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Author(s): Christopher Aaron Kalinowsky, Mary Carla Curran and Joseph W. Smith
Source: *Southeastern Naturalist*, Vol. 15, No. 4 (2016), pp. 714-728
Published by: Eagle Hill Institute
Stable URL: https://www.jstor.org/stable/44657970
Accessed: 11-03-2024 17:33 +00:00

2016 SOUTHEASTERN NATURALIST 15(4):714–728

Age and Growth of *Rachycentron canadum* (L.) (Cobia) from the Nearshore Waters of South Carolina

Christopher Aaron Kalinowsky[1,*], Mary Carla Curran[2], and Joseph W. Smith[3]

Abstract - The purpose of this study was to define growth parameters, age-at-length, and the sex ratio for *Rachycentron canadum* (Cobia) in Port Royal Sound and the nearshore waters of South Carolina. We sampled Cobia from recreational-fishing efforts, and used otoliths to estimate age. Female Cobia (n = 245) fork length (FL) ranged from 798 mm to 1425 mm (mean = 1059 mm) and male (n = 221) FL ranged from 670 mm to 1183 mm (mean = 936 mm). The ratio of females to males was 1.1:1.0. Cobia ranged in age from 2 to 11 years; most (60.8%) were age 3. Estimates of von Bertalanffy growth parameters for Cobia were $L_\infty = 1212$, $K = 0.53$, and $t_0 = -0.13$ for females and $L_\infty = 1101$, $K = 0.51$, and $t_0 = -0.13$ for males. Life-history characteristics of Cobia as defined by this study provide managers with critical age-at-length and growth information necessary for the effective management of the species.

Introduction

Rachycentron canadum (L.) (Cobia) are large, coastal, pelagic fish of the monotypic family Rachycentridae that are distributed worldwide in tropical and subtropical seas, except the eastern Pacific (Herre 1953, Robins and Ray 1986, Shaffer and Nakamura 1989). Along the east coast of the US, Cobia occur in nearshore waters from the Mid-Atlantic Bight to the Gulf of Mexico (Williams 2001). This Cobia population is divided into 2 regional stocks (Gulf and Atlantic), each of which is managed by its representative fisheries management council under the Coastal Pelagics Management Plan (SEDAR 2013a, b; Shaffer and Nakamura 1989; Williams 2001). Migration of individuals between the Gulf of Mexico and the Atlantic Ocean has been documented through tagging studies, and early genetic studies (using mtDNA analysis) indicated that the 2 stocks are genetically similar (Franks et al. 1991, Howse et al. 1992, Hrincevich 1993). However, more-recent studies have found that the 2 stocks have disparate allele-frequency distributions, indicating some degree of isolation between the stocks (SEDAR 2013a, b). The Gulf of Mexico stock extends around the tip of Florida as far north as Brevard County, where some degree of overlap occurs with the Atlantic stock. Currently, there is not enough resolution in the genetic or tagging studies to identify exactly where the 2 stocks split. Genetic analysis indicates that a mixing zone occurs somewhere to the north of the Brevard County line (SEDAR 2013a, b). For

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[1] Georgia Department of Natural Resources-Coastal Resources Division, 185 Richard Davis Drive Suite 104, Richmond Hill, GA 31324. [2] Department of Marine and Environmental Sciences, Box 20467, Savannah State University, Savannah, GA 31404. [3] NOAA/NMFS, 101 Pivers Island Road, Beaufort, NC 28516. [*] Corresponding author - Chris_Kalinowsky@dnr.state.ga.us.

Manuscript Editor: Benjamin Keck

management purposes, it was decided that the stocks would be separated at the FL/GA line (SEDAR 2013a, b).

Cobia are a highly prized gamefish, and a significant recreational fishery exists for them in the US (Hammond 2001). It was estimated that over 2.4 million Cobia were caught recreationally on the Gulf and Atlantic coasts from 1989 to 2000 (Hammond 2001). A majority of these landings (72%) occurred along the Gulf Coast; more specifically, 55% of the landings occurred along the west coast of Florida (Hammond 2001). Commercial harvest of Cobia is limited and occurs mostly as by-catch from other fisheries (Shaffer and Nakamura 1989).

Stock status of Cobia in the Gulf of Mexico and the Atlantic remains uncertain. This uncertainty is largely the result of limited data on migration patterns, overwintering locations, and population estimates. A 2001 stock assessment from the Gulf of Mexico had a high degree of uncertainty due to the lack of landings data and gaps in general life-history information (Williams 2001). The results from that assessment were highly variable and suggested that the population status could range from overfished to well above maximum sustainable yield (Williams 2001). Based on the results of the 2001 assessment, Williams (2001) stated that the population of Gulf Cobia had increased since the 1980s and comprehensive coast-wide sampling and ageing of Cobia would be necessary to improve future population estimates. The most recent stock assessment, conducted in 2012, also contained a high degree of uncertainty around estimates for both the Gulf and Atlantic stocks. The current assessment continues to lack consistent data regarding many aspects of Cobia life history and the fisheries that impact the species. Gaps in the data include the identification of stock boundaries along the Western Central Atlantic, release mortality for both commercial and recreational fisheries, spawning location, and size at maturity. Despite these many uncertainties, results indicated that neither stock was overfished and that overfishing was not occurring (SEDAR 2013a, b).

Despite the popularity of Cobia, little is known about the status of the fishery or the life history of the species along the South Carolina coast (Hammond 2001). The purpose of the present study was to better define life-history characteristics of Cobia so that managers will have the age and growth information required to accurately manage the species. Port Royal Sound in Beaufort County, SC, is among several areas along the Western Central Atlantic Coast where Cobia move inshore in spring to spawn (Lefebvre 2009). Anglers in Beaufort County land ~80–85% of Cobia caught in South Carolina waters (Hammond 2001); thus, our objectives were to determine growth parameters, age-at-length, and the sex ratio for Cobia in Port Royal Sound and the adjacent waters of Beaufort County, SC.

Field-site Description

We sampled Cobia from recreational catches originating in Port Royal Sound and the nearshore waters of Beaufort County, SC (Fig.1). Port Royal Sound is a large, deep, highly saline system that has no significant source of freshwater input. Port Royal Sound is bordered by St. Helena Island to the north and Hilton Head Island to the southwest. Moving upriver, the sound splits into 3 distinct channels—

the Beaufort River to the north, the Broad River in the middle, and the Chechessee River to the south. The Broad River is the deepest and largest of the three.

Methods

Sample collection

We sampled Cobia opportunistically from the Port Royal Sound and adjacent waters of Beaufort County (Fig. 1). Specimens (*n* = 485) were collected from a targeted recreational fishery, including recreational anglers, charter boats, and local sportfishing tournaments during May, June, and July 2005–2007. We neither employed additional methods to collect undersized Cobia nor interviewed anglers about discarded, undersized fish. We collected Cobia samples from volunteer recreational anglers; thus, there was no way to measure effort or control sampling

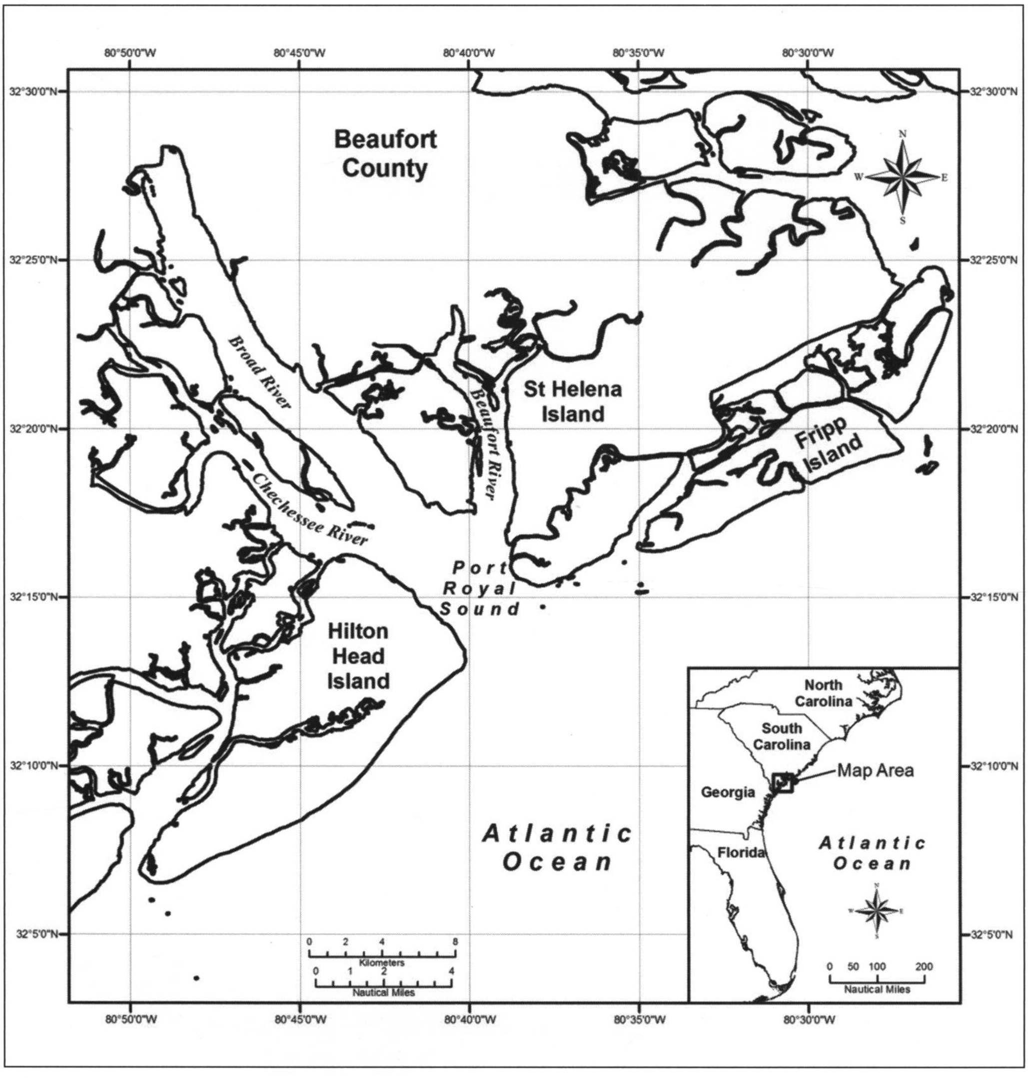

Figure 1. Map of Port Royal Sound and the adjacent waters of Beaufort County, SC.

methods of the fishermen. We used a measuring board to determine the fork length (FL) of each specimen to the nearest millimeter. When available, we recorded whole weight to the nearest ounce using a calibrated digital scale and then converted the values to grams. We determined sex for all specimens by gross examination of reproductive tissue.

Otolith sectioning

We removed sagittal otoliths in the field by opening the cranium above and slightly posterior to the preoperculum. Once removed, otoliths were rinsed in fresh water and stored dry in labeled coin envelopes or plastic vials. Prior to sectioning, we marked otolith cores (focus of the otolith) with a fine-point marker and then embedded whole otoliths in a two-part epoxy in a small (14-mm) bullet mold (Pelco #10504, Pelco Tool and Mold, Glendale Heights, IL). We placed molds with embedded otoliths concave side down on microscope slides, secured them with cyanoacrylate glue, and cross-sectioned them through the focus using a Buehler low-speed saw equipped with a diamond-edged wafering blade (Buehler, Lake Bluff, IL). We mounted the otolith sections onto a microscope slide with an acrylic resin (CytoSeal 60, Thermo Fisher Scientific, Waltham, MA) and viewed them with a dissecting microscope at 16x using transmitted light to determine the quality of the section. If a second section was deemed necessary, we remounted the remaining half of the bullet mold, cut a section adjacent to the first cut, and mounted it on the same slide as the original. We viewed finished slides under a Leica S8APO stereomicroscope (10–80x) using fluorescent light to discern and count annuli.

Ageing methods

Three experienced readers independently examined sectioned otoliths, and assigned age estimates by counting opaque zones along the mid-portion of the ventral lobe per Burns et al. (1998), Franks et al. (1999), Smith (1995), and Thompson et al. (1991). Ages were assigned without reference to fork length, weight, or date caught. All otoliths had a wide band of translucent material extending toward the terminal edge from the prior year's annuli. Most otoliths also had a distinct opaque zone at the terminal edge of the section, making age determination straightforward and resulting in strong agreement among readers (97.3%). However, there were a few otoliths ($n = 13$) that had a faint, but still visible, opaque zone that was not as distinct as the prior year's annuli. Those otoliths accounted for the majority of disagreements in age determination among readers. In these instances, we determined that any opaque zone present along the terminal edge indicated that the annulus was forming at the time of capture and it was counted as another year. For example, a fish was assigned an age of 3 if it had 2 opaque zones with a large translucent zone and faint opaqueness at the terminal edge. Those few problematic otoliths were reviewed and ages reassigned. In all cases of reader disagreement, at least 2 of the 3 readers independently assigned the same age during their initial determination. When reader-assigned ages differed, readers re-examined otoliths independently and re-assigned ages. We excluded 2 otoliths from the study because readers could not agree on an age. Franks et al. (1999) found that age estimates from both the left and right otoliths agreed when compared; however, to enhance consistency in the present study, we always used the left otolith unless it was damaged.

Analysis of length

We sorted fork lengths of specimens into 50-mm bins (range = 600–1450 mm FL) and constructed length-frequency distributions by sex. We employed the Kolmogorov-Smirnov 2-sample test to compare the length-frequency distributions of males and females by using the NPAR1WAY procedure in SAS (SAS Institute Inc. 1999).

For the parameter estimates observed, age and length data were fitted to the von Bertalanffy growth model using the least-squares method. We chose this method because it is widely used in fisheries studies (Haddon 2001). The Von Bertalanffy growth model ($l_t = L_\infty(1 - e^{-K[t - t_0]})$) is a 3-parameter equation, where l_t is the length at age t, L_∞ is the asymptotic maximum length, K is the growth rate coefficient that determines how quickly maximum size is reached, and t_0 is the hypothetical age at which the species has zero length (Haddon 2001).

To compensate for the lack of age-1 Cobia, we applied the Diaz-adjusted von Bertalanffy method to generate alternative parameter-estimates. This method assumes a censored-normal distribution for variability of observed lengths about predicted lengths in the nonlinear regression of length-at-age. Age data were truncated for younger fish because of harvest regulations prohibiting the take of fish smaller than 838 mm FL (i.e., only the larger fish were sampled from younger age classes because of the minimum-size-limit (838-mm) FL regulation. We made a third attempt to further refine parameter estimates by using the Diaz-adjusted model with a fixed t_0 value of -0.13 for males. This procedure was based on the assumption that t_0 should be similar for both females and males, and that initial estimates of t_0 for males were skewed because of: (1) the limited age-2 data used for the initial model and (2) the data restrictions inherent to the Diaz-adjusted model.

Analysis of growth

Cobia have been documented to have sex-specific growth patterns in North Carolina and the Gulf of Mexico; therefore, we fitted growth models to sex-specific data. We generated initial parameter-estimates by fitting observed length and age data to the standard von Bertalanffy growth equation (Ricker 1975) and we obtained secondary estimates by fitting age–length data to a Diaz-adjusted von Bertalanffy growth equation (Diaz et al. 2004). We employed this method to compensate for truncated age-1 data resulting from the regulatory minimum-size limit for Cobia. We generated a third model using the standard von Bertalanffy techniques that included non-truncated age-1 data from fish ($n = 9$) captured in a previous study in North Carolina (Smith 1995). We intended to use this third model to compare the results of the Diaz method to results using actual age-1 data to determine if a better growth curve and a more accurate t_0 could be produced. We fitted the age data to a standard von Bertalanffy model for both sexes and used likelihood ratio tests (Kimura 1980) to compare the results of this third model to determine if there were significant diferrences in the growth curves of males and females.

Results

Over all collection years, Cobia (n = 485) ranged in size from 670 mm to 1425 mm FL (mean = 999 mm; Table 1). Female Cobia (n = 245) attained a greater maximum size than males and ranged from 798 mm to 1425 mm FL (mean = 1059 mm); males (n = 221) ranged from 670 mm to 1183 mm FL (mean = 936 mm; Table 1). Unsexed specimens (n = 19) were recorded and used for combined age analysis and combined length analysis.

Analysis of length

Length-frequency distributions for females and males were significantly different (Kolmogorov-Smirnov 2-sample test: $d = 0.47$, $P < 0.05$), with female Cobia larger than males (Wilcoxon-Mann-Whitney, $P < 0.05$; Fig. 2). The sex ratio of females to males was 1.1:1. Modal length range for both sexes combined was 950–1000 mm FL, accounting for 17.6% of all samples. The modal size was 1000–1050 mm FL for females (20.2% of all females and 10.3% for all fish) and 900–950 mm FL for males (32.0% of all males and 14.7% of all specimens).

Table 1. Size range (mm FL) and mean length (mm FL ± 1 SE) by sex and by year (2005–2007) for *Rachycentron canadum* (L.) (Cobia; n = 485) from Port Royal Sound and the adjacent waters of Beaufort County, SC. Unsexed specimens (n = 19) were used to calculate all Cobia means (last column).

	Female			Male			All Cobia		
Year	*n*	Range	Mean	*n*	Range	Mean	*n*	Range	Mean
2005	79	819–1410	1119 ± 15	39	855–1158	1002 ± 14	119	819–1410	1081 ± 12
2006	23	840–1236	1095 ± 23	34	811–1176	968 ± 17	57	811–1236	1019 ± 16
2007	143	798–1425	1019 ± 9	148	670–1183	910 ± 5	309	670–1425	964 ± 6
Combined	245	798–1425	1059 ± 8	221	670–1183	936 ± 6	485	670–1425	999 ± 6

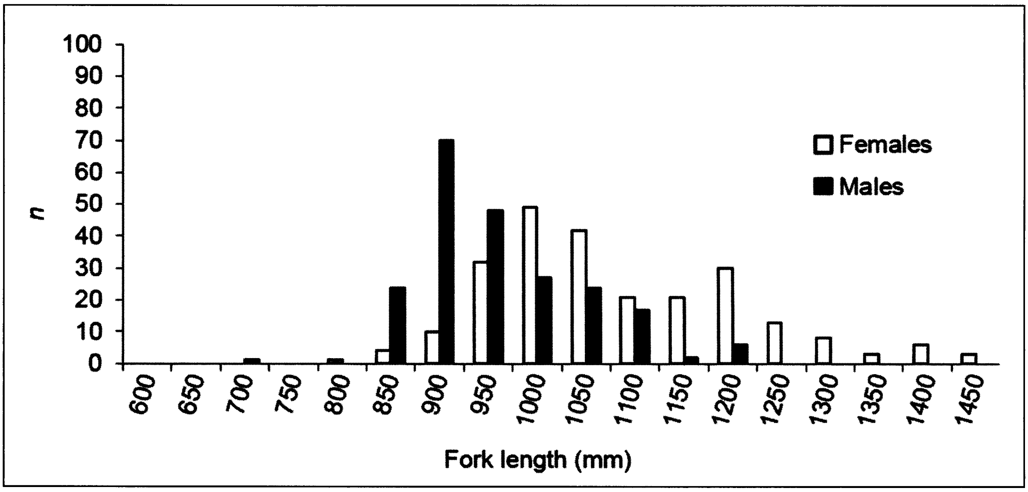

Figure 2. Length-frequency diagrams for *Rachycentron canadum* (L.) (Cobia) collected between 2005 and 2007 from Port Royal Sound and the adjacent waters of Beaufort County, SC. Females (n = 245) and males (n = 221).

Analysis of age

We examined sectioned annual zonal deposition of sagittal otoliths from 474 specimens. Estimates of Cobia ages ranged from 2 y to 11 y based on counts of opaque zones on sectioned otoliths (Fig. 3). Modal age for females (54.2%) and males (66.6%) was age 3 (Fig. 3). Ranges of FL by age showed considerable overlap among most age groups for both sexes. For example, age-2 females ranged from 798 mm to 905 mm FL, while age-3 females ranged from 839 mm to 1160 mm FL.

Analysis of growth

The 2 sexes had significantly different growth curves ($\chi^2 = 66.13$, df = 3, $P < 0.001$). Therefore, we separated length-at-age data by sex and used them to create sex specific age–length tables (Table 2). Initial parameter estimates obtained from the von Bertalanffy growth function were $L_\infty = 1425$ mm FL (the asymptotic maximum length), $K = 0.21$ (growth rate coefficient), $t_0 = -2.48$ (modeling artifact used to represent age when average length was zero) for females and $L_\infty = 1213$, $K = 0.21$, $t_0 = -3.45$ for males (Fig. 4A). Secondary-parameter estimates using the Diaz-adjusted von Bertalanffy function were $L_\infty = 1212$ mm FL, $K = 0.53$, $t_0 = -0.13$ for females and $L_\infty = 1173$ mm FL, $K = 0.28$, $t_0 = -2.14$ for males (Fig. 4B). We ran the Diaz-adjusted model a second time using a fixed t_0 value of -0.13 for males, and the parameters for males were $L_\infty = 1101$ mm FL, $K = 0.51$ (Fig. 4C). For comparative purposes, we made a fourth and final attempt to refine parameter estimates using age-1 data ($n = 9$) obtained from an ageing study in North Carolina (Smith 1995). These data produced the following parameter estimates: $L_\infty = 1358$ mm FL, $K = 0.33$, $t_0 = -0.68$ for females; and $L_\infty = 1155$ mm FL, $K = 0.42$, $t_0 = -0.51$ for males (Fig. 4D). This method provided the most realistic estimates for all parameters (Fig. 4D).

In general, the predicted age-at-length model developed from the von Bertalanffy formula provided a good fit to the data. The fit was best for those age groups

Figure 3. Age-frequency diagrams for *Rachycentron canadum* (L.) (Cobia) collected between 2005 and 2007 from Port Royal Sound and the adjacent waters of Beaufort County, SC. Females ($n = 245$) and males ($n = 221$).

Table 2. Age–length table for female ($n = 236$) and male ($n = 214$) *Rachycentron canadum* (L.) (Cobia) from Port Royal Sound and the adjacent waters of Beaufort County, SC, as compared to Smith (1995). Lengths were predicted using a standard von Bertalanffy growth model.

	Present Study (SC)					NC Study (Smith 1995)				
Sex	Age (y)	*n*	Range observed FL (mm)	Mean observed FL (mm) ± 1 SE	Von Bertalanffy FL (mm)	Age (y)	*n*	Range observed FL (mm)	Mean observed FL (mm) ± 1 SE	Von Bertalanffy FL (mm)
♀	1	0	0	0	0	1	3	490–630	550 ± 40	610
	2	8	798–905	855 ± 14	871	2	18	570–1060	810 ± 30	770
	3	127	839–1160	979 ± 5	977	3	50	790–990	890 ± 10	890
	4	22	935–1180	1068 ± 9	1061	4	23	880–1320	1020 ± 20	990
	5	21	1061–1204	1133 ± 9	1131	5	13	980–1130	1060 ± 10	1070
	6	20	1070–1294	1180 ± 11	1187	6	20	990–1260	1110 ± 20	1130
	7	24	998–1381	1226 ± 16	1232	7	11	1100–1260	1170 ± 20	1170
	8	2	1194–1373	1284 ± 90	1269	8	8	1140–1280	1230 ± 20	1210
	9	8	1161–1410	1308 ± 35	1299	9	7	1140–1340	1250 ± 20	1240
	10	2	1271–1356	1314 ± 43	1323	10	3	1170–1330	1270 ± 50	1260
	11	2	1314–1425	1370 ± 56	1342	11	1	1210	1210	1280
	12	0	-	-	-	12	3	1250–1300	1270 ± 20	1300
	13	0	-	-	-	13	2	1340–1420	1380 ± 40	1310
	14	0	-	-	-	14	0	-	-	-
♂	1	0	0	0	0	1	6	390–640	500 ± 40	560
	2	5	811–844	829 ± 6	825	2	22	630–930	740 ± 20	710
	3	143	670–1010	897 ± 4	898	3	41	680–1020	820 ± 10	820
	4	16	844–1095	956 ± 17	957	4	32	820–970	880 ± 10	890
	5	18	950–1095	1020 ± 10	1005	5	20	780–990	920 ± 10	940
	6	12	938–1158	1058 ± 17	1045	6	7	900–1030	950 ± 20	970
	7	13	934–1104	1042 ± 13	1076	7	6	940–1080	1000 ± 20	1000
	8	3	1078–1176	1116 ± 30	1102	8	8	890–1070	990 ± 20	1010
	9	2	1150–1151	1151 ± 1	1123	9	6	990–1360	1070 ± 60	1030
	10	1	1163	1163	1140	10	5	1010–1090	1050 ± 10	1030
	11	1	1183	1183	1153	11	3	1020–1090	1050 ± 20	1040
	12	0	-	-	-	12	0	-	-	-
	13	0	-	-	-	13	1	-	1130	1040
	14	0	-	-	-	14	1	-	1060	1050

with the most samples. For example, observed mean FL for age-3 females ($n = 127$) was 979 ± 5 mm, which encompasses the predicted FL of 977 mm based on the von Bertalanffy model (Table 2). Mean FL for age 3 males ($n = 143$) was 897 ± 4 mm, which also encompassed the predicted FL of 898 mm (Table 2). Even in those age groups with the fewest samples, there was only a 28-mm difference for females at age 11 ($n = 2$) and 30 mm difference for males at age 11 ($n = 1$), or 2%, between observed and predicted FLs (Table 2).

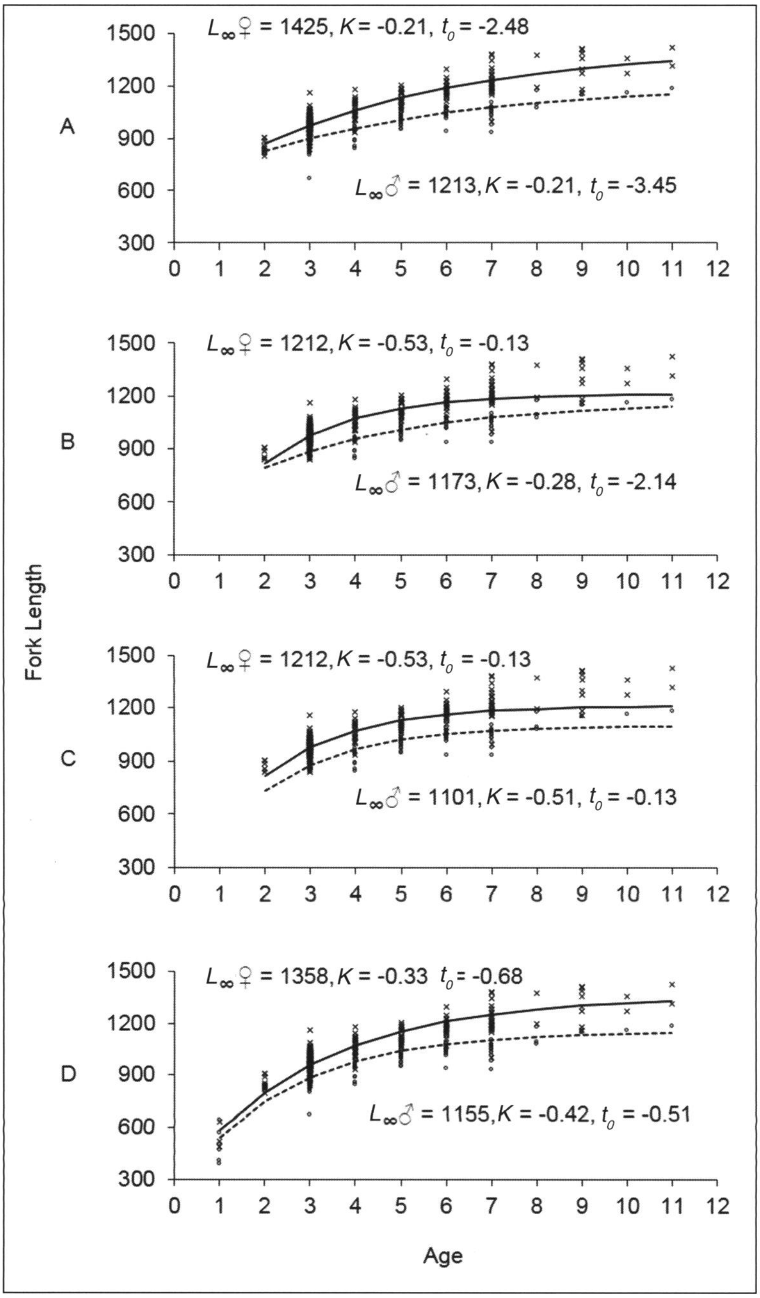

Figure 4. Von Bertalanffy growth curves for female and male *Rachycentron canadum* (L.) (Cobia) from Port Royal Sound and the adjacent waters of Beaufort County, SC (2005–2007) (x = female, o = male). (A) Using standard von Bertalanffy methods. (B) Using Diaz-adjusted von Bertalanffy methods. (C) Using standard von Bertalanffy methods with fixed male t_0 values. (D) Using standard von Bertalanffy methods including actual age-1 fish from NC (Smith 1995).

Discussion

This study provides critical age and growth information for Cobia from South Carolina, and the growth parameters generated from this study will aid in the management of Cobia in the western central Atlantic. Prior to this study, managers had little information on how Cobia from this region compared to those in others. Our data show that Cobia from Port Royal Sound and adjacent waters of Beaufort County, SC, have similar size ranges and growth rates as those from other nearby regions. Smith (1995) found that female Cobia from North Carolina waters ranged from 490 mm to 1420 mm FL (mean = 1090 mm), and males ranged from 390 mm to 1360 mm FL (mean = 940 mm) (Table 3). Although similar in mean length, both sexes of Cobia from North Carolina (Smith 1995) had a wider FL range than the Cobia we sampled for our study (Table 3). This difference was most likely due to a greater availability of samples accessible to Smith (1995), who obtained specimens from a wide variety of non-selective gear including trawls, gill nets, pound nets, stop nets, long hauls, and purse seines. These gear types typically recruit a larger range of specimen sizes and ages. Mean lengths from the present study are also similar to those reported by Franks et al. (1999), who found that female Cobia from the Gulf of Mexico ranged from 335 mm to 1651 mm FL (mean = 1050 mm), and

Table 3. Regional parameter estimates for the von Bertalanffy growth model for *Rachycentron canadum* (L.) (Cobia) from the present study and a table taken from Franks et al. (1999). Differences in parameter estimates may be the result of different aging techniques (scales vs. otoliths) or different size ranges due to sampling methodology, sample size, and/or lack of age-1 data. F = female and M = male.

Region	Sex	Size range FL (mm)	n	L_∞	k	t_0	Structure	Authors
Virginia	F	582–1377	156	1640	0.23	-0.08	Scales	Richards 1967
	M	544–1194	101	1210	0.28	-0.06		
North Carolina	F	490–1420	92	1350	0.24	-1.53	Otoliths	Smith 1995
	M	390–1360	116	1050	0.37	-1.08		
Western Louisiana	F	358–1445	-	1294	0.56	0.11	Otoliths	Thompson et al. 1991
	M	528–1432	-	1132	0.49	-0.49		
Northeastern Gulf of Mexico	F	335–1651	395	1555	0.27	-1.25	Otoliths	Franks et al. 1999
	M	345–1450	170	1170	0.43	-1.15		
South Carolina								
Initial von Bertalanffy estimates	F	798–1425	236	1425	0.21	-2.48	Otoliths	Present study
	M	670–1183	214	1213	0.21	-3.45		
Initial Diaz-adjusted estimates	F	840–1425	233	1212	0.53	-0.13	Otoliths	Present study
	M	844–1183	209	1173	0.28	-2.14		
Secondary Diaz-adjusted	F	840–1425	233	1212	0.53	-0.13	Otoliths	Present study
	M	844–1183	209	1101	0.51	-0.13		
Estimates using NC age-1	F	490–1425	239	1358	0.33	-0.68	Otoliths	Present study (Including age-1 fish from Smith [1995])
	M	500–1183	220	1155	0.42	-0.51		

males ranged from 345 mm to 1450 mm FL (mean = 952 mm). Franks et al. (1999) also had access to more juvenile fish, which had been confiscated as undersized specimens but made available for their use. The similarity in growth rates and lengths between these different regions is interesting given the vast differences in habitat type between the areas. This result may be due primarily to the overwintering preferences of the species and the fact that fish migrate south or east in search of warmer waters during the winter.

The pattern of annulus formation in Cobia from South Carolina that we observed may result from slowed growth during migration to the coastal spawning areas. This type of annulus formation has been documented in other species (Chiang et al. 2004, Sun et al. 2002, Tserpes and Tsimenides 1995). The presence of an opaque zone along the terminus of most otoliths examined in the present study supports this theory. The opaque zones form before the fish appear in coastal waters of South Carolina, thus suggesting that they are the result of slowed growth during migration to the region. Our findings are similar to those observed by Franks et al. (1999), who surmised that Cobia from the northeastern Gulf of Mexico formed their opaque zones during migration into that region. These authors based this conclusion on the presence of a terminal opaque zone on otoliths from Cobia sampled in April and in sexually immature fish. Because these fish were just entering the area or were not yet sexually mature, Franks et al. (1999) presumed that the terminal bands were formed during the migration to the region rather than as a result of the spawning event. Furthermore, other studies by Burns et al. (1998), Smith (1995), and Thompson et al. (1991) utilized otoliths to age Cobia, and all documented a singular annulus formation in the spring–summer months. Therefore, in the present study, age for Cobia is presumed to be equal to the number of opaque zones present in the sectioned sagittae.

It is also possible that annulus formation is the result of an energy shift from somatic growth to reproductive output during spawning season, as observed in *Scomberomorus cavalla* (Cuvier) (King Mackerel) by de L. Sturm and Salter (1989). This hypothesis could be evaluated by maintaining Cobia in captivity year-round to determine whether formation of opaque zones occurs in otoliths when fish are prevented from participating in migrations but remain reproductively active.

We obtained all specimens collected for the present study by sampling recreational-angler catches during May–July. Our overall sample was truncated by a minimum-fork-length harvest regulation (838 mm) enforced by the South Carolina Department of Natural Resources. As a result, age-1 and age-2 fish were underrepresented in our study. In addition, all samples were collected using hook-and-line gear, which has been shown to have the potential to create a size bias based on hook size or angler activity (Ralston 1990). This gear-selectivity bias can be problematic because it tends to create a skewed representation of the age structure of the stock, which can misinform assessments and impact the estimated status of a fish stock (Cowan 2011). We recognize that our initial estimates of the von Bertalanffy growth parameters may have been skewed by the lack of data for age-1 fish, the truncation of age-2 data (Fig. 4A), and by gear selectivity. The lack of age-1 and some age-2 fish skewed our initial estimates of K and t_0. The variability in estimates of k and t_0 between the present study and studies from other regions (Table 3) is most likely the result of these missing age classes. To overcome this missing component, we tried using data on younger fish from nearby (NC) as well as analytical techniques (Diaz et al. 2004) to try and adjust for those ages we lacked.

The Diaz-adjusted von Bertalanffy method has been effective in overcoming truncated age data for parameter estimates for other fisheries (Diaz et al. 2004), such as Red Snapper (SEDAR 2013c). In the current study, this method helped adjust the growth curve toward 0, compensating for the missing age-1 fish and providing more reasonable estimates for both K and t_0. We assumed that t_0 should be similar for both sexes and that estimates of t_0 for males were probably skewed by the paucity of age-2 males ($n = 1$). Using a fixed t_0 for males with the Diaz-adjusted method lowered the slope of the growth curve and provided a more realistic K value for males; nevertheless, this approach may have underestimated L_∞ for males (Fig. 4C). For comparative purposes, age-1 data ($n = 9$) from an earlier study of Cobia from North Carolina (Smith 1995) were used to generate additional sex-specific growth curves (Fig. 4D). This method provided the most realistic estimates for all parameters (Fig. 4D). Based on the parameters estimated by all 4 von Bertalanffy growth models, female Cobia in South Carolina achieved greater theoretical asymptotic length than did males (Fig. 4).

Currently, coastal development along the southeastern coast of the US is occurring at accelerated rates. Population densities grew from 55.5 persons per km^2 in 1980 to a projected 94.1 persons per km^2 in 2008 (Crossett et al. 2004). Williams et al. (2008) found that biomass of targeted fish species was negatively correlated to the local human population in the Hawaiian Islands, indicating increased fishing pressure in areas with increased coastal populations. We presume fishing pressure on Cobia will increase; thus, a better understanding of the species' life-history is necessary for the effective management of the fishery. At present, few definitive statements can be made regarding Atlantic Coast stock status for Cobia, mainly because of the lack of comprehensive life-history information for the species (Williams 2001). The most current assessment indicates that Cobia stocks (both Gulf and Atlantic) are not overfished (SEDAR 2013a, b). As a result of that assessment, annual catch limits were established for both stocks in order to comply with the Magnuson–Stevens Reauthorization Act of 2006. These measures are a step in the right direction, but additional work is needed to further improve assessment estimates and adjust catch limits (SEDAR 2013a, b).

Continued collection of data to improve regional stock assessments is needed for populations of Cobia in the Western Central Atlantic and Gulf of Mexico to better elucidate the overall stock status of Cobia. The life-history characteristics of Cobia as defined by this study provide managers with additional age and growth information that help to effectively manage the species. For example, the data collected during this study was used during the most recent assessment (SEDAR 2013b) on Cobia and provided managers with growth parameters from a region that had not been studied before. Future research should focus on tagging Cobia to better describe migratory behavior and identify specific overwintering locations, and on sampling age 0–1 fish to increase the accuracy of t_0 estimates.

Acknowledgments

We thank S. Lynn and S. Kalinowsky for all of their assistance in the field. We are grateful to the staff of the South Carolina Department of Natural Resources (SCDNR): M. Denson, W. Jenkins, K. Brenkert, J. Yost, C. Taylor, and all other staff, interns, and volunteers of the SCDNR Marine Resources Division (MRD) that participated in this effort. We benefitted from the assistance of J. Smith, D. Vaughan (NMFS-Beaufort Laboratory), E. Robillard, and Sonny Emmert (Georgia DNR-CRD). We thank the marina operators and tournament officials who allowed us to sample at their facilities and events including: Lemon Island Marina, Bryans Seafood, Hilton Head Food and Beverage Tournament, Fillin' Station Tournament, Lowcountry Marine Tournament, and Hoots Tournament. We also appreciate the recreational anglers that allowed us to sample their catches and the Hilton Head Sportfishing Club for the continued support throughout this effort. We are grateful to M. Sherman for extensive editing assistance funded by a Department of Education Title VII grant awarded to M.C. Curran (# P382G090003) and to the NIH SCORE program for funding assistance. Finally, we thank Capt. J. Clark, Capt. B. Parker, Capt. J. Deloach, Capt. M. Upchurch, Capt. J. Walker, and all other charter-boat captains that donated their time and effort to help make this project a success. This publication is also listed as Contribution Number 1838 of the Belle W. Baruch Institute for Marine and Coastal Science.

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