Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 24(3): 85 – 95 (2020)
www.ejabf.journals.ekb.eg

Length-weight, condition factor and reproductive aspects of the cobia, *Rachycentron canadum* (Linnaeus, 1766) in the Arabian Gulf off the United Arab Emirates

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ARTICLE INFO

Article History:
Received: March 25, 2020
Accepted: May 8, 2020
Online: May 14, 2020

Keywords:
Arabian Gulf,
Cobia,
Condition factor,
Length-weight relationship,
Rachycentron canadum.

ABSTRACT

The present study provides the basic information in the fisheries biology and stock assessment for the cobia, *Rachynentron canadum* in the Southern part of the Arabian Gulf off the United Arab Emirates. A total of 371 individuals were sampled. The length-weight relationships of *R. canadum* were estimated as $W=0.0022*L^{3.2536}$, $R^2=0.99$ for all individuals, $W=0.0028*L^{3.1875}$, $R^2=0.98$ for males and $W=0.0022*L^{3.258}$, $R^2=0.99$ for females. According to *b* values, the growth type of this species was positive allometric growth (b>3), (t-test: $p<0.05$). Condition factors ranged from 0.60 to 0.77 for males and from 0.61 to 0.85 for females, while the relative condition factor for males ranged between 0.92 and 1.07 and between 0.96 and 1.14 for females. The monthly calculated mean values of the gonado-somatic index (GSI) of females increased from April, reaching the highest value in May then declined in July. The male/female ratio of this species was 1/1.82. The length at first sexual maturity for *R. canadum* was estimated at 63.31cm and 75.08cm TL for males and females respectively.

INTRODUCTION

The cobia *Rachycentron canadum* is large, coastal, pelagic fish of the monotypic family Rachycentridae that distributed in tropical and subtropical waters, but absent in the eastern Pacific **(Herre 1953, Robins & Ray 1986** and **Shaffer & Nakamura 1989)**. Length and weight data are useful and widely used in fisheries science for estimation of the weight for a given length, estimation of biomass when length frequency distribution is known and the estimation of condition indices **(Froese *et al.*, 2011)**. On the other hand, the knowledge of the length-weight relationship makes it easier to determine the mass where only the length is known **(Kara & Bayhan, 2008)**. Condition factor at different body lengths can give valuable information on maturation and spawning of the fish, whereas seasonal variation in the condition factor values may give definite clues regarding the breeding seasons **(Le Cren, 1951)**. Condition factor decrease with increase in length **(Bakare, 1970** and **Fagade, 1979)**; and also influences the reproductive cycle in fish **(Welcome, 1979)**.

The reproductive biology of a species will provide vital information on its life history traits, which will be of use in management and conservation of the resources, as well as in

evolving aquaculture and husbandry practices. Many biological characteristics of cobia have been investigated by several authors. The length weight relationship and condition factor from Indian waters were estimated by **Sajeevan & Kurup (2017)** and **Maharshi *et al.* (2017)**. The feeding intensity, systematics, distribution and abundance of cobia inhabiting Indian waters were provided by **Sajeevan & Kurup (2013; 2014 a&b)**. Preliminary information on reproductive biology of cobia from Indian waters were provided by many authors **(Rajan *et al.*, 1968; Somvanshi *et al.*, 2000; Pillai *et al.*, 2009; Ganga *et al.*, 2012 and Sajeeven & Kurup, 2017). Richards (1967), Smith (1995)** and **Lotz *et al.* (1996)** have reported the size at maturity of cobia from other parts of the world.

Despite the popularity of cobia, little is known about the status of the fishery or the life history of this species along the Arabian Gulf. The purpose of the present study was to better define the life-history characteristics of cobia so that managers will have the preliminary information required to accurately manage this species.

MATERIALS AND METHODS

Fish samples:

Samples of *Rachycentron canadum* were collected from the commercial catches landed at the landing sites off the United Arab Emirates during the period from January to December 2017. Total length (cm) and total weight (g) were recorded for each sampled specimen. To avoid any bias resulted from weights of gonads and stomachs, the gutted weight (*Wg*) was used. Sex and maturity stages were macroscopically determined and recorded. Weight of gonads (*GW*) was recorded to the nearest 0.01 g. Stages of maturity were classified as follows: I immature; II developing; III mature; IV ripe; V running ripe; and VI spent according to **Nikolsky (1963)**.

Length weight relationship

The relationship between the length (*L*) and weight (*W*) of fish was expressed by equation of **Pauly (1983)**: $W=aL^b$ where *W* is the weight of fish in g, *L* is the total length of fish in cm, *a* is a constant and *b* is the slope of the relation. The relationship was established for both males and females by linear regression of the logarithms of the length and weight data following Pauly (1983). Bailey's t-test **(Snedecor & Cochran, 1967)** was employed to find out whether *b* value significantly deviated from the expected cube value of 3 $[t=(b-3)/S_b]$, where *b* is the regression coefficient and S_b is the standard error of the slope.

Condition factor

The Fulton's condition Factor K_c was calculated employing the formula of **Fulton (1904)** as $K_c=W/L^3*100$ where: K_c is the condition factor, *W* is the weight of fish, L is the length of fish. Relative condition factor K_n was established to assess the condition of the species under study. K_n is defined as $W/\hat{W}$ where W is the observed weight and $\hat{W}$ is the calculated weight derived from length-weight relationship **(Le-Cren, 1951)**. Good growth condition of the fish is deduced when $K_n \geq 1$, while the organism is in poor growth condition compared to an average individual with the same length when $K_n<1$.

Reproductive biology

Gonado-somatic index *GSI* was calculated monthly for both males and females of *R. canadum* by the following equation: $GSI=WG/Wg*100$ where: *GW* is the fish gonad weight and *Wg* is the fish gutted weight as mentioned by **Claereboudt *et al.* (2005)**. The sex ratio (male: female) was calculated and the significant differences from the theoretical ratio (1.0: 1.0) were tested by means of chi-squared test χ^2 **(Sokal & Rohlf, 1981)**. The length at which 50% of all

individuals were sexually mature L_{50}, was estimated from the proportion of mature individuals in each 5.0 cm length class and the fitted logistic curve **(King, 1995)** as follows: $P = 1/1+exp[r*(L-L_{50})]$ where P is the proportion of mature individuals within a length class, r is the slope of the curve, and L_{50} is the length at 50% sexual maturity.

RESULTS

Length-weight relationship

A total of 371 specimens of *R. canadum* were collected (236 females, 130 males and 5 unsexed), the total length of males, females and pooled data varied from 44.0 to 110 cm with average of 66.95cm; from 40.0 to 163 cm with average of 82.29 cm and from 36.0 to 163.0 cm with average of 76.0 cm, respectively. Sample sizes (n), minimum and maximum values of lengths and weights, as well as parameters *a* and b of the length-weight relationship and the coefficient of determination r^2 are given in **Table (1)**.

Table (1): Descriptive statistics and estimated parameters of length-weight relationships for males, females and pooled data of *R.canadum*.

Sex	N	TL range (cm)	Wt. range (g)	a	b	r^2
Males	130	44 - 110	531 - 10864	0.0028	3.188	0.98
Females	236	40 - 163	375 - 36400	0.0022	3.258	0.99
Pooled	371	36 - 163	264 - 36400	0.0022	3.254	0.99

N: sample size, TL: total length, Wt.: weight, a and b: parameters of length-weight relationship

The length-weight relationship of *R. canadum* was estimated as: $W=0.0028*L^{3.1875}$, $r^2=0.98$ for males; $W = 0.0022*L^{3.258}$, $r^2=0.99$ for females and $W= 0.0022*L^{3.2536}$, $r^2=0.99$ for pooled data of both sexes **(Figures 1-3)**. The analysis of covariance indicated no significant difference in the regression coefficients. As may be seen from the equations, the coefficient of correlation, r^2 for both sexes and pooled data of total length and body weight are identical and equal to 0.99 which is highly significant at 1% level. According to the t-test, there is a significant difference between *b* value and the cube value in both sexes and pooled data. This indicates that both males and females follow positive allometric growth. The corresponding logarithmic regression equations can be represented as follows: Log W= -2.5414+ 3.1875*Log L for males; Log W = -2.6566+3.258*Log L for females and Log W = -2.6538+3.2536*Log L for pooled data.

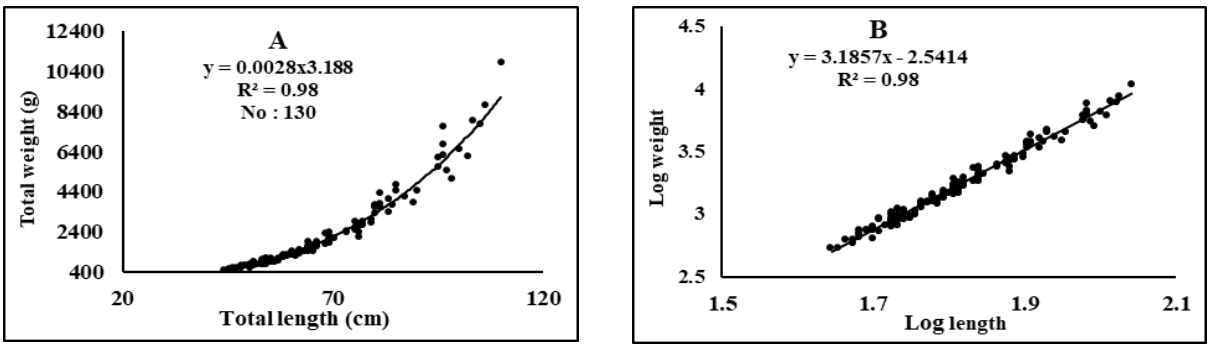

Figure 1. Length-weight relationship of males *R. canadum* (A) power equation and (B) logarithmic relationship

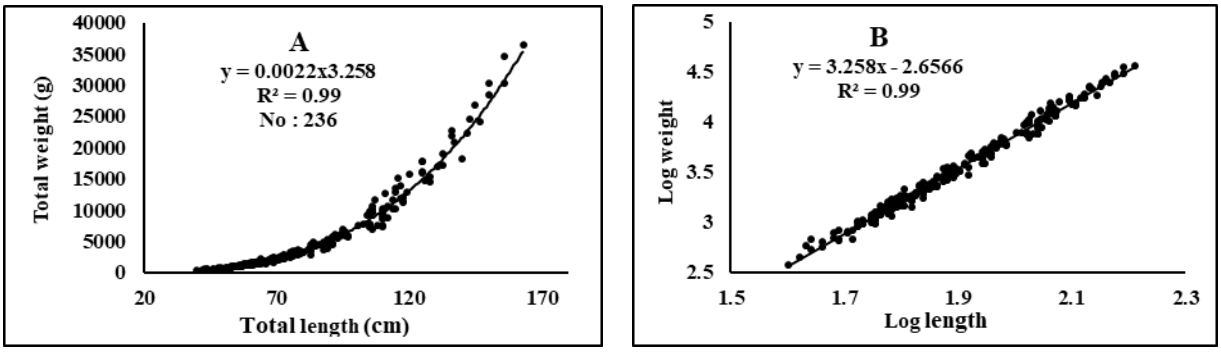

Figure 2. Length-weight relationship of females R. canadum (A) power equation and (B) logarithmic relationship

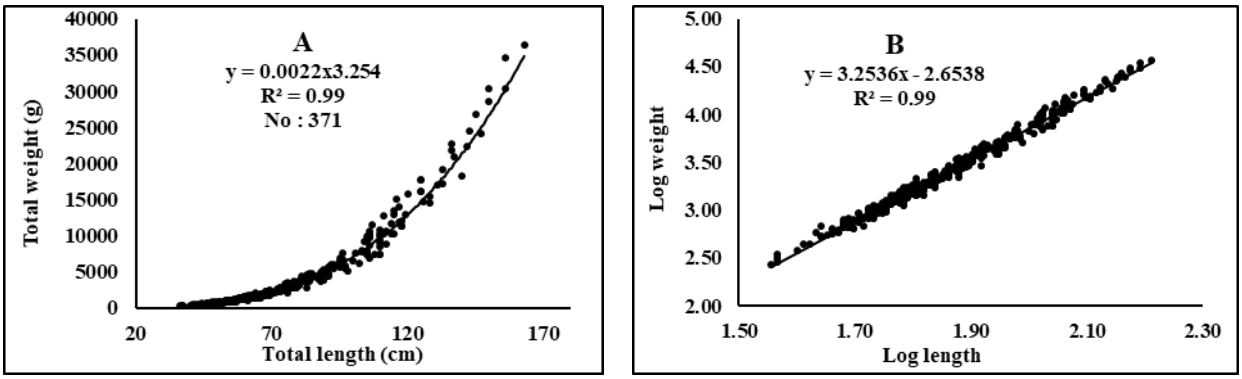

Figure 3. Length-weight relationship of combined sexes R.canadum (A) power equation and (B) logarithmic relationship

Condition factor and relative condition factor

Figure (4) shows the seasonal fluctuation of the condition factor K_c for both sexes, the results revealed that, the maximum values of condition factor were recorded during Summer (0.70 and 0.71) and the minimum values occurred in Autumn (0.61 and 0.64) for males and females respectively. In general, the mean value of condition factor of females higher than that of males. On the other hand, the relative condition factor K_n was estimated for both sexes and declared that, the maximum and minimum values of relative condition factor were estimated during Summer and Autumn respectively. Generally, the mean value of K_n in males (1.06) was higher than that of females (1.01).

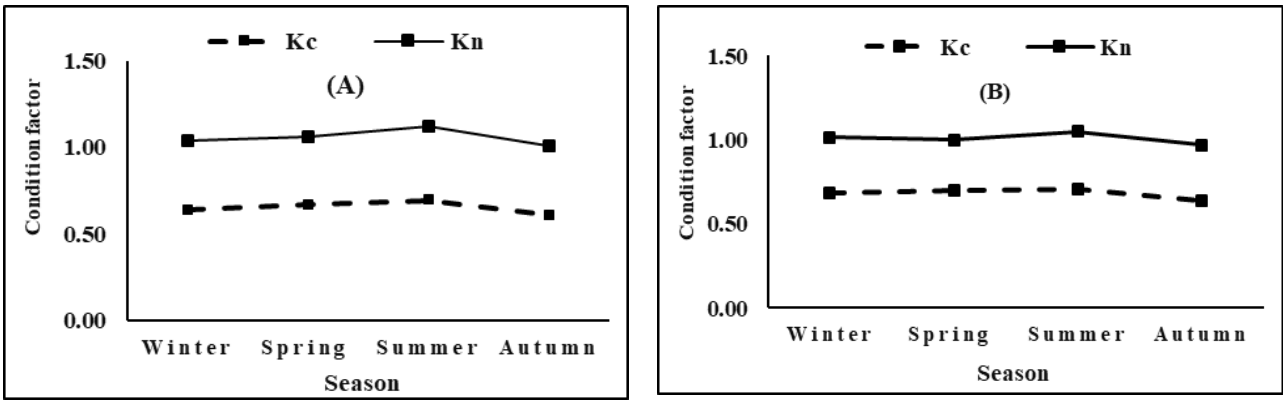

Figure 4. Seasonal variations of Kc and Kn of males (A) and females (B) R. canadum

The average condition factor Kc at different length groups for both sexes was calculated and tabulated in Table (2). In females, the average Kc values were found to vary from 0.61±0.053 to 0.85±0.057 while in males ranged from 0.60±0.044 to 0.77±0.059. It was observed that the value of Kc tends to be lower between 46 and 65 cm length group in females and from 56 to 65 cm in males indicating that these length groups were in the worst condition. The higher Kc values in females was gradually increased from length group 126-135 cm and reached to the maximum value 0.85 in the largest length group 156-165 cm; in males it was recorded in length group 106-115 cm. However, the value of relative condition factor Kn was observed to vary from 0.96 ±0.048 to 1.14±0.147 for females and between 0.92±0.080 to 1.07±0.075 in males. The lowest value of Kn was seen in 126-135 cm length group in females and in length group 86-95 cm in males. Whereas, the highest value of Kn was found in the length group of 36-45 cm in females and in length group 106-115 cm for males. Generally, the average Kc and Kn in females was higher than that in males.

Table 2. Variation in condition factor Kc and relative condition factor Kn of *R. canadum* with different length groups

Length group	Females					Males				
	No	**Kc**	**SD**	**Kn**	**SD**	**No**	**Kc**	**SD**	**Kn**	**SD**
36-45	5	0.66	0.089	1.14	0.147	2	0.61	0.022	1.06	0.042
46-55	21	0.61	0.053	1.01	0.089	36	0.61	0.050	1.02	0.085
56-65	62	0.64	0.059	1.01	0.091	37	0.60	0.044	0.96	0.069
66-75	32	0.64	0.072	0.97	0.106	19	0.63	0.050	0.98	0.078
76-85	26	0.68	0.075	1.00	0.110	20	0.66	0.080	0.99	0.115
86-95	22	0.69	0.070	0.98	0.096	5	0.63	0.060	0.92	0.080
96-105	14	0.71	0.075	0.98	0.100	9	0.68	0.101	0.96	0.146
106-115	23	0.75	0.120	1.01	0.162	2	0.77	0.059	1.07	0.075
116-125	12	0.82	0.096	1.09	0.125					
126-135	6	0.75	0.039	0.96	0.048					
136-145	7	0.82	0.081	1.05	0.104					
146-155	3	0.84	0.070	1.05	0.084					
156-165	3	0.85	0.057	1.05	0.072					
No.	**236**					**130**				
Av.		**0.73**	**0.074**	**1.02**	**0.103**		**0.65**	**0.058**	**0.99**	**0.086**

Reproductive biology

Sex ratio

The total number of female samples was greater than that of males. The estimated sex ratio for all samples was 0.55 which significantly differed (X^2=57.92; p<0.01) from the expected 0.05. The proportion of females was higher than males in all months except June and September (predomination of males). **Table (3)** gives our results on the sex of the 366 specimens of *R. canadum* collected during the study period, grouped by month. The sex ratio of the collected samples was 1:1.82 males to females, respectively.

Table 3. Sex ratio of *R. canadum* collected during 2017.

Month	Females		Males		Sex ratio
	No	%	No	%	M : F
Jan.	11	52	10	48	1 : 1.10
Feb.	23	61	15	39	1 : 1.53
Mar.	16	57	12	43	1 : 1.33
Apr.	19	83	4	17	1 : 4.75
May.	39	89	5	11	1 : 7.80
Jun.	11	44	14	56	1 : 0.79
Jul.	10	59	7	41	1 : 1.43
Aug.	21	95	1	5	1 : 21.0
Sep.	20	35	37	65	1 : 0.54
Oct.	24	71	10	29	1 : 2.40
Nov.	19	63	11	37	1: 1.73
Dec.	23	85	4	15	1 : 5.75
total	**236**	**64**	**130**	**36**	**1 : 1.82**

Gonado-Somatic Index and sexual maturity

The calculated means of monthly gonado-somatic index for males and females of *R. canadum* are presented in **Figure (5)**. The monthly calculated mean values of (GSI) of males and females were indicate to increase from April, reached its highest value in May and declined in July. It could be concluded that there was one peak of spawning period for *R. canadum* in May. The gonado–somatic index ranged in the females from 0.51 to 2.43 with a mean of 1.0 ± 0.57. While in males, the gonado-somatic index ranged from 0.25 to 2.33 with a mean of 0.87± 0.71. The smallest sexually mature male was 54.0 cm TL whereas the same for female was 60.0 cm TL. Based on graphical methods, 50% sexual maturity ($L_{50\%}$) of *R. canadum* was recorded at 63.31cm TL for males and at 75.08 cm TL for females **(Figure 6)**.

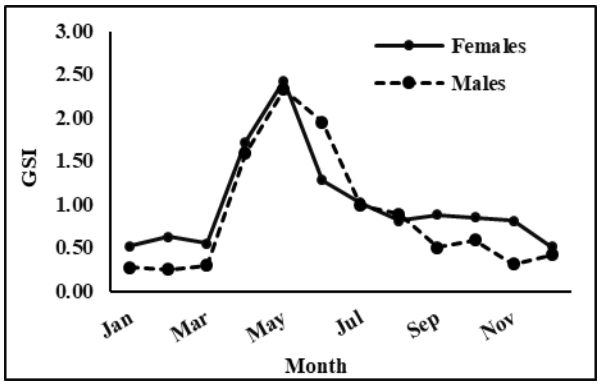

Figure 5. Seasonal variation in gonado-somatic index for *R. canadum*

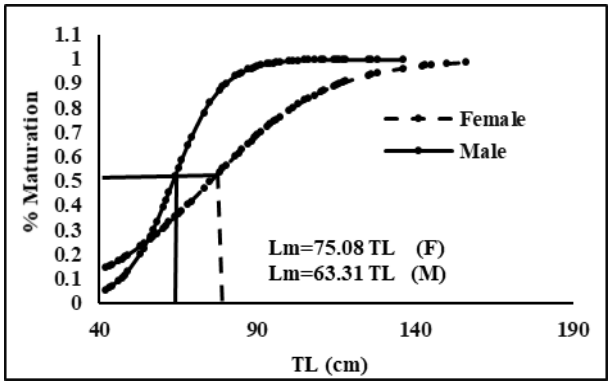

Figure 6. Length at first sexual maturity L_m for *R. canadum*

DISCUSSION

The length weight relationship parameters (a and b) of the fish are affected by a series of factors such as season, habitat, gonad maturity, sex, diet, stomach fullness, health and annual differences in environmental conditions **(Bagenal & Tesch, 1978** and **Froese, 2006)**. Weight of fish increases logarithmically with an increase in length, with

the slope value *b* lying between 2.5 and 3.5, similar studies done by **Carlander *et al.* (1969)**. In the present study, the *b* values obtained for males and females were 3.19 and 3.26 respectively, suggesting that females were heavier and grow faster than males and the exponent *b* close to 3.0. Length weight relationship of cobia reported by various authors from different parts of the world are furnished in **Table (4)**.

Table 4. Length-weight relationship of *R. canadum* reported by different authors from different localities

Area of study	Author/s	Sex	Length (TL/FL)	a	b
Northeastern Gulf of Mexico	Franks *et al.* 1999	Pooled	FL	0.0015	3.428
North west coast of India	Somvanshi *et al.* 2000	Male Female	TL	0.0096 0.0036	2.874 3.1603
Gulf of Mexico	Williams, 2001	Pooled	FL	$10.8x10^{-8}$	2.970
South west Coast of India	Abdurahiman *et al.* 2004	Male Female	TL	0.010 0.004	2.876 3.092
Northwest Coast of India	Sajeevan and Madhusoodana, 2015	Male Female Pooled	TL	0.0044 0.00396 0.00421	3.078 3.1075 3.0895
South East Coast of India	Maharshi *et al.* 2017	Male Female	TL	0.00469 0.00219	3.1165 3.364
South Coast of Arabian Gulf off Emirates	Present study	Male Female Pooled	TL	0.0028 0.0022 0.0022	3.188 3.256 3.254

Condition factor values were assessed for males and females of *R. canadum*. Data were analyzed for various length group and for different months to understand the well-being of the species and also to infer information on reproductive behavior, feeding habits etc. **(Froese, 2006)**. According to **Bennet (1970)**, Fulton's condition factor ≥0.56, relative condition factor ≥1 and are considered as well-being bench mark values of a fish, hence fishes with condition factor values above the well-being bench mark were considered to be in good condition. Result of the present study indicated that *R. canadum* occurring in southern part of Arabian Gulf in good condition throughout the study period. **Sajeevan & Madhusoodana (2015)** declared the male of *R. canadum* was in good condition throughout the year except during October, in which they were in average condition, while in female the condition factor values during August, October and November were below 0.56.

The overall sex-ratio (M: F) for *R. canadum* was 1.0:1.82 which is deviated from the expected 1:1 in favor of females. This agrees with the results obtained for the same species in Chesapeake Bay and adjacent mid-Atlantic waters **(Richards, 1967)**, in northern part of the Arabian Gulf off Iranian water **(Daghooghi *et al*., 2008)**, in the northeastern Gulf of Mexico **(Franks *et al*., 1999)**. On the contrary, sex ratios of the same species where male population dominate over females were reported in Louisiana waters **(Thompson *et al*., 1991)**. In South Carolina, the ratio of males to females was 1.0:1.1 **(Kalinowsky *et al*., 2016)**. In the present study the spawning season was recorded from April to June with peak in May. **Joseph *et al*. (1964)** mentioned the presence of gravid females and appearance of cobia eggs in plankton collections indicated that spawning occurs between mid-June and mid-August in the Atlantic Ocean adjacent to the mouth of the Chesapeake Bay. **Richards (1967)** indicated that cobia spawn from late June through mid-August off Virginia. In the Caribbean Sea, **Erdman (1968)** indicated that August was the peak month of spawning for cobia in Puerto Rican waters. A female with maturing eggs was collected from Madagascar waters in October 1964 **(Richards 1967)**. In the Indian waters, **Day (1967)** took a ripe female in March; **Darracott (1977)**

indicated that cobia eggs have not yet been recorded from the Indian Ocean, although ripe fish are found year-round. She also indicated that cobia may migrate from the southern Indian Ocean to spawn off coastal areas of the Arabian Sea. In Pakistan waters, ripe cobia is found in March and April along the Baluchistan coast **(Bianchi, 1985)**. In Iranian waters, **Daghooghi *et al*. (2008)** declared the spawning season during spring and summer with main peak in June

The estimated size of 50% maturity ($L_{50\%}$) for females and males of *R. canadum* in this study was 75.08 and 63.31 cm, respectively. The smallest sexually-mature length was 60.0 and 54.0 cm for females and males, respectively. The sizes at first maturity reported by different authors from various localities are shown in Table (5). The results of the present study are in concurrence with these findings. However, all the studies are concurrent in reporting that size at maturity of male and female differs from each other. The present study indicates that male cobia matures at smaller length than female, as reported by other workers **(Williams, 2001; Kaiser & Holt, 2005; Tonya *et al.* 2010** and **Sajeevan &Madhusoodana, 2017)**. In contrast, **Rajan *et al.* (1968)** found that male mature at length larger than females.

Table 5. Length at first maturity of *R.canadum* reported by various authors from different localities

Area of study	Author/s	Length at first maturity (cm) (TL/FL)*	
		Female	Male
Chilka Lake, India	Rajan *et al.* 1968	42.6 (TL)	----
Gulf of Mexico	Williams, 2001	84.5 (FL)	64.0 (FL)
Texas, USA	Kaiser and Holt, 2005	83.4 (FL)	64.0 (FL)
North-eastern Australia	Tonya *et al.* 2010	78.4 (FL)	77.0 (FL)
North-west Coast of India	Sajeevan and Kurup, 2017	70.0 (TL)	63.0 (TL)
Present study		75.8 (TL)	63.31 (TL)

*TL: total length, FL forked length

CONCLUSION

In conclusion, this paper provides the basic information of the large, economically important fish species in the southern part of the Arabian Gulf, *Rachycentron canadum*. The analyzed data shows positive allometric growth rate and the weight of fish increase logarithmically with an increase in length, as a result of the small number of samples, it is possible that these results will change if the number of samples increases. This the first report on length weight, condition factor and some reproductive aspects of the *R.canadum* off the Emirates coastline and could strongly helpful to the researchers and policy makers for the preparation of very effective sustainable management plans of fishery resources.

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