Development of laboratory-reared sheepshead, *Archosargus probatocephalus* (Pisces: Sparidae)*

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Twenty-two sparid species are known from the western Atlantic and 15 from eastern coastal waters of the United States and Canada, including two in the genus *Archosargus*: *A. probatocephalus*, sheepshead, and *A. rhomboidalis*, Caribbean sea bream (Johnson, 1978; Robins et al., 1991). Two previous publications have provided partial descriptions of mid- to late larval and juvenile sheepshead based on wild specimens. Hildebrand and Cable (1938) described wild sheepshead larvae and juveniles, beginning with 6-mm-TL larvae. Mook (1977) described osteology of 2–25 mm wild sheepshead, with notes on pigmentation and illustrations of mid- to late larvae and a juvenile. Rathbun (1892) reported a diameter of about 800 µm for sheepshead eggs. Houde and Potthoff (1976) gave a comprehensive description of Caribbean sea bream reared from collected eggs. For other genera in this region, partial descriptions exist for scup (*Stenotomus chrysops*) eggs and larvae (Kuntz and Radcliffe, 1917; Hildebrand and Schroeder, 1928; Wheatland, 1956) and pinfish (*Lagodon rhomboides*) eggs, larvae, and juveniles (Hildebrand and Cable, 1938; Cardeilhac, 1976). This paper describes the size and shape, morphometrics, pigmentation, feeding, and growth for a series of sheepshead reared from eggs to 67-day-old juveniles.

Materials and methods

Specimens

Eggs and milt were stripped from a pair of running ripe adults caught in the Indian River just west of Fort Pierce Inlet on 4 April 1984 (398-g female, 367-g male). Larval and juvenile specimens were reared from 14,000 eggs stocked in a 2.4-m diameter cylindrical fiberglass tank holding 3,500 L of water. Filtered estuarine water was supplied from the Indian River, and exchange was increased from zero at day 5 to 300% per day by day 30. During the culture period, water temperature was 22.1–33.2°C (mean 27.0°) and salinity, 27–36 ppt. For the first 7 days, temperature was 23°C and salinity 34–36 ppt. The tank was in a greenhouse that admitted 35% diffuse natural light. The fish were fed cultured rotifers, *Brachionus plicatilis* (days 3–31); cultured artemia nauplii to adults (days 14–47); cultured and wild copepods, *Tigriopus japonicus* and *Acartia tonsa* (days 18–67); bay scallop and penaeid shrimp meal (days 24–77); commercial dry salmon starter feed (days 27–100); wild crab larvae (occasionally during days 28–45); and commercial soft-moist salmon feed (days 36–80). Details of spawning, culture conditions, and foods are given in Tucker (1987). Specimens were preserved in 5% formalin buffered with sodium acetate; 145 of the preserved specimens and several live specimens were used for the description.

Measurements and counts

Measurements were made with an ocular micrometer in a stereomicroscope, except that standard and total length of postflexion larvae longer than 9 mm SL were determined with a millimeter scale. Mean diameters of the yolk and oil globule were determined and volumes calculated for ten specimens of each age from 2.5 haf (hours after fertilization) until yolk and oil were exhausted. Notochord length (NL), standard length (SL), total length (TL), snout length, horizontal eye diameter, predorsal length (snout to first dorsal spine [snout-DSp1]), snout to first dorsal ray (snout-DRa1), snout to pelvic spine (snout-PvSp1), preanus length (snout-anus), and body depth at anus were measured as in Houde and Potthoff (1976). Other measurements were upper jaw length—snout tip to posterior margin of maxillary; head length (HL)—horizontal distance from tip of snout to anterior margin of cleithrum at body midline; head depth—greatest vertical depth of head; body depth at pelvic fin—vertical distance from dorsal to ventral body margin at base of second pelvic ray (body at Pv); and caudal peduncle depth—least vertical distance from dorsal to ventral body margin.

Most specimens were fairly transparent, and internal structures such as myomeres were visible during preflexion without clearing and staining. Vertebrae were not counted. The following counts were taken

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from larvae and juveniles with a stereomicroscope: caudal rays, dorsal spines and rays, anal spines and rays, pectoral rays, and pelvic spine and rays.

Results and discussion

Egg development

The planktonic eggs were spherical. The chorion was transparent and smooth; the yolk clear, homogeneous, and unpigmented; and the single oil globule yellow. The perivitelline space was very narrow (12–39 μm before fertilization, 10–48 μm at 5 haf, and 31–77 μm at 28 haf). Diameter of live eggs at 2.5 haf was in the range of 806–865 μm (mean 824 μm) and was constant until hatching; oil globule diameter range was 187–241 μm (mean 206 μm). At 2.5 haf, mean yolk volume was 254 nL and oil globule volume was 4.58 nL (Fig. 1). Just before hatching (Fig. 2A), the embryo had sparse pigmentation on the snout and behind the eye. Several punctate melanophores were present on the oil globule. At 23°C, about 90% of the eggs hatched at 28 ±0.5 haf.

Larval development

Hatchlings had unpigmented eyes, undeveloped mouths, and clear finfolds (ranges 1.58–1.70 mm NL, 1.68–1.78 mm TL, Fig. 2B). The pigmented oil globule was near the posterior margin of the unpigmented yolk sac, close to the anus. Distinct melanophores were visible on the ventral midline, halfway between the anus and the notochord tip. Several small contracted melanophores were on the body, but no distinct pattern was seen in the examined material. Sixty-seven percent of the yolk remained and 70% of the oil (Fig. 1). At 15 hah (h after hatching), pigmentation was not visible. At 25 hah, live larvae had five distinct vertical bands of yellow pigment, one above the yolk sac, three between the anus and the notochord tip, and one at the notochord tip (Fig. 2C; yellow pigment not shown here, but see photograph in Tucker, 1986). Six percent of the yolk remained and 33% of the oil (Fig. 1). At 45 hah, eyes were only partly pigmented, and the mouth was not yet open. Except for the eyes, no pigmentation was visible in preserved specimens. Two percent of the yolk remained and 10% of the oil (Fig. 1). Between 3 and 4 dah (d after hatching), nearly all larvae developed functioning digestive systems and fully pigmented eyes and began to feed on rotifers. Lower jaw length averaged 0.29 mm. Pigmentation was present on the ventral surface of the gut and anus. Some melanophores were visible along the ventral midline. At 73 hah, only 0.2% of the yolk remained and 0.4% of the oil (Fig. 1). At 4.0 dah, larvae were feeding efficiently (Fig. 3A). Rayless pectoral fins were present at 2.37 mm NL. Pigmentation was sparse. Melanophores on the head had disappeared, and those on the gut had contracted. Dendritic melanophores were visible on the surface of the gut and were densest on the dorsal surface. Several distinct melanophores were on the ventral midline. No fin rays were visible. In at least half the specimens, yolk and oil were exhausted; the rest had a trace. At 5.0 dah, shape and pigmentation had not changed appreciably, but by 6 dah, all larvae had melanophores on the gut, as well as preanal and postanal pigmentation on the ventral midline.

At 9 dah, nine larvae (2.78–3.24 mm NL) were still in preflexion (Fig. 3B), and one (3.50 mm NL) had begun notochord flexion. Pigmentation was as for 6 dah. Number and position of branching melanophores on the ventral midline were variable. The larva undergoing notchord flexion also had internal melanophores in the center of the auditory vesicle, one branched melanophore on the forehead, and melanophores on the lower jaw angle and throat. At 14 dah, two larvae (4.16–4.66 mm NL) were in preflexion and eight (4.66–5.36 mm NL) in flexion. Four of the flexion specimens were in early flexion and four in midflexion. Rays began forming above the center of the pectoral fin at 4.66 mm NL and just below the center of the caudal fin at 4.91 mm NL (Table 1).

At 17 dah, all 10 specimens were in midflexion. Caudal rays continued to develop. Rays began forming in the posterior part of the soft dorsal fin at 5.29 mm NL and in the posterior part of the anal fin at 5.36 mm NL. Larvae had two melanophores on the forehead, four

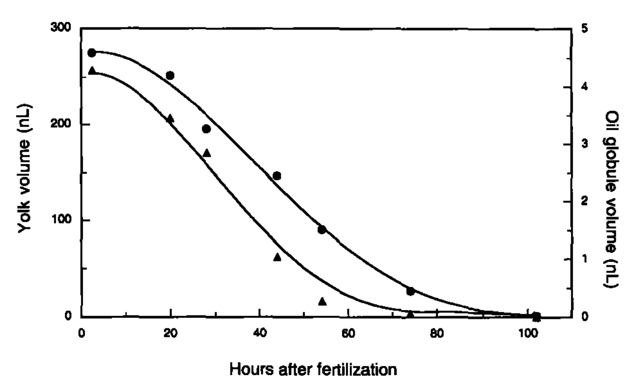

Figure 1

Yolk and oil globule depletion in sheepshead, *Archosargus probatocephalus*, eggs and larvae. Triangles represent yolk and dots represent oil.

melanophores along the ventral midline, and one large melanophore on the posterior part of the anus. At 21 dah, all larvae were in late flexion (Fig. 3C) and were characterized by a more rounded head and increased pigmentation. Large dendritic melanophores spread over the gut and along the ventral midline. One distinct dendritic melanophore was visible on the forehead and another behind the eye. Small punctate melanophores were visible on the ventral abdomen. In live larvae, reddish chromatophores were scattered over the body but mainly between the developing dorsal and anal fins (not shown in Fig. 3C, but see photograph in Tucker, 1986).

At 28 dah, five larvae had completed flexion. The finfold was gone, and caudal, dorsal, anal, and pectoral fin spines and rays were well developed (Table 1). Caudal rays numbered 21–29 and pelvic rays 0–3. Ten dorsal spines were present in all larvae; the last one was yet to form. Rays began forming at the center of the pelvic fin at 6.24 mm SL. The first and second anal spines were present in all specimens. Punctate melanophores were scattered over the entire body.

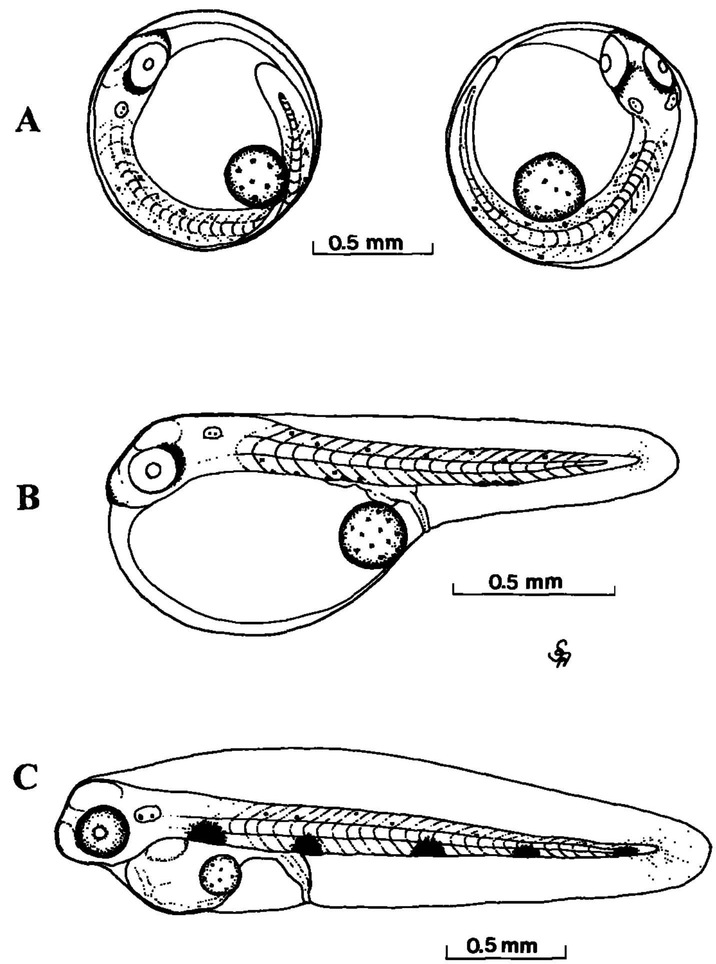

Figure 2

Sheepshead, *Archosargus probatocephalus*, eggs and yolksac larvae: (**A**) eggs just before hatching (28 h after hatching, 820 mm diameter); (**B**) newly hatched larva (28 h after fertilization, 1.58 mm NL, 1.68 mm TL); and (**C**) yolksac larva (21 h after hatching, 2.46 mm NL, 2.59 mm TL). Drawings A and B are from preserved specimens, and C is from a live specimen.

Prejuvenile development

By 28–30 dah, transformation was nearly complete. Adult counts of spines and rays were reached in all fins except for a lack of 0–2 caudal rays, the last dorsal spine, the lowermost 1–2 pectoral rays, and the last pelvic ray (Table 1). Coloration was similar to that of adults, and 5–6 of the characteristic lateral black bars had formed, but the fish were more slender than adults. This could be considered a prejuvenile phase. At 28 dah, two specimens (8.54 and 8.81 mm SL) had become prejuveniles (Fig. 3D). By 38 dah, the adult complement of fin elements was present except for 1–2 caudal rays, one anal spine, and one pectoral ray in some specimens; 1–2 pelvic rays still were missing. Ten of 14 specimens were fully scaled.

Juvenile development

Between 38 and 53 dah, all specimens reached the juvenile stage and had adult counts for fin elements. By 42 dah, the body had deepened, but the eye was relatively large. By 67 dah, body proportions of the juveniles were similar to those of adults.

Proportions

Snout length:head length (HL) varied slightly until 53 dah, then increased to 28% at 67 dah (Table 2). Eye diameter:HL was largest at 0.6 dah (69%) and decreased to 36% at 67 dah. Upper jaw length:HL was greatest at 17 dah and least at 67 dah. HL:body length (BL) was least at 0.6 dah and most at 38 dah, then decreased at 53–67 dah. Snout to first dorsal spine:BL, snout to first dorsal ray:BL, and snout to first pelvic spine:BL were greatest at 38 dah. Snout

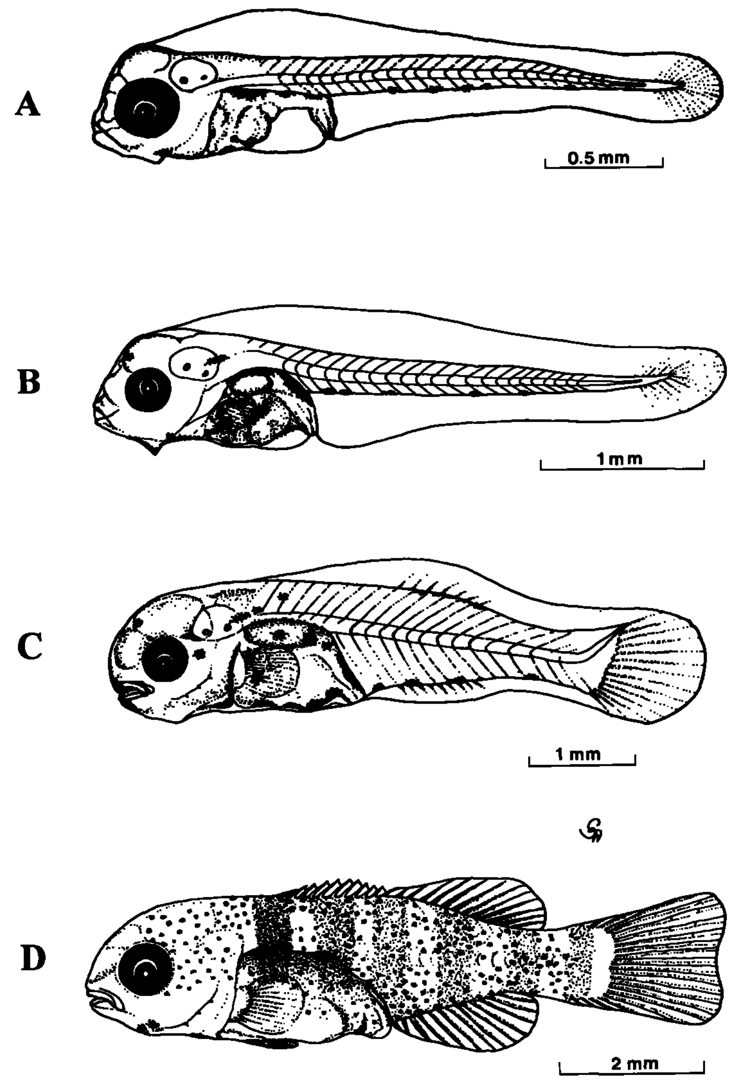

Figure 3

Sheepshead, *Archosargus probatocephalus*, preflexion to postflexion larvae (preserved): (**A**) yolk exhaustion (4 d after hatching, 2.45 mm NL, 2.64 mm TL); (**B**) preflexion (9 dah, 3.24 mm NL, 3.47 mm TL); (**C**) flexion (21 dah, 4.97 mm NL, 5.74 mm TL); and (**D**) prejuvenile (28 dah, 8.81 mm SL, 11.4 mm TL).

to anus:BL was minimal at 5–9 dah and greatest at 38 dah. Total length:BL and head depth:BL were least at hatching and most at 38 dah. Body depth at pelvic fin:BL increased between 28 dah and 38–67 dah. Body depth at anus:BL decreased from 17% at 0.6 dah to 14% at 5–6 dah, then rose to 35–36% for 28- and 38-day-old prejuveniles. Caudal peduncle depth:BL increased between 9 dah and 28–38 dah.

At 28 dah, prejuveniles were slightly deeper than postflexion larvae at the pelvic fin and anus. All lengths and depths divided by BL were highest at about 38 dah. Thereafter, postanal length increased relatively faster than the other lengths and depths, leading to a decrease in proportional measurements, except for body depth at pelvic fin:BL, which was constant during 38–67 dah.

Growth and survival

Growth of sheepshead to 27.5 mm TL at 67 dah (Fig. 4) was similar to that of Caribbean sea bream (Houde and Potthoff, 1976). Mean dry weight rose from 14.5 µg (about 69 (µg wet) at 7 dah to 88 µg (464 µg wet) at 67 dah (Fig. 4); mean wet weight was 7.6 g at 101 dah. Survival was 40% from fertilization to 101 dah, and 100% thereafter to 3 years.

Comparison with other sparids

Our specimens up to 9 dah (Fig. 3B) were younger than previously described sheepshead; most larvae were longer than those at the same stage illustrated by other authors (Hildebrand and Cable, 1938; Mook, 1977), until 6 mm. The 3.9-mm TL larva in Fig. 3B corresponded to the 2-mm specimen illustrated by Mook (1977). The 6.1-mm specimen in Fig. 3C fitted between Mook's (1977) 4- and 4.5-mm specimens and corresponded with Hildebrand and Cable's (1938) ca. 6-mm specimen. The 8.9-mm specimen in Fig. 3D fitted between Mook's (1977) 8- and 11-mm specimens. As Riley et al. (1995) have discussed, net damage to field-caught larvae can shrink and distort them to different degrees, depending on species and stage.

At 23°C, sheepshead hatched at ~28 haf, first fed at ~84 hah (~112 haf) and exhausted their yolk and oil by ~96 hah (~124 haf). At 26°C, Caribbean sea bream hatched by ~22 haf, first fed at about 35 hah (~57 haf), and exhausted yolk by 50 hah (~72 haf) (Houde and Potthoff, 1976). Eggs of gilthead sea bream, *Sparus aurata* (native to the Mediterranean region), with a mean diameter of 1,020 µm, are larger than those of sheepshead and Caribbean sea bream (Table 3) and contain about twice as much yolk and oil (Ronnestad et al., 1994). At 25 haf, gilthead sea bream eggs had 430 nL yolk and 5.8 nL oil, but sheepshead had only 184 nL yolk and 3.6 nL oil. At 18°C (first 6 h at 15–18°C), gilthead

Table 1

Meristic ranges for 65 reared sheepshead, *Archosargus probatocephalus*, larvae and juveniles.

Days after hatching	No. of specimens	Caudal rays	Dorsal spines	Dorsal rays	Anal spines	Anal rays	Pectoral rays	Pelvic spines	Pelvic rays
Preflexion									
9	5	0	0	0	0	0	0	0	0
14	2	0–7	0	0	0	0	0	0	0
Flexion									
9	1	0	0	0	0	0	0	0	0
14	8	7–11	0	0	0	0	2–3	0	0
17	10	9–17	0	5–10	0	3–9	5–7	0	0
21	2	15–16	0	0–6	0	6–9[2]	7–9	0	0
Postflexion									
28	5	21–29	10[2]	11–12[2]	2–3[1]	10	11–13	0	0–3
Prejuvenile									
28	2	30–32[1]	10	11–12	3	10–11	13–14	1[1]	4
38	10	30–34	11	11–13	2–3	10–11	14–15[1]	1	3–4
Juvenile									
53	10	32–34	11	12–13	3	10–12	15	1	5[1]
67	10	32–34	11	12–13	3	10–11	15	1	5

[1] First reached adult number.
[2] First reached adult number, but one more will be added.

sea bream hatched at ~55 haf, first fed at ~100 hah (~155 haf) and exhausted their yolk at ~115 hah (~170 haf) and their oil slightly later. Also at 18°C, pinfish (with similar sized eggs) hatched at ~48 haf and were ready to feed sooner, by ~76 hah (~124 haf)(Cardeilhac, 1976). Oil of unfed pinfish was exhausted at ~150 hah (~198 haf) and yolk at ~165 hah (213 haf).

Distinguishing characteristics

Between hatching and full eye pigmentation, Caribbean sea bream had little coloration, but sheepshead had five large ventral melanophores and scup three large ventral melanophores. In both sheepshead and scup, one melanophore was over the gut and the second over the anus. In sheepshead, the remaining three were evenly spaced between the anus and notochord tip. In scup, the third melanophore was about halfway between the anus and notochord tip, and each of the three areas of pigment formed more of a lateral band than in sheepshead. From about 2.7 mm to at least 10 mm TL, both sea bream and scup had a ventral row of postanal melanophores associated with myosepta; sheepshead had scattered ventral melanophores, rather than an evenly-spaced row. By about 9 mm TL, prejuvenile sheepshead had five or six distinct lateral black bars on the body; all juveniles had six. Sheepshead from the Atlantic typically have six complete bars, whereas those from the Gulf of Mexico typically have five (Johnson, 1978). By about 15 mm TL, Caribbean sea bream had six indistinct bars (Houde and Potthoff, 1976). By about 25 mm TL, scup had six irregular bars (Johnson, 1978). By about 30 mm TL, pinfish had five or six indistinct bars (Hildebrand and Cable, 1938).

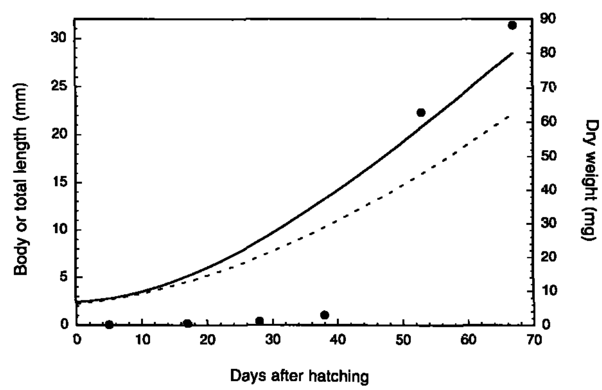

Figure 4

Growth of sheepshead, *Archosargus probatocephalus*, larvae and early juveniles. The dashed curve represents mean body length and the solid curve represents mean total length. Dots represent mean dry weight.

Meristics are only slightly helpful for identification. Western North Atlantic sparids usually have 10 precaudal vertebrae and 14 caudal vertebrae (Jordan and Evermann, 1896–1900; Miller and Jorgenson, 1973; Hoese and Moore, 1977; Johnson, 1978).

Table 2

Summary of proportional measurements of 145 reared sheepshead, ***Archosargus probatocephalus***, larvae and juveniles. Except for body length, values are in percentage of head length (HL) or body length (BL). Mean ±standard deviation is on the first line, and range on the second. A zero means ≤0.5%. For BL, notochord length (NL) was used through flexion and standard length (SL) after flexion. DSp1 = first dorsal spine, DRa1 = first dorsal ray, PvSp1 = first pelvic spine, and Pv = pelvic fin.

			Percent of head length			Percent of body length									
			Length			Length						Depth			
Events and days after hatching	*n*	Body length (mm)	Snout (%)	Eye (%)	Upper jaw (%)	Head (%)	Snout-DSp1 (%)	Snout-DRa1 (%)	Snout-PvSp1 (%)	Snout-anus (%)	Total (%)	Head (%)	Body at Pv (%)	Body at anus (%)	Caudal peduncle (%)
Hatching															
0	10	1.65 ±0.03	24 ±5	58 ±5		19 ±1					104 ±1	13 ±1			
		1.58–1.70	14–29	52–67		18–20					103–106	11–15			
0.6	10	2.21 ±0.03	22 ±4	69 ±4		14 ±1				47 ±1	105 ±1	14 ±1		17 ±1	
		2.16–2.25	19–30	64–77		13–14				46–49	103–106	12–14		16–19	
1.0	10	2.42 ±0.01	22 ±1	50 ±1		17 ±0				43 ±1	106 ±1	14 ±0		16 ±1	
		2.34–2.47	20–24	47–52		16–18				41–46	105–107	13–15		15–18	
1.9	10	2.59 ±0.02	24 ±1	50 ±1		18 ±0				41 ±1	106 ±0	17 ±0		15 ±0	
		2.55–2.60	21–26	49–51		17–18				39–43	105–107	16–18		15–17	
Eye pigmentation and first feeding															
3.0	10	2.55 ±0.06	21 ±2	48 ±2		20 ±0				41 ±1	107 ±0	19 ±1		15 ±0	
		2.45–2.65	19–24	46–51		19–20				40–44	106–107	18–20		14–15	
Yolk and oil exhaustion															
4.0	10	2.46 ±0.16	22 ±2	46 ±2		21 ±1				40 ±2	107 ±1	20 ±2		15 ±2	
		2.20–2.65	20–26	43–50		20–24				38–44	106–108	17–24		13–17	
5.0	10	2.49 ±0.04	22 ±2	45 ±2		20 ±1				38 ±1	107 ±0	19 ±0		14 ±1	
		2.43–2.56	19–25	42–48		19–22				37–40	107–108	18–20		12–15	
6	10	2.43 ±0.09	20 ±1	42 ±1	37 ±4	22 ±0				40 ±1	107 ±1	20 ±1		14 ±1	
		2.25–2.54	19–22	40–44	29–41	21–22				38–42	103–108	18–20		12–17	
9	5	3.10 ±0.12	22 ±5	43 ±4	36 ±6	22 ±1				39 ±1	107 ±2	21 ±2		16 ±2	3 ±1
		2.78–3.24	17–31	39–48	30–43	21–24				38–42	105–111	18–23		14–17	2–4
14	2	4.41 ±0.35	20 ±2	40 ±0	36 ±8	25 ±1				49 ±1	105 ±1	25 ±1		24 ±1	7 ±1
		4.16–4.66	18–22	40	28–43	24–25				48–50	104–106	24–27		23–24	6–8
Flexion															
9	1	3.50	21	40	31	23				40	106	22		18	4
14	8	5.06 ±0.21	21 ±3	38 ±2	38 ±6	26 ±1				51 ±1	106 ±2	26 ±1		24 ±1	8 ±1
		4.66–5.36	18–26	36–42	34–51	24–27				49–52	103–110	25–27		23–25	8–9
17	10	4.92 ±0.51	23 ±5	37 ±5	41 ±3	28 ±2				54 ±4	114 ±5	27 ±2		26 ±3	11 ±3
		3.90–5.41	14–35	26–43	36–44	24–30				49–59	104–124	26–30		21–31	4–13
21	2	4.95 ±0.05	22 ±4	38 ±0	35 ±2	28 ±0				54 ±0	116 ±1	28 ±1		25 ±0	10 ±0
		4.92–4.97	19–24	38	33–36	28–29				54	115–117	28–29		25–26	10
Postflexion															
28	5	6.60 ±0.79	22 ±2	41 ±2	32 ±3	34 ±2	40 ±1	65 ±2	37 ±2	59 ±2	124 ±2	34 ±2	33 ±3	31 ±3	14 ±1
		5.83–7.93	20–25	38–43	27–36	30–36	39–42	63–67	35–39	57–61	122–126	29–35	29–36	26–35	13–15
Prejuvenile															
28	2	8.68 ±0.19	23 ±1	39 ±0	28 ±7	35 ±2	39 ±3	64 ±3	40 ±1	59 ±0	124 ±1	34 ±1	35 ±1	36 ±2	15 ±1
		8.54–8.81	22–24	39	23–33	33–36	37–41	62–66	39–40	59	123–124	33–35	34–36	34–37	14–15
38	10	7.22 ±0.64	21 ±1	39 ±1	26 ±1	40 ±1	44 ±2	77 ±2	44 ±1	68 ±2	132 ±3	35 ±1	37 ±2	35 ±2	15 ±1
		6.05–10.3	19–23	37–40	24–29	38–42	42–47	74–79	42–46	65–71	126–134	34–38	35–38	30–37	13–16
Transformation															
53	10	18.6 ±3.2	22 ±1	38 ±1	26 ±1	33 ±1	34 ±1	63 ±1	36 ±1	61 ±1	129 ±1	28 ±0	38 ±2	33 ±2	13 ±0
		13.7–24.7	21–24	35–40	25–27	30–35	33–36	62–66	34–39	60–63	128–130	27–29	36–42	31–36	12–14
67	10	21.5 ±5.2	28 ±3	36 ±2	24 ±2	33 ±1	36 ±2	65 ±2	40 ±2	62 ±2	128 ±0	29 ±1	37 ±1	32 ±2	13 ±0
		15.9–33.7	22–34	33–39	20–26	31–35	34–38	62–68	37–42	59–65	126–130	27–31	36–40	31–35	12–14

Dorsal ray, anal spine, anal ray, pectoral ray, and caudal ray counts of sheepshead overlap with those of most other sparids (Table 4). For most species of *Archosargus*, *Calamus*, *Diplodus*, *Lagodon*, *Pagrus*, and *Stenotomus*, 11 or 12 dorsal spines are typical, with a range of 10–13. Dorsal rays mostly number 10–12, with a range of 9–16, and anal rays mostly are 10–11, with a range of 8–15. Caudal rays usually are in the range of 32–38, with 9+8 principal rays. For sheepshead, typical counts followed by ranges in parentheses are caudal rays 32–33 (8–9+9+8+7), dorsal spines 12 (10–12), dorsal rays 11 (10–13), anal

Table 3

Spawning, egg, and hatchling data for sheepshead, *Archosargus probatocephalus*; Caribbean sea bream, *Archosargus rhomboidalis*; pinfish, *Lagodon rhomboides*; and scup, *Stenotomus chrysops*.

	Sheepshead	Sea bream	Pinfish	Scup
Location	Florida	Florida	Florida	Northeastern U.S.
Spawning season	Feb–Apr	Sep–May	Oct–Mar	May–Aug
Egg diameter (µm)	806–865	800–940	990–1,050[1]	800–1,150
Oil globule diameter (µm)	187–241	210–260	~200[1]	140–280
Hatching temperature (°C)	23	24	18	22
Incubation time (h)	28	~<22	48	≤40
Hatchling length (mm TL)	1.7–1.8	2.1–2.3		~2
References	Present study	Houde and Potthoff, 1976	Caldwell, 1957 Cardeilhac, 1976	Kuntz and Radcliffe, 1917 Hildebrand and Schroeder, 1928 Wheatland, 1956

[1] Unfertilized.

Table 4

Comparison of selected larval and juvenile characters of sheepshead, *Archosargus probatocephalus*, reared at a mean temperature of 23°C and Caribbean sea bream, *Archosargus rhomboidalis*, reared at 26°C (Houde and Potthoff, 1976): size and age from first development to completion in all specimens. Less common counts are in parentheses. Because specimens were not taken every day, age ranges are approximate. BL = body length; dah = days after hatching.

	Archosargus probatocephalus			*Archosargus rhomboidalis*		
	Adult number	BL (mm)	Age (dah)	Adult number	BL (mm)	Age (dah)
Hatchling		1.6–1.7			2.0–2.2[1]	
Flexion		3.5–5.0	9–21		4.2–4.9	9–11
Pectoral rays	15	4.7–10.3	14–38	14(15)	5.0–~8.0	11–15
Caudal rays	(8)9+9+8+7–8(9)	4.9–13.7	14–53	(10)8–9+9+8+7–8(9)	4.1–10.2	7–16
Dorsal rays	12–13	5.3–13.7	17–53	10–11	5.0–5.7	11–13
Anal rays	10–11(12)	5.4–6.4	17–28	10(11)	5.0–5.7	11–13
Pelvic rays	5	6.2–13.7	28–53	5	6.6–15.6	26–37
Dorsal spines	11	7.2–8.5	28–38	(12)13(14)	5.7–8.2	13–16
Prejuvenile[2]		≥6.0, <13.7	≥28, <53			
Pelvic spines	1	8.5–9.5	28–38	1	6.6–15.6	26–37
Anal spines	3	8.5–13.7	28–53	3	5.4–7.1	13–26
Juvenile[3]		13.7	>38, ≤53		20.0	~35

[1] Smallest specimens described.
[2] Juvenile coloration attained; all fin elements present except last dorsal spine, last pectoral ray, and last one or two pelvic rays.
[3] All fin elements present, and fish fully scaled.

spines 3, anal rays 10–11 (9–11), pectoral rays 15–17, pelvic spine 1, pelvic rays 5 (Miller and Jorgenson, 1973; Johnson, 1978). Caribbean sea bream usually have 13 dorsal spines, whereas sheepshead, pinfish, and most other sparids usually have 12. *Diplodus* spp. have slightly higher counts than most sparids: 11–13 dorsal spines, 13–16 dorsal rays, and 13–15 anal rays. *Pagrus* species have fewer anal rays, usually 8.

Stage of development at a given size could be useful for distinguishing larvae. At the same stage, scup tended to be much longer than sheepshead (Fig. 4) and Caribbean sea bream. Kuntz and Radcliffe's (1917) 25-mm TL scup (their Fig. 36) corresponds with Houde and Potthoff's (1976) 12.8-mm TL sea bream (their Fig. 5a) and our 8.9-mm TL sheepshead (Fig. 3D).

The proportions snout length:BL (3–8%), eye diameter:BL (7–14%), predorsal length:BL, snout to first dorsal ray:BL, snout to pelvic spine:BL, preanus length:BL, and body depth at anus:BL (Table 2) all were similar during development of sheepshead and Caribbean sea bream (Houde and Potthoff, 1976). Eye diameter and body depth are relatively small in scup at 10 mm TL. At that size, eye diameter:HL was about 32% in scup, 37% in sea bream, and 39% in sheepshead; depth at pelvic fin:SL was 27% in scup, 34% in sea bream, and 37% in sheepshead.

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