate that cobia mature early (40- 50 cm) in tropical waters. Rajan *et al.* (1968) reported 42.6 cm long mature female specimens from Chilka Lake (India). Richards (1967) estimated the size at early maturity of male cobia from Chesapeake Bay, USA at 51.8 cm. These findings indicate that cobia mature early in tropical waters.

Sizes at first maturity of cobia reported by different authors from various localities are furnished in Table.3. As depicted in Table 3, size at first maturity reported by various authors reported from different waters ranged from 42.6 cm (Rajan, *et al.* (1968), Chilka Lake, India) to 84.5 cm (Williams (2001) Gulf of Mexico). Results indicate that the size at first maturity of cobia differs from one habitat to other. However, all the studies are concurrent in reporting that size at maturity of male and female differs from each other. Size and age at first maturity depends on the nature of the environment in which the population of the species inhabits (Moyle and Cech, 2000). Hence geographical differences, differences in physicochemical parameters of the habitat, differences in food availability etc can be considered as the major reasons for such variations. The present study is the premier one which estimated the size at first maturity of cobia occurring in Indian waters using the L50 method following logistic curves. Hence there is no available record to compare the values estimated by the present study.

The present study recorded that the male cobia matures at a smaller length than females. Findings of Richards (1967), Lotz *et al.* (1996), Williams (2001), Kaiser and Holt (2005) and Tonya *et al.* (2010) are in full agreement with the results of the study. Faster growth rates recorded for female cobia (Sajeevan, 2011) can be attributed as one of the reasons for this difference in size at first maturity of both the sexes.

Age at first maturity estimated for male and female cobia was 1.77 and 2.17 years, respectively. Gopakumar *et al.* (2011) reported that cobia mature at the age of 1-2 years. Similarly, Kaiser and Holt (2004) reported that male cobia can reach sexual maturity at the age of one and female mature at the age of two. These findings are in concurrence with the results of the

present study. However, Richards (1967) estimated the age at maturity of cobia inhabiting in Chesapeake Bay as 2 and 3 years for male and female, respectively. Geographical differences of the study areas may be the reason for this variance.

Spawning season

Month-wise occurrence of maturity stages of Cobia (Fig. 3) showed the occurrence of all the five stages throughout the year in varying percentages. This is an indication of protracted spawning behavior of cobia. Results of month-wise percentage of mature specimens and GSI values (Fig. 4) led to the conclusion that cobia breeds throughout the year with peak spawning activity during July-August and November- January. Peak spawning season of cobia recorded by the various authors from different geographical locations is furnished in Table 3. As furnished in Table 3, spawning season of cobia occurring in different habitats vary from place to place. Valinasaab *et al.* (2008) reported spawning season of cobia as July – September from the Persian Gulf which is in agreement with the finding of this study. Results of all other studies on duration of spawning period of cobia (i.e. cobia follows a protracted spawning season) are in agreement with the findings of the present study. Longhurst and Pauly (1987) and Houde (1989) observed that coastal fishes in the tropics and sub-tropics are mainly serial spawners with a protracted spawning season, in contrast to species in temperate regions. This observation is true in the case of cobia inhabiting in the northwest coast of India and also consensus with the results of the present study.

In fishes, spawning usually occurs at a time when environmental conditions are most favorable for larval survival and development (Moyle and Cech, 2000). The period of occurrence of favorable conditions may differs from place to place and are affected by the various environmental factors like water temperature, photoperiod, monsoon, food availability etc. Hence, spawning season of fish populations may vary from habitat to habitat. The peak spawning season of cobia documented by the present study coincides with the period of monsoon seasons (south west monsoon and northeast monsoon) along the northwest coast of India. The monsoon season is known for upwelling, plankton bloom and congregation of other prey items, hence considered as the most conducive period for spawning activity and embryonic development of fishes.

Maturity stages and feeding condition

Results of the present study indicate that cobia takes very less food during their spawning period. Feeding absenteeism of cobia during the spawning period was an interesting phenomena recorded during the study. An in-depth study to identify the hormonal changes during the spawning period may reveal the reason for feeding absenteeism during the spawning season.

Results on the reproductive biology of cobia inhabiting in different water

bodies round the world is furnished in Table 1. Except Lotz *et al.* (1996) Brown-Peterson *et al*. (2001) and Daghogi *et al.* (2006) all other studies were carried out with less number of specimens or for a lesser duration. All the studies utilized samples either collected from sport fishery or commercial fishery. The present study utilized more number of specimens collected over a two year duration. Moreover, samples collected from both exploratory resource survey and commercial multi gear fishery (Trawlers, Gillnets and hook and line) were utilized for the study. This makes the results of the present study more significant than others. Environmental parameters that induce spawning behavior of cobia in the wild also need to be ascertained. Hence the present study advocates for an in-depth study on the impact of physicochemical changes in the environment, feeding intensity and hormonal changes on cobia during the spawning season.

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