Stomach contents of juvenile cobia, *Rachycentron canadum*, from the northern Gulf of Mexico

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The cobia, *Rachycentron canadum*, is a monotypic member of the family Rachycentridae. It is a migratory pelagic fish that occurs worldwide in tropical, subtropical, and warm temperate seas, except in the central and eastern Pacific Ocean (Shaffer and Nakamura, 1989). In the western Atlantic, the cobia occurs from Massachusetts and Bermuda to Argentina (Briggs, 1958) but is most common in the Gulf of Mexico (Migdalski and Fichter, 1983), ranging from Key West, Florida, along the Gulf coast to Campeche, Mexico (Dawson, 1971).

Some individual cobia are seasonal migrants, moving from wintering grounds near the Florida Keys into the Gulf of Mexico during spring, generally entering northern Gulf waters from April through May and returning to the wintering grounds during late fall and early winter (Franks et al., 1991; Biesiot et al., 1994). The timing of these migrations may relate to the availability of important prey species (Darracott, 1977).

A few observations on the food habits of adult *R. canadum* from the Gulf (Gulf of Mexico) have been reported. Knapp (1951) listed the stomach contents of 24 cobia taken near Port Aransas, Texas, and Miles (1949) briefly discussed the foods of 11 cobia from Aransas Bay, Texas. Reid (1954) mentioned the stomach contents of a single adult taken in the vicinity of Cedar Key, Florida, and Boschung (1957) remarked on the prey in four cobia collected off coastal Alabama. Christmas et al.[1] reported the prey of 11 adult cobia taken off Mississippi. A brief review of reported foods of cobia was presented by Shaffer and Nakamura (1989). Stomach contents of 287 cobia caught by hook and line in the northern Gulf of Mexico recreational fishery, mostly adults taken off Mississippi, were reported by Meyer and Franks (1996). None of these studies identified which prey, if any, were specifically consumed by juvenile cobia, rather, these observations were reported either for adults, for a size range comprising both juveniles and adults, or for cobia "in general." This paper represents the first study describing specifically the diet of juvenile *R. canadum*.

Knowledge of the feeding habits of juvenile cobia is necessary for understanding the role of diet in the recruitment processes of this economically important species and is a necessary prerequisite for management of this resource. The specific objective of this study was to analyze quantitatively the diet of juvenile cobia from the northern Gulf of Mexico.

Methods

Juvenile cobia were collected by trawl during fisheries resource surveys conducted in the northern Gulf of Mexico by the National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center, Pascagoula, Mississippi. Fish were collected in July (n=7) and September (n=40) 1993 and in March (n=2) 1994 north of lat. 28°32'N and between long. 85°40'W and long. 93°55.4'W (Fig. 1). Most of the specimens (71%) were collected during September 1993 off Mississippi and Alabama. Bottom water depth ranged from 9 to 6 m.

Collection gear included a 28-m high-profile fish trawl with 0.6-cm codend mesh; a 19-m "western jib" shrimp trawl with 4-cm codend mesh; a 17-m "mongoose" shrimp trawl with 4-cm codend mesh; and

[1] Christmas, J. Y., A. Perry, and R. S. Waller. 1974. Investigations of coastal pelagic fishes. Gulf Coast Research Laboratory, P.O. Box 7000, Ocean Springs, MS 39566-7000. Completion Rep. to the U.S, Bur. Comm. Fish, Proj. 2-128-R, 105 p.

Manuscript accepted 13 December 1995.
Fishery Bulletin 94:374–380 (1996).

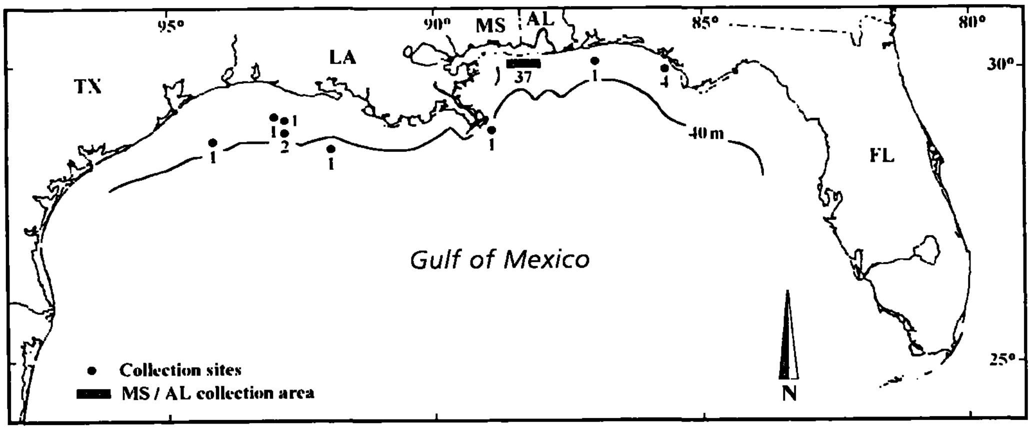

Figure 1
Collection sites and sample sizes of juvenile cobia, *Rachycentron canadum*, from the northern Gulf of Mexico. The MS/AL collection area comprised 17 collection sites.

a 13-m otter trawl with 4-cm codend mesh. Towing speed was 2.5 knots, and the duration of tows ranged from 0.25 to 1 h. Time and location were recorded for each tow. Juveniles were collected in 25 net hauls (18 by day; 7 at night). Whole specimens were frozen aboard the research vessel, generally <0.5 h following capture. In our laboratory, specimens were thawed, measured to the nearest mm fork length (FL), and weighed to the nearest 0.1 g total weight (TW). Stomachs were removed, opened, and designated either as containing food or as empty. Stomach contents were fixed in 10% buffered formalin and then placed in 50% ethanol. A cursory examination revealed that intestinal contents were too digested to be identified; thus, intestines were separated from stomachs at their confluence and discarded.

Stomach contents were placed onto a 0.840-mm mesh screen sieve and gently washed with fresh water. Prey were identified to the lowest taxa possible, counted, weighed (blotted wet weight) to the nearest 0.1 g, and measured volumetrically to the nearest 0.1 mL by water displacement in a graduated cylinder. Prey too digested for unequivocal identification were assigned to one of the appropriate principal prey categories (fish, crustaceans, or cephalopods) as "remains" and included in the determination of the contributions of those principal categories to the diet.

Stomach-content data were pooled for all stomachs and analyzed for percent numeric abundance (*%N*), percent of total volume (*%V*), and percent frequency of occurrence (*%F*) of prey items to describe quantitatively the diet, where *%N* = (number of individuals of one prey taxon divided by total number of all prey individuals) × 100; *%V* = (volume of one prey taxon divided by total volume of all prey) × 100; and *%F* = (number of stomachs containing prey of one taxon divided by total number of stomachs that contained any prey items) × 100. These methods have been reviewed by Windell (1971) and Hyslop (1980). These values were used to calculate an index of relative importance (*IRI*) (Pinkas, 1971), where the importance of an item is directly related to the size of the value:

$$IRI = (\%N + \%V) \times \%F.$$

Percent *IRI* (*%IRI*) was also calculated and consisted of the *IRI* value of each prey taxon divided by the sum of the *IRI* values (Eggleston and Bochenek, 1989). Empty stomachs were excluded from the above computations.

A small number of other items found in stomachs (e.g. mollusc shells and both larval and postlarval crustaceans and parasitic worms) were considered miscellaneous or nonfood items probably ingested incidentally in normal feeding. These were not used in calculating percentages or indices describing relationships of food items in the diet.

A stomach fullness index was calculated by dividing the total prey weight of each cobia by its total body weight × 100 (Sullivan and Gillman, 1993; Rooker, 1995). Stomach fullness was tested between daytime and nighttime captures, and to further examine diel feeding periodicity based on stomach fullness, cobia were grouped by time of capture into 6, 4-h periods: 0000–0400 (n=2); 0400–0800 (including dawn) (n=5); 0800–1200 (n=15); 1200–1600 (n=10); 1600–2000 (including dusk) (n=8); and 2000–2400 (n=9). A one-way analysis of variance (ANOVA) was used to test for differences in mean fullness between time intervals.

Chi-square (χ^2) 2 × 2 contingency table analyses and Fisher's exact test were used to test for differences in frequency occurrence of principle prey categories (fish, crustaceans, and cephalopods) between two size (FL) groups of juvenile cobia, small (236–338 mm) and large (340–440 mm), that represented all juveniles with food in their stomachs. The χ^2 test and Fisher's exact test were used to identify significant differences in frequency occurrence of principle prey categories between two geographic areas of juvenile collection (east of long. 89°W; west of long. 89°W), essentially described as east and west of the Mississippi River delta. The diet was also examined for seasonal differences in the occurrence of principal prey.

Results

Stomach contents of 49 juvenile *R. canadum* ranging from 236 to 440 mm FL (mean 335 mm) and from 0.08 to 0.81 kg TW (mean 0.34 kg) were examined. Thirty-nine of the 49 (80%) stomachs examined contained prey. The diet comprised three principal categories: fish, crustaceans, and cephalopods (Table 1).

Fishes occurred in 31 (79.5%*F*) of the stomachs containing food and represented 40.9% of the total number of prey and 37.7% of the total volume of prey (Fig. 2). The fish category dominated the %*IRI* (60.0%) (Fig. 2). Fish prey were represented by nine species (Table 1). Other fishes, owing to various states of digestion, could be identified only to genus (*Anchoa* sp. and *Symphurus* sp.) or family (Serranidae).

Anchovies were by far the predominant fish prey items, accounting for 19.7%*N* and 18.4%*V* of all items in the diet (Table 1). The striped anchovy, *Anchoa hepsetus*, was the dominant species by %*V* (9.2), *IRI* (163.8), and %*IRI* (4.9). The bay anchovy, *Anchoa mitchilli*, exhibited the highest numeric percentage (8.4) among fish in the diet; however, all specimens of *A. mitchilli* occurred in one stomach. The dominance of anchovies would be even greater if one considered that unidentifiable fish remains (15.1%*N*, 6.9%*V*, and 74.4%*F*) were primarily anchovies.

Crustaceans ranked first in importance numerically (42.7%*N*) and second by volume (37.4%*V*) and occurred in 59.0% of the stomachs (Fig. 2). Decapods were the most common crustaceans encountered (Table 1). The roughback shrimp, *Trachypenaeus similis*, was the dominant food item in the diet on the basis of %*N* (19.2), but all of these specimens occurred in only two stomachs. Other decapod species were brown rock shrimp, *Sicyonia brevirostris*, lesser rock shrimp, *Sicyonia dorsalis*, and iridescent swimming crab, *Portunus gibbesii*. Other decapods were identifiable only to Portunidae, Xanthidae, or Brachyura. *Sicyonia brevirostris* and *P. gibbesii* contributed 9.1%*V* and 5.9%*V* to the total diet, respectively (Table 1). Decapod remains (2.2%*V*) were categorized as being either those of shrimp (11.8%*N*, 33.3%*F*) or crab (0.8%*N*). The mantis shrimp, *Squilla empusa* (Stomatopoda), contributed 6.4%*V* but only 2.1%*N* to the diet.

Cephalopods were present in 17.9% of the stomachs and comprised 16.3%*N* and 24.9%*V* of prey organisms (Fig. 2). This group was represented by two species, the slender inshore squid *Loligo plei*, and the longfin inshore squid, *Loligo pealei*. Overall, *Loligo plei* dominated the diet among identifiable prey (17.0%*V*, 15.4%*F*, 494.3 *IRI* and 14.9% *IRI*) and was the second most important food item based on %*N* (15.1) (Table 1). *Loligo pealei* was the fifth ranking food item by volume, contributing 7.7%.

The proportion of empty stomachs was significantly greater for juveniles collected during the night (40%) than during the day (12%) (χ^2=3.518, df=1, P<0.05). Mean stomach fullness was found to vary significantly (with 95% confidence) between daytime (3.13) and nocturnal (0.92) collections (ANOVA, df=1, P<0.05) (Fig. 3). When further measured for specific time intervals of capture, mean fullness values were 0.08 (0001–0400), 2.00 (0400–0800), 3.29 (0800–1200), 2.45 (1200–1600), 3.70 (1600–2000), and 0.73 (2000–2400)

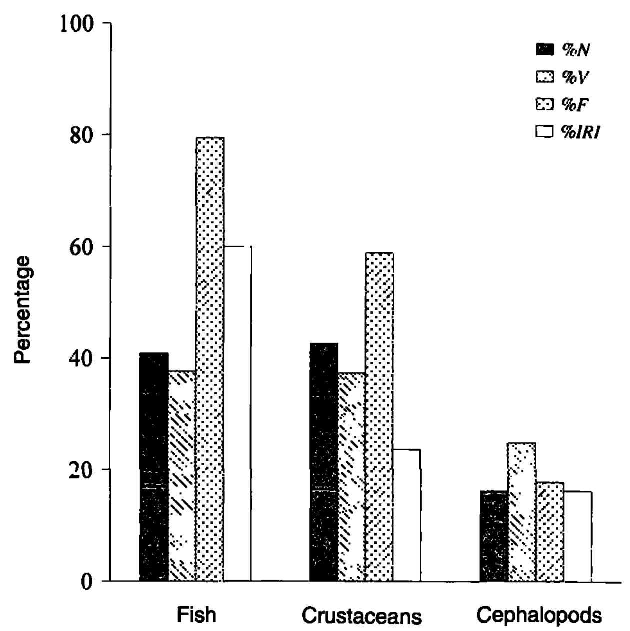

Figure 2

Percent numerical abundance (%*N*), percent total volume (%*V*), percent frequency of occurrence (%*F*), and percent index of relative importance (%*IRI*) for primary prey categories in the diet of juvenile *Rachycentron canadum* from the northern Gulf of Mexico.

(Fig. 4); however, the difference between these means was not statistically significant (ANOVA, df=5, P>0.05).

Comparison of the percent occurrence of principal prey categories between the diets of two groups of juvenile cobia based on length (group 1=236–338 mm FL; group 2=340–440 mm FL, Fig. 5) showed that the smaller juveniles fed primarily on crustaceans and fish, whereas fish were the primary foods of group 2. Crustaceans were found in 21 of 25 (84%) stomachs of fish in group 1 but in only 5 of 14 (36%) stomachs of fish in group 2. This indicated a highly significant (χ^2=8.469, df=1, P<0.05) difference in diet and was directly related to the greater frequency occurrence of shrimp (including shrimp remains) in the diet of group-1 fish. Fish were important prey for both groups of juveniles (Fig. 5), and although we encountered fish more frequently in the stomachs of group-2 fish, fish occurrence between the two

Table 1

Prey items occurring in the stomachs of 39 juvenile cobia, *Rachycentron canadum*, from the northern Gulf of Mexico, 1993–94. % Frequency of occurrence is based on stomachs containing food (n=39). Unid = unidentified.

Prey	Number of individual prey items	% Number	Volume (mL)	% Volume	% Freqnency of occurrence	Index of relative importance (IRI)	% IRI
Class Osteichthyes							
Anchoa hepsetus	16	6.7	36.0	9.2	10.3	163.8	4.9
Anchoa mitchilli	20	8.4	29.0	7.4	2.6	41.1	1.2
Anchoa sp.	11	4.6	7.0	1.8	12.8	81.9	2.5
Saurida brasiliensis	2	0.8	7.0	1.8	2.6	6.8	0.2
Prionotus rubio	1	0.4	8.5	2.2	2.6	6.8	0.2
Centropristis philadelphica	2	0.8	5.0	1.3	2.6	5.5	0.2
Unid. serranid	3	1.3	0.5	0.1	2.6	3.6	0.1
Stenotomus caprinus	1	0.4	12.5	3.2	2.6	9.4	0.3
Abudefduf saxatilis	1	0.4	1.0	0.2	2.6	1.6	0.1
Trichiurus lepturus	1	0.4	1.0	0.2	2.6	1.6	0.1
Symphurus plagiusa	2	0.8	10.5	2.7	5.1	17.9	0.5
Symphurus sp.	2	0.8	3.0	0.7	5.1	7.7	0.2
Fish remains	36	15.1	27.0	6.9	74.4	1,636.8	49.5
Class Crustacea							
Stomatopoda							
Squilla empusa	5	2.1	25.0	6.4	7.7	65.5	2.0
Squilla chydaea	3	1.3	1.5	0.4	2.6	4.4	0.1
Squilla sp.	2	0.8	1.0	0.3	5.1	5.1	0.2
Decapoda							
Trachypenaeus similis	46	19.2	44.5	11.4	5.1	156.1	4.7
Sicyonia brevirostris	3	1.3	35.5	9.1	5.1	53.0	1.6
Sicyonia dorsalis	2	0.8	4.0	1.0	2.6	4.7	0.1
Portunus gibbesii	7	3.0	23.0	5.9	2.6	23.1	0.7
Unid. portunid	2	0.8	1.5	0.4	2.6	3.1	0.1
Unid. xanthid	1	0.4	0.5	0.1	2.6	1.3	0.1
Unid. brachyuran	1	0.4	1.0	0.2	2.6	1.6	0.1
Shrimp remains	28	11.8	8.5	2.1	33.3	462.9	13.9
Crab remains	2	0.8	0.5	0.1	5.1	4.6	0.1
Class Cephalopoda							
Loligo plei	36	15.1	66.5	17.0	15.4	494.3	14.9
Loligo pealei	2	0.8	30.0	7.7	5.1	43.4	1.3
Squid remains	1	0.4	1.0	0.2	2.6	1.6	0.1
Total	239		392.0			3,309.2	
Total stomachs analyzed	49						
No. (%) containing food	39 (80%)						
No. (%) empty	10 (20%)						

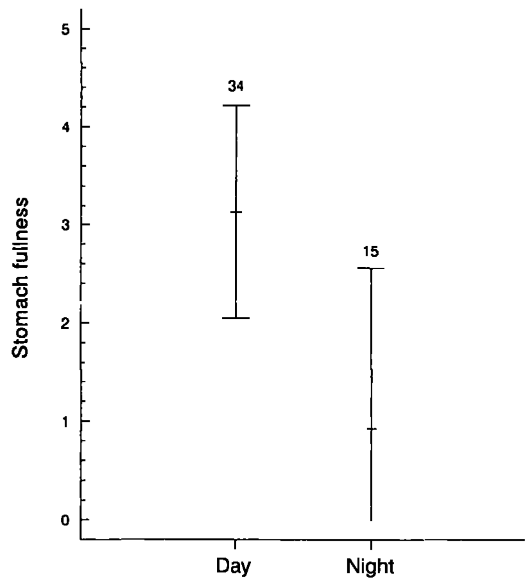

Figure 3
Comparison of day and night mean stomach fullness values (±95% CL) for juvenile *Rachycentron canadum* from the northern Gulf of Mexico. Number of fish sampled is given for each time period. Stomach fullness = prey weight/predator weight·100.

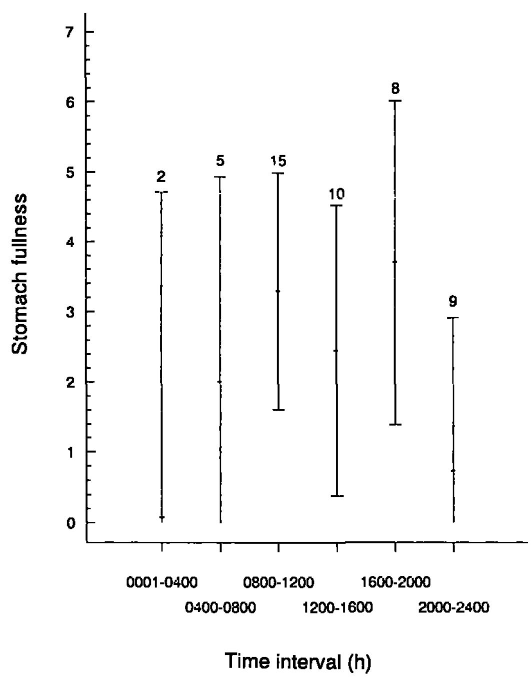

Figure 4
Diel feeding periodicity based on mean stomach fullness (±95% CL) for juvenile *Rachycentron canadum* from the northern Gulf of Mexico. Numbers over each series of values are sample sizes. Stomach fullness = prey weight/predator weight·100.

groups was not statistically different. The percent occurrence of cephalopods (squid) was low for both groups and differed insignificantly.

Chi-square contingency analysis suggested that geographic location did not significantly affect the diet, although we did observe that cephalopods (squid) were absent in the stomachs of all juveniles (n=6) collected west of the Mississippi River. The stomachs of the 2 cobia collected in March (spring) contained, collectively, the only specimens of sea bass (Serranidae, n=3) and xanthid crab (n=1) encountered in the study. The only other prey found in the stomachs of the juveniles collected in March were anchovies which, notably, were the predominant fish prey among the summer (July and September) cobia. A larger sample size is needed to assess accurately any geographic or seasonal variations in diet.

Discussion

We found that juvenile cobia captured by trawl in the northern Gulf of Mexico during fall 1993 and early spring 1994 were carnivorous and fed exclusively on small fish, crustaceans, and squid. Fish, crustaceans, and cephalopods also comprised the diet of adult cobia collected in the northcentral Gulf of Mexico (Meyer and Franks, 1996). On the basis of the frequency occurrence of prey in the diet of cobia caught near Aransas Bay, Texas, Knapp (1951) reported the predominance of fishes (83%), followed by stomatopods (58%), penaeid shrimps (46%), portunid crabs (42%), and squid (17%). Meyer and Franks (1996) reported that the percent frequency of occurrence and numeric percentage of crustaceans (79.1%*F*, 77.6%*N*) dominated that of fishes (58.5%*F*, 20.3%*N*) and cephalopods (13.2%*F*, 2.2%*N*). Our results showed that fish and crustaceans were present in the diet in approximately equal volumes, and, as reported by Miles (1949) and Christmas et al.)[1] for cobia taken off Texas and Mississippi, respectively, occurred in nearly equal numbers; however, we found that fish occurred in the diet with somewhat greater frequency than did crustaceans. Based on *IRI* calculations, the relative importance of fishes (*IRI*=1,984.5) as prey items was approximately three times that of shrimp (*IRI*=676.7) and three and one-half times that of squid (*IRI*=539.3).

In our study, anchovies were the dominant prey among the fish consumed and were major contributors to the diet. Unidentified fish remains, probably anchovies, occurred in almost 75% of the stomachs

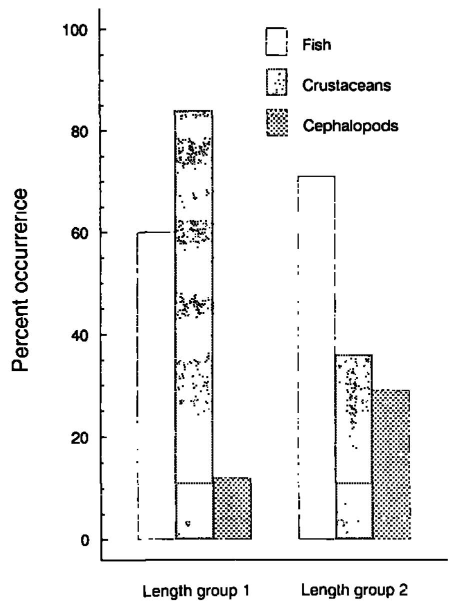

Figure 5

Principal prey of two length groups of juvenile *Rachycentron canadum*: Group 1 (236–338 mm FL, n=25) and Group 2 (340–440 mm FL, n=14), expressed as percent frequency of occurrence.

and were demonstrably important in the overall diet, exhibiting the highest *IRI* (1,636.8) and *%IRI* (49.5) of all food items. We observed that anchovies occurred in 36% of group-1 juveniles, whereas only 14% of the stomachs of group-2 juveniles contained anchovies. Because anchovies were rarely encountered (0.3%*F*) in the diet of northern Gulf adult cobia (Meyer and Franks, 1996), our findings may suggest a possible ontogenetic shift in feeding between juveniles and adults.

Trachypenaeus similis was a key component of the juvenile cobia diet on the basis of numeric and volumetric percentages, and our data show that shrimp, including shrimp remains, occurred in more than 41% of the stomachs, exceeded only by fish in percent frequency occurrence of prey. We found that crustaceans, primarily shrimp, occurred at a significantly higher frequency in the stomachs of smaller juveniles (84%) than in larger juveniles (36%). In contrast, Meyer and Franks (1996) reported that crustaceans, primarily portunid crabs, were the primary foods of adult cobia, based on percent occurrence, and essentially dominated the adult diet.

Loligo plei was one of the most important identified prey consumed by juvenile cobia. This species of squid is abundant in the northern Gulf of Mexico, particularly in shallower Gulf waters during spring and fall of the year (Hixon, 1980). Knapp (1951) reported the percent occurrence for *Loligo* in the diet of cobia as 17%. We report a similar percentage (18%) for *Loligo* and a percent occurrence of 21% for all loliginids combined. Meyer and Franks (1996) reported the percent occurrence of loliginids as ~12%.

Evaluation of diel feeding periodicity based on stomach fullness showed that juvenile cobia feed primarily during daylight. Although fullness peaked during the day, notably during late afternoon through dusk, there was no significant difference in fullness between daytime collection time intervals, including those containing dawn, noon, or dusk. Diana (1979) remarked that when fish with diel feeding cycles are collected at different intervals of time, some stomachs should be empty. We found that 20% of the stomachs we examined were empty.

Field observations in this study did not include reference to regurgitation of prey (i.e. everted stomachs or partially digested food in the mouth). Bowman (1986) stated that undetected regurgitation relative to fish food studies could produce severe underestimation of prey consumption, and he[2] reported that regurgitation is frequently observed in fishes trawled from depths exceeding 100 m. In our study only two cobia were collected at depths >40 m (i.e. 56 m and 66 m), and the stomach of each contained food. Incidentally, the juvenile from the 66-m site contained the second highest volume of food measured from all juvenile stomachs. Most cobia in our study (94%) were trawled from waters <30 m in depth. Even though somewhat limited by the small sample size of stomachs with prey, we were able to observe that increasing size (length) in juveniles appeared to influence an apparent ontogenetic shift from crustacean to piscine prey. Diet composition of juvenile cobia showed no marked changes in prey taxa between seasons or geographic locales.

Cobia are strong swimmers, quick enough to catch fish, squid, and decapod crustaceans. Personal observations, made by the senior author of cobia in culture systems and in natural habitats, reveal that *R. canadum* is a very aggressive feeder and quite capable of catching motile prey. Interestingly, prey species in this study demonstrate considerable diversity in the foraging behavior of juvenile cobia. Anchovies and squid are important components of the open-water nekton. Portunid crabs are both nektonic and benthic organisms. The shrimps and the Brachyuran crab, though capable of swimming, are

[2] Bowman, R. E. 1981. Examination of known and potential causes of variation in fish feeding studies. Northeast Fisheries Science Center, Natl. Mar. Fish. Serv., NOAA, 166 Water St., Woods Hole, MA 02543. Woods Hole Lab. Ref. Doc. 81-23, 29 p.

predominantly benthic inhabitants. Other prey, such as the blackwing searobin, *Prionotus rubio*, rock sea bass, *Centropristis philadelphica*, Atlantic cutlassfish, *Trichiurus lepturus*, longspine porgy, *Stenotomus caprinus*, and blackcheek tonguefish, *Symphurus plagiusa*, are essentially demersal. The variety of the diet in this study suggests that juvenile cobia often feed in the water column and possibly near the surface but primarily on or near the sea floor, exhibiting opportunistic feeding behavior comparable to that reported for adults (Meyer and Franks, 1996).

Acknowledgments

Special thanks go to Ian Workman, Dan Foster, Rob Caylor, and Mark Grace of the National Marine Fisheries Service, Pascagoula, Mississippi, for providing the specimens of juvenile cobia, as well as the field collection data, examined in this study. We thank Dianne Scott and Amber Garber for their assistance in the processing of stomachs. Appreciation is extended to Robin Overstreet, Harriet Perry, Gabriele Meyer, and Guillermo Sanchez for their help in the identification of stomach contents. Lisa Engel assisted in data entry. We also thank Robin Overstreet, Chet Rakocinski, and Patricia Biesiot for reviewing earlier versions of the manuscript and offering helpful comments. We also greatly appreciate the constructive comments and suggestions of two anonymous reviewers. Funding for this study was provided by the Gulf Coast Research Laboratory, the Mississippi Department of Marine Resources, and the Department of the Interior, U.S. Fish and Wildlife Service, Federal Aid for Sportfish Restoration Project F-91.

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