Larval development, distribution, and ecology of cobia *Rachycentron canadum* (Family: Rachycentridae) in the northern Gulf of Mexico

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Larval development, distribution, and ecology of cobia *Rachycentron canadum* (Family: Rachycentridae) in the northern Gulf of Mexico*

James G. Ditty
Richard F. Shaw
Coastal Fisheries Institute, Wetland Resources Building
Louisiana State University, Baton Rouge, Louisiana 70803-7503

Abstract. – Cobia is a highly prized recreational species of worldwide distribution in tropical and subtropical seas, but the development, distribution, and ecology of its early life stages are poorly known. Eggs are spherical, average 1.24 mm in diameter, and have a single oil globule (mean diameter 0.45 mm). The perivitelline space is narrow and the embryo heavily pigmented. Eggs hatch in about 24 h at 29°C based on the relationship between egg diameter and water temperature to predict development time in other marine fishes. Larvae hatch at about 2.5 mm SL. Cobia spawn in both estuarine and shelf waters during the day, and eggs and larvae are usually collected in the upper meter of the water column. Larvae are recognized by the large supraorbital ridge with a single spine, laterally swollen pterotics, heavy body pigmentation, minute epithelial spicules covering the body integument, and a pair of moderate-to-large, simple spines on either side of the angle of the posterior preoperculum. Only 70 larvae <20 mm SL were collected and identified from the Gulf of Mexico between 1967 and 1988; most occurred between June and September at surface temperatures $\geqslant 25°$C, salinities $>27‰$, and within the 100 m depth contour. Similar patterns of head spination provide evidence of a sister-group relationship between cobia and dolphinfish rather than that previously hypothesized between cobia and remoras.

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Cobia, in the monotypic family Rachycentridae, is distributed worldwide in tropical and subtropical seas (Briggs 1960), except the eastern Pacific, and is found seasonally in temperate waters (Hassler and Rainville 1975). A highly prized recreational species, most of the U.S. landings are from Gulf of Mexico (Gulf) waters; they are also caught incidentally in commercial fisheries (Shaffer and Nakamura 1989). Recreational landings are not well documented, but cobia are reportedly not abundant and recruitment is considered low (Gulf of Mexico & S. Atl. Fish. Manage. Counc. 1985). Cobia are migratory and usually absent from commercial and recreational catches of the northern Gulf during late fall and winter at which time they are caught off the Florida Keys. They migrate north and west along the Gulf coast during the spring (Shaffer and Nakamura 1989) and reappear in northern Gulf waters during March and April (Springer and Pirson 1958). Cobia are usually caught in shallow coastal waters (Shaffer and Nakamura 1989), although they are often taken offshore along the Louisiana and Texas coasts in association with oil and gas platforms and rafts of *Sargassum* (RFS, pers. observ.).

Despite the recreational value of cobia, its ecology, distribution, and morphological development during early life stages are poorly known. Only 23 specimens <20 mm SL are reported in the historical literature for the Gulf (Dawson 1971, Finucane et al. 1978ab, Houde et al. 1979). Richards (1967) reviewed cobia general life history, Shaffer and Nakamura (1989) compiled biological data, and Hassler and Rainville (1975) developed techniques for hatching and rearing cobia. In addition, Johnson (1984) discussed the utility of cobia early life stages for examining previous phylogenetic hypotheses and the evolutionary interrelationships of echeneoids (Rachycentridae–Coryphaenidae–Echeneididae). Aspects of early egg development have been described (Ryder 1887, Joseph et al. 1964, Hassler and Rainville 1975) but not development of early larvae <12.6 mm SL. Most larval illustrations and photographs are of poor quality (Ryder 1887, Dawson 1971, Hassler and Rainville 1975, Finucane et al. 1978a, Johnson 1984). The objectives of this study are to describe cobia egg and larval development, to provide data on the seasonal occurrence, distribution, and ecology (i.e., relationship of larvae to water temperature, salinity, and station depth at time of capture) of early life stages of cobia in the Gulf, and to further examine the interrelationships of the echeneoids.

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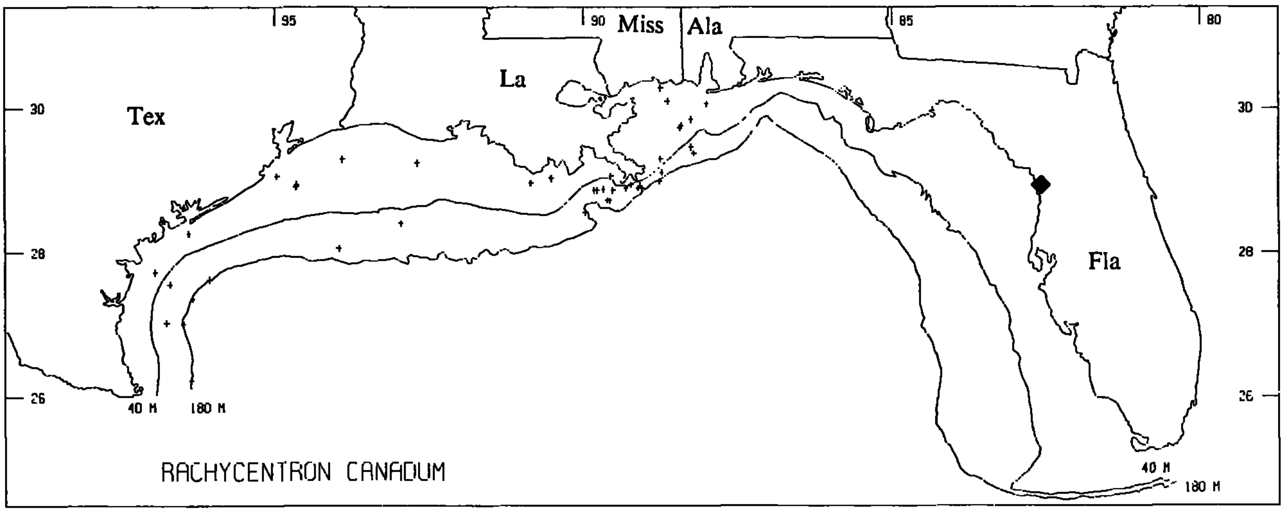

Figure 1
Distribution of larval cobia *Rachycentron canadum* in the northern Gulf of Mexico. Plus signs are positive catch stations; diamond is location of Crystal River estuary where cobia eggs and yolksac larvae were collected.

Methods

Eggs and larvae were obtained from museum collections along both the Gulf and Atlantic coasts. We examined 70 cobia eggs (all late-stage embryos) and 76 larvae 2.6–25 mm SL and determined their seasonal occurrence, distribution, and ecology. Hydrographic parameters were weighted by the total number of larvae caught at each station to derive mean and median values. All specimens were formalin-preserved except those from Southeast Area Monitoring and Assessment Program (SEAMAP) ichthyoplankton surveys of the Gulf which were in ethyl alcohol. We considered lat. 26°00′N as the southern boundary of our survey area (Fig. 1). Temperature and salinity data were from the surface only.

Body measurements were made to the nearest 0.1 mm with an ocular micrometer in a dissecting scope and follow Hubbs and Lagler (1958) and Richardson and Laroche (1979). All lengths refer to standard length (SL) unless otherwise noted. A compound scope was used to examine the origin and location of epithelial spicules. Representative specimens were illustrated with the aid of a camera lucida. Specimens were not cleared and stained because of the paucity of material. Fin rays were counted when their pterygiophores were visible; spines when they resembled formed structures (Richardson and Laroche 1979). Myomeres were difficult to count in fish >6 mm due to heavy larval pigmentation and opacity of the musculature, even under polarized light, but all specimens <6 mm had 24 myomeres. Cobia undergoing transition to the juvenile stage were those with a full complement of formed rays in all fins. Egg staging followed Moser and Ahlstrom (1985).

Egg and larval development

Cobia eggs were spherical and measured 1.15–1.3 mm ($\bar{x}$ 1.24, *N* 31), with a single oil globule 0.4–0.65 ($\bar{x}$ 0.45, *N* 13) in diameter. The oil globule was pigmented and lay near the vegetal pole opposite the developing embryo. The perivitelline space was narrow with the embryo occupying about 85% of egg volume (range 70–92%, *N* 13). The chorion was smooth and unornamented. Cobia eggs hatch in about 24 h at 29°C based on Pauly and Pullin's (1988) relationship between egg diameter and water temperature to predict development time in marine fishes.

The embryo of late-stage Gulf cobia eggs was heavily pigmented except for the caudal peduncle which was unpigmented. Late-stage embryos from north of Cape Hatteras, NC, had pigment lightly scattered over the peduncle. Early yolksac larvae (2.6–3.2 mm) were heavily pigmented externally and lacked a functional mouth, eye pigment, and all fins. A single oil globule with pigment was also present in the middle of the yolksac. External pigment occurred over the snout and in a band immediately behind the primordial eye. The eye remained unpigmented until larvae were 3.5–4.0 mm (Fig. 2). At higher magnification, tiny epithelial

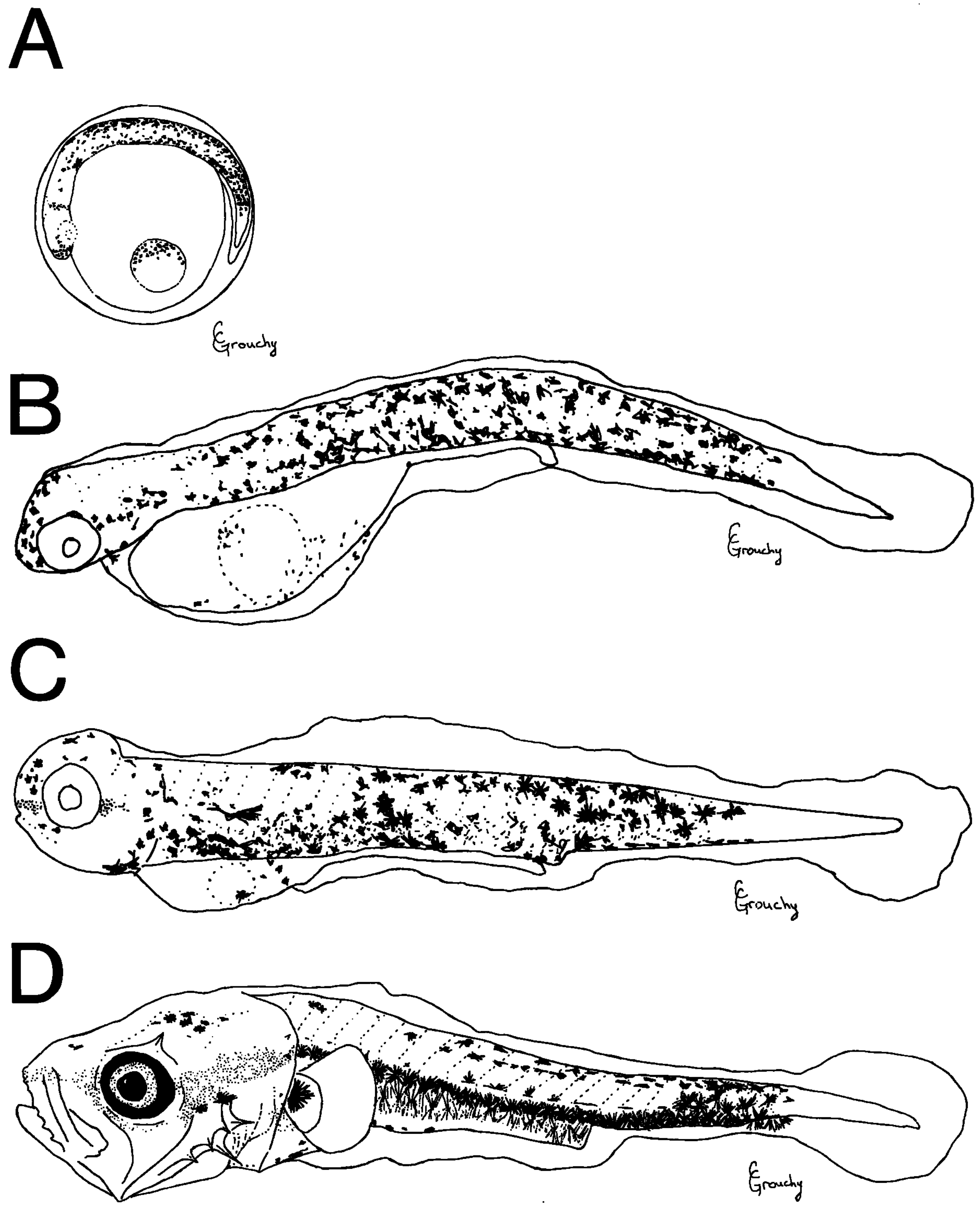

Figure 2

Eggs and larval development of cobia *Rachycentron canadum*. (A) Late-stage egg, diameter 1.24 mm; (B–C) yolksac larvae 2.6 and 3.0 mm SL; (D–H) larvae 4.5 mm, 6.8 mm, 10.0 mm, 14.1 mm, and 18.9 mm SL.

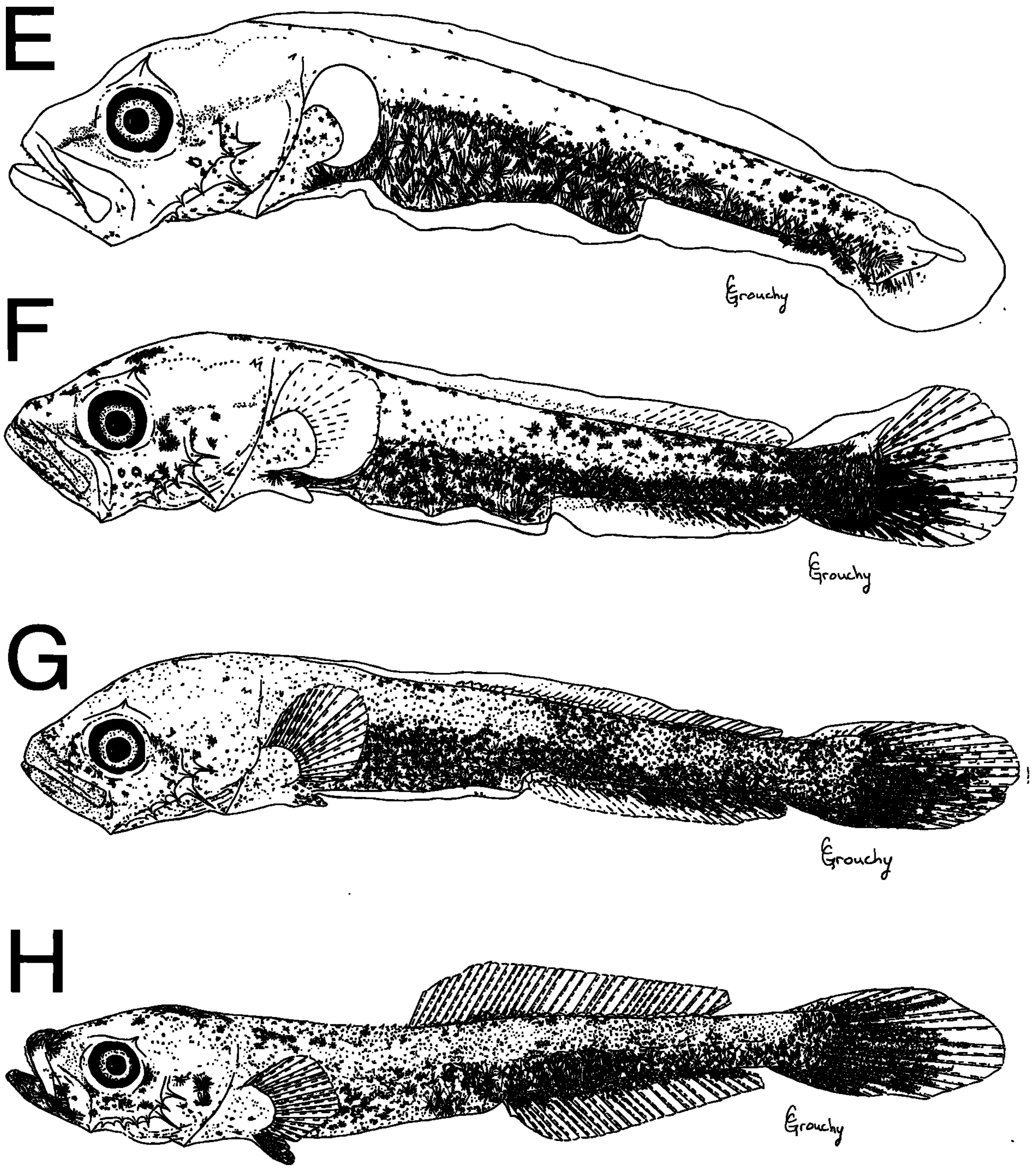

Figure 2 (continued)

Table 1

Body proportions of larval cobia *Rachycentron canadum* from the Gulf of Mexico, expressed as % standard length (SL).

SL	*N*	Preanal length	Head length	Snout length	Orbit diameter	Upper jaw length	Body depth cleithrum	Predorsal length	Prepelvic length	Peduncle length
2.6	1	61.5								
3.2	1	62.5								
4.0–4.9	2	64.4–65.0	27.8–31.2	6.7–7.5	10.0–11.2	10.0–13.8	18.9–21.2			
5.0–5.9	3	68.0–68.6	31.4–34.0	7.6–10.0	11.0–12.7	13.6	20.3–20.6		33.9	
6.0–6.9	3	63.2–67.2	27.9–31.7	7.3–8.3	8.8–10.8	10.3–12.7	19.8–23.3		30.9	
7.0–7.9	3	64.1–65.3	26.9–29.5	7.0–8.7	9.0–10.0	10.9–13.3	17.9–20.0	52.6	30.8–33.3	12.0–12.8
9.8	1	64.3	30.6	8.7	9.2	12.8	21.4	51.0	33.7	12.8
10.0–10.9	3	57.1–64.1	27.5–29.5	7.0–8.1	9.0–10.0	11.5–13.3	19.0–20.0	50.0–56.3	30.0–36.9	12.1–13.3
11.0–11.9	3	57.3–60.9	27.7–29.9	6.7–7.8	8.4–8.7	11.3–12.0	18.3–19.2	49.6–52.2	31.1–34.2	11.5–12.6
12.0–12.9	2	63.2–63.7	28.2–28.8	7.2–8.0	8.8–8.9	11.2–11.3	16.1–18.4	49.2–50.4	32.0–32.2	12.5–12.8
14.0–14.9	2	56.6–58.7	26.2–27.3	6.9–7.0	8.0–8.3	11.0–11.2	17.2–17.5	49.0–50.3	29.4–30.3	11.0–11.2
16.0–16.9	3	58.4–59.9	26.5–26.9	7.2–7.8	7.8–8.4	10.2–10.5	15.0–16.8	48.2–49.4	28.9–30.1	12.0–13.6
19.5	1	57.4	27.2	7.7	7.7	10.2	15.4	46.2	29.7	12.8
21.0	1	57.1	24.8	6.7	7.1	9.5	14.3	47.6	27.1	12.8
25.0	1	56.0	24.0	6.0	7.2	8.8	14.9	46.8	26.8	12.0

spicules were also visible over the entire body integument, except the pupil of the eye, by 4mm.

Body measurements were made on 30 cobia larvae to examine developmental morphology (Table 1). Preanal length was 61.5–62.5% SL in yolksac larvae and increased slightly during preflexion, but decreased steadily thereafter. A single intestinal loop, visible through the body wall, gave the ventral visceral mass a bulbous appearance by 7mm. Body depth was about 20% SL in larvae <10mm but decreased to about 15% by 25mm. Likewise, orbit diameter decreased from about 11–7% SL as larvae increased in length. Other body proportions were relatively stable until larvae were >10mm. Thereafter, a slow but steady decline occurred in all proportions when compared with SL, except caudal peduncle length which remained constant (Table 1). The relationship between standard and total lengths (TL), as defined by regression analysis, was linear and highly correlated ($\mathrm{SL} = 0.73\mathrm{TL} + 1.44$; N 29, r^2 0.998) at all sizes.

The supraorbital ridge and two largest preopercular spines were visible by 4mm, and the pterotics were laterally swollen. The two preopercular spines were located on either side of the angle of the posterior preopercle. Three smaller spines, the largest of which was inserted between the two posterior preopercular spines, were also present along the anterior preopercle. Spines were added along both the anterior and posterior preopercle until a total of 4 anterior and 4–5 posterior preopercular spines was reached by 14–15mm. A single spine occurring along the supraorbital ridge of each frontal bone by 4.5mm was directed posterolaterally by 6mm. The supraorbital spine and swollen pterotics were best observed when viewed dorsally (see Hardy 1978 for illustration). A supracleithral spine also occurred about 10.5–11 mm, and two posttemporal spines (supratemporal of Dawson 1971) originating from a common base were visible by 12mm. All head spination was simple and unserrated.

In early larvae, internal pigment on the roof of the mouth and ventral to the hindbrain and otic capsule formed a mediolateral stripe through the head. Externally, melanophores were scattered over the snout, fore- and midbrains, on the nape, and over the operculum. Pigment also occurred immediately anterior to the cleithral symphysis and along the isthmus. Both the tip of the quadrate bone and dentary remained unpigmented until 7–7.5mm. Head pigmentation increased with length (Fig. 2). Minute epithelial spicules (Johnson 1984) covered the body by 4mm, but were best observed on the head and larval finfold. Spicules were more easily observed on the integument as larvae increased in length.

Along the dorsal midline, a bilateral row of melanophores extended posteriorly from the nape to above the anus, behind which these rows coalesced to form a continuous band of postanal, dorsal pigment. By 4.5mm, pigment occurred on the pectoral fin base, and larvae were sparsely pigmented dorsolaterally but heavily pigmented ventrolaterally. The caudal peduncle was unpigmented in early larvae, but pigment extended onto the peduncle by 5.5–6.5mm and over the lower hypural bones by 7mm. Pigment was also present on the posterior third of the anal finfold and proximally on the ventral caudal-fin rays by 7.5mm. Body and anal- and caudal-fin ray pigment increased with length. Pigment occurred on the posterior dorsal-fin pteryio-

Table 2

Fin ray counts of larval cobia *Rachycentron canadum* from the Gulf of Mexico.

Size (mm SL)	*N*	Dorsal*	Anal	Pectoral	Pelvic
9.8	1	30	25	9	
10.0–10.9	3	27–30	22–25	12–13	
11.0–11.9	3	28–31	24–26	13–17	
12.0–12.9	2	30–33	24–26	14	
14.0–14.9	2	31	25	17	3
16.0–16.9	3	28–32	I, 24–26	17–19	I, 5
19.5	1	31	I, 25	20	I, 5
21.0	1	31	I, 25	21	I, 5
25.0	1	29	I, 25	20	I, 5

* Dorsal spines are virtually impossible to count on uncleared or unstained specimens.

phores by about 10.5mm. Fin pigmentation progressed anteriorly along the dorsal base and extended onto posterior dorsal rays by about 18–19mm. Pelvic rays were first pigmented at about 13mm, but pectoral fins remained unpigmented at all sizes examined (Fig. 2).

A 49mm juvenile had a jet black caudal fin except for the distal tips of the upper principal rays. Pelvic fins were completely black, but pigment was present basally on only the upper few rays of the pectoral fin. Pigment also covered all of the posterior rays of both the dorsal and anal fins. Fin pigment decreased anteriorly, however, such that only the basal portions of the anterior dorsal and anal rays were pigmented. All dorsal spines were visible and the integument was entirely jet black.

Fin development

A continuous median finfold extended posteriorly along the body from the nape to the cleithral symphysis of early larvae. About 5mm, a ventral thickening occurred near the tip of the unflexed notochord. Anlagen began to form obliquely downward in the caudal finfold during flexion (~6.5–8mm). As the hypural complex shifted to a terminal position, caudal ray development proceeded both dorsally and ventrally until the adult complement of 9+8 principal rays was present at 10.5–11mm. By 19.5mm, the caudal fin was distinctly spatulate and heavily pigmented. Dorsal- and anal-fin-base development coincided with notochord flexion. These fin bases began to differentiate centrally, and development proceeded both anteriorly and posteriorly with all pteryiophores countable by 10–11mm in both fins. Dorsal- and anal-ray anlagen, however, began to develop along the posterior fin base and proceeded anteriorly. Development of anal rays consistently preceeded that of dorsal rays. All anal fin elements were countable by 17mm. Dorsal spines were very difficult to count in specimens not cleared and stained because spines were short and often covered by integument. One partially cleared 16.7mm specimen had 7 poorly-formed, short dorsal spines, 11 precaudal and 14 caudal vertebrae (including urostyle), and 7 branchiostegal rays. Pelvic buds were visible by 6mm, with the full complement of elements (I, 5) present by 16.5–17mm. Pectoral rays were first visible at about 10mm and the full complement (20–21 rays) was present by 19–20mm. A full complement of rays in all fins (around 20mm) marked the beginning of transition to the juvenile stage (Table 2).

Distribution and ecology

The only confirmed collection of both cobia eggs and yolksac larvae from the Gulf was from the Crystal River estuary, Florida, during July 1984. These specimens were collected from waters 28.1–29.7°C and 30.5–34.1‰, except for a single 3.2mm yolksac larva from a power plant discharge canal at 36.7°C and 25.2‰. All other eggs and early larvae were from stations along the outer perimeter of the study area at station depths of 3–6m. No eggs or larvae were collected at stations located over oyster reefs, in the salt marsh, or in tidal creeks. Gulfwide, larvae were first collected during late May, with most (98%) collected June–September. Cobia larvae also primarily (85%) occurred at 25–30°C ($\bar{x}$ 28.2°C, range 24.2–32.0°C), at >27‰ ($\bar{x}$ 30.8‰, range 18.9–37.7‰), and most (75%) at station depths <100m (median 50m, range 3.1–300m) (Fig. 3).

Discussion

Our data suggest that cobia eggs hatch in about 24h at 29°C. Ryder (1887) projected a 36h incubation time at an unspecified temperature. Based on Pauly and Pullin's (1988) predictive relationship to derive incubation time and a mean egg diameter of 1.24mm from this study, Ryder's cobia eggs were probably incubated at about 25°C. In cooler waters of the mid-Atlantic Bight and northward during the spring/early summer (i.e., ~20°C), projected incubation time increases to 56h. Cobia hatch at about 2.5mm based on collection of wild-caught early yolksac larvae (2.6–3.2mm) with unpigmented eyes and on the work of Hassler and Rainville (1975).

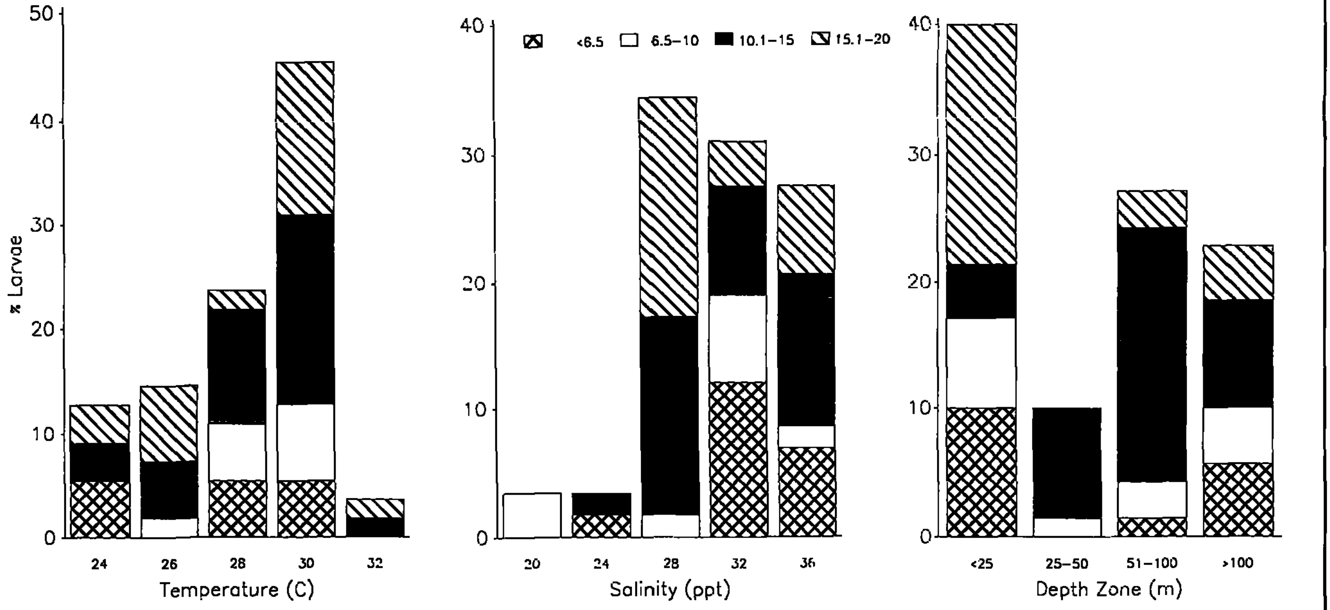

Figure 3
Distribution of cobia *Rachycentron canadum* larvae in the Gulf of Mexico with respect to hydrography. Larval stage/length class was assigned as follows: preflexion, <6.5 mm SL; flexion/early postflexion, 6.5–10.0 mm SL; late postflexion, 10.1–15.0 mm SL; and transition larvae, 15.1–20.0 mm SL.

Our data on egg and oil globule diameter agree with historical data (Ryder 1887, Joseph et al. 1964, Richards 1967, Hassler and Rainville 1975) except that our mean oil globule diameter (0.45 mm) is greater than that found for eggs from the Chesapeake Bay area (0.37 mm, Richards 1967; 0.38 mm, Joseph et al. 1964). Only two cobia eggs are previously illustrated, one in early- and the other in midstage development (Ryder 1887). The diameter of the early-stage egg, however, is considerably smaller than that of the midstage egg, and the specific identification of the early egg is unclear.

Cobia spawn during the day, since all embryos examined from the Gulf are at similar stages of development (i.e., late stage after Ahlstrom and Moser 1980) when collected during midmorning, except for one collection of late-stage eggs near midnight. Furthermore, daytime spawning cobia have been reported about 48 km southwest of Panama City, Florida (see Shaffer and Nakamura 1989 for details) in waters we estimate at 82–165 m deep. Our data also show that cobia larvae occur in both estuarine and shelf waters of the Gulf (Figs. 1, 3), primarily during May–September. The only confirmed cobia eggs and yolksac larvae collected together in the Gulf are from the Crystal River estuary at station depths of 3–6 m. Early larvae (≤6.8 mm) are also collected at stations within the 65–134 m isobath range off Texas during September (Finucane et al. 1978b). The location of these collections suggests that some spawning also occurs on the shelf 50–90 km from the coast. Offshore waters beyond the edge of the continental shelf are relatively well sampled during May (SEAMAP 1983–87) when histological analyses indicated adult cobia are ripe (Thompson et al. 1991), but no cobia larvae were identified. Seven cobia larvae (all >9.5 mm) were identified from beyond the 180 m depth contour during this study and all were collected off the Mississippi River delta. Distribution of larvae centered around the Mississippi River delta, however, may reflect the intensity of neuston net sampling in this area rather than actual distribution of spawning adults. Only two larvae were collected off Florida during a comprehensive multiyear survey of eastern Gulf waters >10 m, both during August (Houde et al. 1979).

Seasonal occurrence and ecological data from along the Atlantic coast of the United States support our findings from the Gulf. Cobia eggs occur primarily between May and August at surface water temperatures >20 °C (Joseph et al. 1964, Hassler and Rainville 1975, Eldridge et al. 1977; W.F. Hettler and L. Settle, NMFS Southeast Fish. Sci. Cent., Beaufort NC, pers. commun.; P. Berrien, NMFS Northeast Fish. Sci. Cent., Sandy Hook NJ, pers. commun.; D. Hammond, S.C. Dep. Wildl. Mar. Resour., Charleston SC, pers. commun.). Eggs are collected in lower Chesapeake Bay (Joseph et al. 1964), inlets to North Carolina estuaries

(W.F. Hettler and L. Settle, pers. commun.), in coastal waters 20–49 m deep (App. Table 1), and both near the edge of the Florida Current and in the Gulf Stream (Hassler and Rainville 1975, Eldridge et al. 1977). Off North Carolina, cobia eggs are usually collected on flood tides but few larvae are found in tidal inlets (W.F. Hettler and L. Settle, pers. commun.). Cobia eggs and larvae are usually collected in the upper meter of water with surface-towed nets (Joseph et al. 1964, Hassler and Rainville 1975 [implied], Eldridge et al. 1977; W.F. Hettler, pers. commun.). Neither cobia study off the Atlantic coast of the United States (Joseph et al. 1964, Hassler and Rainville 1975) provides environmental data, but eggs are successfully hatched at 19–35‰ (Hassler and Rainville 1975).

Similarities in larval morphology provide evidence of a sister-group relationship between cobia and dolphinfishes (Coryphaenidae) rather than that previously hypothesized between cobia and remoras (Echeneididae) (Johnson 1984). Larvae of both cobia and the dolphinfishes share similar patterns of head spination: laterally swollen pterotics; a single, simple spine on the supraorbital ridge of each frontal bone (except in pompano dolphin *C. equiselis*, which may have multiple spines along the ridge; JGD, pers. observ.); a small posttemporal spine; and several spines along the anterior and posterior preopercule, including an enlarged spine on either side of the angle. However, cobia have a small supracleithral spine (Dawson 1971, this study) that dolphinfishes lack. Remoras completely lack head spines. Both cobia and the dolphinfishes have epithelial spicules, a specialization unique to larvae of these species (Johnson 1984). We found spicules visible on the integument of both cobia and the dolphinfishes by 4 mm (JGD, pers. observ.) and they cover the entire body surface, except the pupil of the eye. Spicule composition and function, however, are unknown (Johnson 1984). Larval cobia are further separated from superficially similar remoras by the presence of large hook-like teeth on the dentary in remoras. Cobia lack these teeth. Larval cobia differ from the dolphinfishes by the lack of dorsal and anal spines and a higher vertebral count in the dolphinfishes (25 in cobia vs. 30–34 in dolphinfishes). Dolphinfishes also usually have 50+ soft dorsal rays, whereas cobia have 27–33.

Acknowledgments

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Appendix Table 1

Station location, collection, and environmental data for cobia *Rachycentron canadum* eggs and larvae. All specimens from the Gulf of Mexico, except those loaned by the MCZ at Harvard and eggs from the NMFS Southeast Fisheries Science Center, Beaufort NC. Water temperature and salinity values were at the surface. NA = data not available.

Station	Date	Lat.	Long.	Stn. depth (m)	Temp. (°C)	Salinity ‰	Gear	*N*	Size (mm SL)	Eggs
4353[1]	6-05-67	30°13	88°47	11	25.9	28.9	7	2	16.6–18.2	
4357	6-05-67	30°02	88°40	18	26.4	29.4	7	1	17.0	
4355	6-10-68	29°24	88°17	55	32.0	36.6	7	2	12.6–15.3	
4356	6-12-67	29°19	88°14	73	30.3	27.8	7	3	13.6–14.2	
4354	6-18-68	29°42	88°27	37	29.4	37.7	7	1	12.9	
00807[1]	6-23-71	29°40	88°28	20	NA	NA	8	1	17.0	
01613	May/Jun 67	27°40	96°59	20	NA	NA	8	1	7.8	
01614	May/Jun 76	28°12	96°27	22	NA	NA	8	1	16.7	
01687	May/Jun 76	27°30	96°45	45	NA	NA	8	3	9.8–12.5	
EPA IV-A[2]	7-13-77	28°51	94°42	17	24.8	33.0	9	2	6.0–12.4	
EPA V-A	7-13-77	28°52	94°41	17	24.8	33.5	9	1	16.6	
EPA V-B	7-13-77	28°51	94°42	17	24.7	33.0	9	1	16.6	
EPA V-D	7-13-77	28°51	94°42	17	24.5	32.8	9	1	13.0	
EPA II-B	7-14-77	28°53	94°41	17	25.5	34.0	9	1	19.5	
BLM II-3[2]	7-06-77	27°18	96°23	131	>25	36.0	10	1	3.8	
BLM III	9-07-75	26°57	96°32	106	<25	36.0	11	1	5.9	
BLM IV-3	9-07-77	26°10	96°24	91	>25	36.0	10	1	12.4	
BLM III-2	9-08-77	26°58	96°48	65	>25	36.0	10	1	6.8	
BLM I-3	9-10-77	27°37	96°06	134	24.2	36.2	10	2	5.0–5.1	

Appendix Table 1 (continued)

Station	Date	Lat.	Long.	Stn. depth (m)	Temp. (°C)	Salinity ‰	Gear	*N*	Size (mm SL)	Eggs
9114 A-2[3]	7-18-84	28°56	82°35	4.6	29.6	31.5	12	1	6.8	14
9121 C-1	7-18-84	28°56	82°35	4.0	36.7	25.2	12	1	3.2	
9179 H-3	7-18-84	28°56	82°35	5.8	29.7	32.6	12	1	7.5	16
9008 H-4	7-18-84	28°56	82°35	6.1	29.7	32.6	12	1	3.1	
9266 I-1	7-18-84	28°56	82°35	6.0	29.4	31.3	12	1	2.6	6
9545 I-2	7-31-84	28°56	82°35	3.7	28.1	30.5	12	2	2.6–4.0	20
9086 I-2	7-18-84	28°56	82°35	4.1	29.6	34.1	12	—	—	4
9584 K-2	7-31-84	28°56	82°35	3.1	28.2	32.2	12	1	4.5	
3088[4]	6-14-84	28°58	90°33	13	28.0	18.9	13	2	6.7–7.8	
5370	6-18-86	28°54	90°53	7	29.7	27.9	10	1	10.5	
426	6-18-82	29°11	92°43	19	29.5	27.6	13	3	16.0–19.5	
432	6-23-82	29°14	93°56	15	NA	30.2	13	1	22.3	
573	6-16-82	28°30	90°00	100	29.4	33.3	10	1	5.0	
1644	6-07-83	30°00	88°02	26	25.0	NA	13	1	12.5	
1647	6-08-83	29°47	88°17	33	25.0	24.0	13	1	12.0	
3166	6-24-84	29°00	95°00	15	30.5	27.2	13	3	16.0–21.0	
3220	7-13-84	28°21	93°00	53	30.3	29.3	13	1	25.0	
4484	9-17-85	29°00	89°36	27	27.3	27.3	13	1	10.3	
94374[5]	6-01-85	34°54	75°40	33	NA	NA	NA	1	6.0	
94505	8-21-68	38°07	70°03	NA	NA	NA	NA	4	10.0–14.5	
AL8507-142[6]	7-28-85	36°50	75°27	21	25.0	31.9	14	—	—	2
AL8507-143	7-28-85	37°06	75°11	36	25.0	32.7	14	—	—	1
DL8604-83	6-21-86	38°38	74°48	20	20.2	31.9	14	—	—	1
DL8604-152	6-25-86	36°47	75°14	26	22.4	32.4	14	—	—	1
EK8006-1	7-16-80	35°41	74°58	49	25.2	36.0	14	—	—	1
EK8006-2	7-16-80	35°16	75°14	24	26.6	35.7	14	—	—	8
P-1[2]	9-12-86	28°48	89°52	82	29.8	27.0	13	1	10.1	
P-5	9-13-86	28°40	89°39	96	28.4	33.0	13	1	11.8	
P-17	9-25-86	28°53	89°16	63	28.6	33.0	13	1	11.0	
P-23	9-25-86	28°50	89°05	195	29.4	34.0	13	4	10.2–18.5	
P-31	9-26-86	28°56	88°48	300	28.6	34.0	13	2	10.7-12.3	
4[2]	5-27-88	29°14	88°47	63	25.1	31.7	13	1	9.5	
31	5-29-88	28°48	89°34	78	25.2	30.3	13	1	12.2	
12	8-26-88	28°40	89°37	101	29.0	NA	13	2	10.0–14.0	
24	8-26-88	28°49	89°43	70	28.8	26.8	13	2	14.0–19.0	
39	8-27-88	28°50	89°21	72	30.1	29.5	13	1	13.0	
44	8-27-88	28°52	89°07	111	29.6	28.0	13	3	10.0–24.5	
45	8-28-88	28°50	89°09	203	29.6	30.5	13	1	9.5	
60	8-27-88	29°03	88°46	157	29.5	29.5	13	1	15.0	

Stations:
[1] Gulf Coast Research Lab, Ocean Springs MS
[2] NMFS, Panama City Lab
[3] Mote Marine Lab, Sarasota FL
[4] SEAMAP 1982–1986
[5] Museum of Comparative Zoology, Harvard
[6] NMFS, Sandy Hook Lab, NJ

Gear:
[7] 1 m, surface tow
[8] Neuston net (size unknown)
[9] 0.5×1.0 m neuston net, 0.505 mm mesh
[10] 60 cm bongo, 0.333 mm mesh, oblique tow
[11] 1 m, 0.250 mm mesh, oblique tow
[12] 1 m, stepped-oblique tow, 0.505 mm mesh
[13] 1×2 m neuston net, 0.948 mm mesh
[14] 60 cm bongo, 0.505 mm mesh, oblique tow