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Description and Identification of Shortnose and Atlantic Sturgeon Larvae[1]

DARREL E. SNYDER

Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado 80523, USA

Abstract.—Larvae of shortnose sturgeon *Acipenser brevirostrum* and Atlantic sturgeon *Acipenser oxyrhynchus*, cultured and collected from various sources, were examined for morphometric, meristic, pigmentary, and size-related characters to document morphological development and facilitate diagnosis. Shortnose sturgeons typically hatch at 9–10 mm standard length (SL), complete yolk absorption by 14 mm SL, acquire their first fin rays and scutes between 21 and 24 mm SL, and acquire the full complement of fin rays, except in the caudal fin, by 57 mm SL. Atlantic sturgeons typically hatch at 7–9 mm SL, complete yolk absorption by 13 to 14 mm SL, acquire their first scutes between 17 and 20 mm SL, acquire their first fin rays at 21 mm SL, and acquire a full complement of fin rays, except in the caudal fin, between 47 and 58 mm SL. Mean myomere counts for both species are 38 preanal and 22 or 23 postanal. Most recently hatched larvae can be tentatively identified by size relative to state of development and, depending on the river, by collection date and location. In some rivers, shortnose sturgeons spawn about a month earlier and farther upstream than Atlantic sturgeons. Following yolk depletion, ventral pigmentation and distance between lobes of the lower lips are the most obvious diagnostic characters. The ventrolateral and ventral surfaces of the abdomen are white on shortnose sturgeons but covered with melanophores on Atlantic sturgeons, except on the midventral surface of smaller specimens. The distance between the two lobes of the lower lip is greater than 25% of mouth width (including lips) for shortnose sturgeons and less than 20% of mouth width for Atlantic sturgeons. For specimens over 60 mm SL, shortnose sturgeons also have 17–22 pelvic and 18–24 anal fin rays, whereas Atlantic sturgeons have 26–33 pelvic and 22–30 anal fin rays.

The Atlantic coast of North America from the Saint Johns River in Florida to the Saint John River in New Brunswick is inhabited by both the shortnose sturgeon *Acipenser brevirostrum* and the Atlantic sturgeon *Acipenser oxyrhynchus oxyrhynchus* (Lee et al. 1980; Dadswell et al. 1984; Smith 1985). Atlantic sturgeon also range north into and above the Gulf of Saint Lawrence, and, as another subspecies *Acipenser o. desotoi*, from the Mississippi Delta to the west coast of Florida and elsewhere in the Gulf of Mexico.

The shortnose sturgeon is protected as an endangered species in the USA, yet the larger and more commercially valuable Atlantic sturgeon has become nearly as rare in many localities. In some South Carolina waters, shortnose sturgeons may actually outnumber Atlantic sturgeons (T.I.J. Smith, Marine Resources Research Institute, personal communication). Atlantic sturgeons are given legal protection only in the states of Connecticut, Rhode Island, New Jersey, Florida, and Mississippi (Johnson 1987).

To better understand these fish, prevent further detrimental impact on their populations due to habitat modifications and pollution, and attempt recovery efforts, it is critical to identify spawning seasons, spawning and nursery grounds, and habitat or ecological requirements of spawning adults, eggs, and larvae. Collections of fish larvae are necessary for gathering much of this information.

As with many other species of North American fishes, the larvae of these sturgeons have been inadequately described for taxonomic purposes. Ryder (1890) described the development of Atlantic sturgeon larvae based on specimens reared from the Delaware River (Delaware) stock but, with one exception, illustrated his description with previously published drawings of European species (*A. ruthenus* and *A. huso*). The exception, a drawing reproduced in larval fish manuals by Mansueti and Hardy (1967), Lippson and Moran (1974), and Jones et al. (1978), is reported to be a just-hatched Atlantic sturgeon measuring 11.5 mm total length (TL). In apparent contradiction, Smith et al. (1980), who documented the early behavior and growth of hatchery-reared Atlantic sturgeon from South Carolina, reported a mean hatching size of 7.1 mm TL.

Most of the descriptive information published

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on shortnose sturgeon larvae, as well as other aspects of shortnose sturgeon biology, was summarized by Dadswell et al. (1984). Pekovitch (1979) provided a few descriptive comments, a table of selected measurements and myomere counts for four shortnose sturgeon larvae between 16.3 and 18.2 mm TL, and three-view drawings of specimens from the Hudson River (New York) that were 16.3 and 32.0 mm TL. Taubert and Dadswell (1980) described shortnose sturgeon larvae collected from the Holyoke Pool of the Connecticut River (Connecticut) and the Saint John River and included photographs of specimens that were 10.0 and 14.7 mm TL. Buckley and Kynard (1981) reported on the behavior of shortnose sturgeon larvae reared from Holyoke Pool stock and published photographs of 2-h-, 1-d-, 4-d-, and 8-week-old specimens.

Dovel (1979) noted that shortnose sturgeons as small as 17 mm TL can be distinguished from Atlantic sturgeons by features of the mouth. His report included ventral-view photographs of the heads of 17-mm specimens of both species but failed to specify the differences. Taubert and Dadswell (1980) suggested that, after the mouth is formed, mouth width (diagnostic for adults) might be useful for separating shortnose from Atlantic sturgeon larvae. Bath et al. (1981) documented the value of mouth width as a diagnostic character and described larvae of both species from the Hudson River (New York). They provided morphometric and meristic data for 26 larvae (8.4–37.0 mm TL) and photographs of seven specimens (8.4–31.5 mm TL). Ratio of mouth width to head width, degree of development (not explained), collection site, and date of capture were found useful for identifying most non–yolk-bearing larvae. Yolk-bearing larvae were tentatively identified according to location and date of capture. Dovel and Berggren (1983) reprinted the ventral head photographs from Dovel (1979) and noted that "while there are differences in pigmentation, shape and size of barbels and features of the mouth, the relative proportion of the space between the fleshy lobes of the mouth to the width of the mouth appears to be a valid distinguishing characteristic. . . ."

The purposes of this paper are to (1) more completely document the morphological development of shortnose and Atlantic sturgeon larvae, (2) confirm and elaborate on the value of previously noted criteria for diagnosis, and (3) reveal additional characters that may be of taxonomic value.

Methods

Most specimens examined for this study were reared or collected in South Carolina (Table 1). However, to expand upon the available size range of naturally spawned specimens and assure that diagnostic criteria derived from this study are applicable to other populations of Atlantic and shortnose sturgeons, additional specimens were solicited for loan from other east coast researchers; most specimens received came from the Hudson and Saint John rivers.

All cultured specimens from the Orangeburg National Fish Hatchery, except 29–39-mm SL Atlantic sturgeons, were preserved in formalin solutions. The remaining specimens were variously preserved in formalin or alcohol solutions (Table 1). Resultant measurements reported here may reflect varying and sometimes considerable degrees of shrinkage, possibly as much as 10% for some very early larvae in alcohol solutions (e.g., the smallest probable Atlantic sturgeon larva from the Savannah River). Shrinkage is much less for specimens preserved in formalin than in alcohol.

Based on definitive diagnostic characters derived from cultured specimens during this study, collected specimens over 12 mm SL were identified or verified as either shortnose or Atlantic sturgeon. Smaller yolk-bearing larvae were tentatively identified or verified on less-certain criteria derived from cultured specimens, as well as information on collection sites and dates. Data from collected material were used to complement and substantiate observations based on cultured material.

Specimens were examined for differences in 52 measurements, 18 counts, external morphology, melanophore pigmentation, and developmental state relative to size under a stereozoom microscope (3.5–30× magnification) with various combinations of reflected and transmitted light. An eyepiece reticle was used for direct measurement of specimens to the nearest 0.05 or 0.1 mm. Repeatability of measurements was within 0.1 mm. Questionable measurements (i.e., those that appeared inconsistent with the same measurements on other, similar-sized specimens) were rechecked for verification or correction. When feasible and not reported by the authors, similar characters were also observed, measured, or counted from published illustrations for comparative purposes.

The specific measurements used in this investigation are diagrammed in Figure 1 and expand upon those detailed by Snyder (1981, 1983). Un-

TABLE 1.—Specimens of shortnose and Atlantic sturgeon larvae examined.[a]

Number examined	Standard length (mm)	Source	History	Preservative	Depository
			Shortnose sturgeon		
24[b]	9–24	ONFH	Cultured; parent stock from Cooper R., SC; hatched Mar 9, 1983; preserved Mar 9–Apr 3, 1983	Formalin	Returned to ONFH
3	15–16	SABS	Cultured; parent stock from Saint John R. near Fredericton, NB; hatched May 25, 1980; preserved Jun 24, 1980	Alcohol	SABS, 678-7
3	9–10	SRL–ECS	Collected from Savannah R., SC, between km 113 and 253, Mar 12 and 26, 1982 and Mar 22, 1980	Alcohol	Returned to ECS
6	9–11	SRL–ECS	Collected from Savannah R., SC, between km 113 and 253, Mar 22–29, 1983	Formalin	Returned to ECS
1	15	LES	Collected from Hudson R., near Albany, NY, km 235, May 21, 1979	Formalin	LFL
10	15–17; 34–57	NYSDEC–HES	Collected from Hudson R., NY, km 187–245, 1977–1980	Alcohol	AMNH
2	<50–51	SCWMRD	Removed from stomach of a yellow perch *Perca flavescens* caught in Merrymeeting Bay near New Brunswick, Maine, Jun 30, 1975	Formalin	Returned to SCWMRD
			Atlantic sturgeon		
20[b]	9–17	ONFH	Cultured; parent stock from Edisto R. and Combahee R., SC; hatched Mar 30, 1981; preserved Apr 12, 1981	Formalin	Returned to ONFH
8[b]	29–39	ONFH	As above but preserved Apr 21, 1981; five specimens cleared and stained for cartilage	Alcohol	Returned to ONFH, except five[b] retained by LFL
9	58–136	ONFH	Cultured; parent stock from Atlantic Ocean off north Georgetown jetty, SC; hatched Mar 1, 1979; preserved Jun 11–14 and Jul 21, 1979	Formalin	Returned to ONFH
3	6–8	SRL–ECS	Collected from Savannah R., SC, between km 113 and 253, May 21 and Aug 12, 1982	Alcohol	Returned to ECS
6	8–14; 47	SRL–ECS	Collected from Savannah R., SC, between km 113 and 253, Apr 26–May 18 and Jun 14, 1983	Formalin	Returned to ECS
1	9	SABS	Collected from Saint John R. near Fredericton, NB, Jun 2, 1980	Alcohol	SABS, 864-7
4	14–31	LES	Collected from Hudson R., NY, km 64 to 90, Jul 2, 1968, Jun 22 and 29, 1976; 20-mm specimen bleached or cleared	Formalin	LFL
1	47	SCWMRD	Collected from Winyah Bay near Georgetown, SC, Jun 1978 (collection 78108, project 01)	Alcohol	Returned to SCWMRD

[a]Abbreviations: AMNH = American Museum of Natural History, NY, NY; ECS = Environmental and Chemical Sciences, Incorporated, Aiken, SC; HES = Hazelton Environmental Sciences Corporation, Northbrook, Illinois; LES = Laboratory for Environmental Studies, New York Medical Center, Tuxedo, NY; LFL = Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado; NB = New Brunswick; NY = New York; NYSDEC = New York State Department of Environmental Conservation, Stamford; ONFH = Orangeburg National Fish Hatchery, SC; R = River; SABS = Saint Andrews Biological Station, NB; SC = South Carolina; SCWMRD = South Carolina Wildlife and Marine Resources Department, Charleston, SC; SRL = Savannah River Laboratory, Aiken, SC.

[b]Additional specimens were available but not specifically measured or analyzed.

less specified as total length (TL), specimen length is reported as standard length (SL) and measured to the end of the notochord. The notochord persists even in adults nearly to the end of the heterocercal tail. Most proportional measurements are reported herein to the nearest whole unit as a percentage of standard length (%SL). Percent total length (%TL) was not used because the membranous end of the caudal fin of some specimens was damaged and required estimation of TL. However, the difference between SL and TL for sturgeons is usually very small, so %SL closely approximates %TL.

Counts made in this investigation also followed those detailed by Snyder (1981, 1983) with some modifications and additions. Only preanal (to posterior margin of vent), postanal, and total myomeres were counted (Figure 1). Preanal myomere counts included the anterior segment immediately behind the region of the occiput (stippled in Figure 1) and all myomeres even partially transected by a vertical line from the posterior margin of the vent (Seifert 1969; Snyder 1981; Fuiman 1982). The first few myomeres are epaxial, and the most anterior vertical myoseptum often appears partial or incomplete. Fin ray counts in-

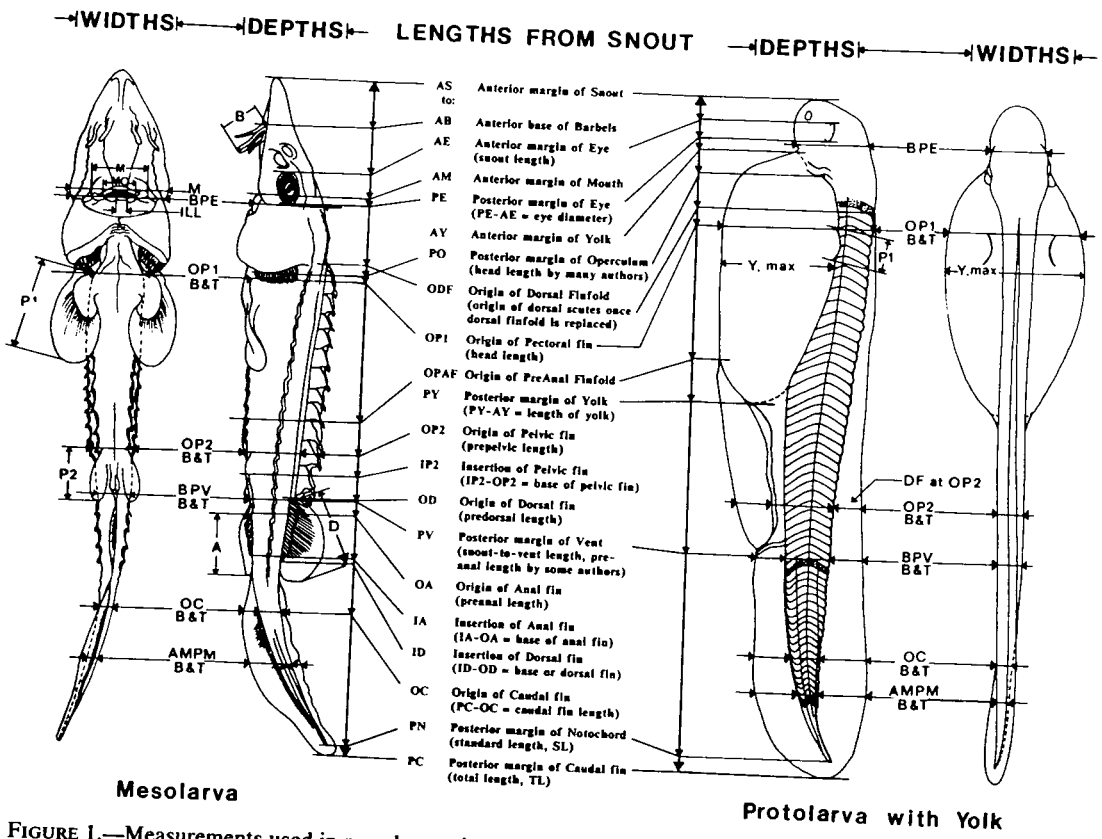

FIGURE 1.—Measurements used in morphometric analyses of sturgeon larvae. The first preanal and first and last postanal myomeres are stippled in the lateral view of the protolarva. Abbreviations not defined in the figure: **B**, barbel (length); **A**, anal fin (length); **D**, dorsal fin (length); **P1**, pectoral fin (length); **P2**, pelvic fin (length); **DF**, dorsal fin fold; **M**, mouth; **MO**, mouth opening; **ILL**, inter–lip-lobe distance; **BPE**, just behind posterior margin of eye; **BPV**, just behind posterior margin of vent; **AMPM**, anterior margin of most posterior myomere; **B&T** associated with depth and width measures, **B** for body exclusive of fin folds, fins, and scutes, and **T** for total, inclusive of these structures; **IOR**, interorbital distance (not illustrated), fleshy width between orbits of eyes. Fin lengths were measured from origin to most distal margin. Positions for OP2 and OC widths and depths prior to formation of referenced structures were approximated at ⅔ PY to PV and ½ PV to PC, respectively. Position of AMPM on some mesolarvae was approximated.

cluded all discernible rays except those incorporated in the spinelike structure along the anterior margin of pectoral fins. When practical, polarizing filters and transmitted light were used to facilitate myomere and fin ray counts. Counts also were made of the skeletal fin ray supports referred to as pterygiophores for the dorsal and anal fins and as radials for the paired fins. Finally, body scutes were counted as dorsal, lateral, and ventral (actually ventrolateral) series (DS, LS, and VS, respectively). Each series began at or near the back of the head; they ended at the anterior margin of the dorsal fin, on the lateral surface of the fleshy portion of the caudal fin, and just anterior to the pelvic fins, respectively. The number and position of scutes between fins posterior to the dorsal and ventral series were also determined. Each count was repeated at least once to ensure accuracy.

Larval phases of development are herein designated as protolarva with yolk, protolarva without apparent yolk, and mesolarva (Snyder 1976, 1983). Protolarvae have no fin rays in the median (dorsal, anal, and caudal) fins. Mesolarvae have some but an incomplete number of principal rays in the median fins or lack pelvic fins or buds. All fin rays of sturgeons are treated as principal rays, and pelvic buds develop during the protolarval phase. Some specimens categorized as protolarvae without yolk may still possess yolk, but its detection would require dissection.

Drawings were traced from enlarged photo-

graphs to provide for accurate body proportions; then the drawings were refined and completed while two or more similar-size specimens were studied under a stereozoom microscope. Final drawings may be composites of two or more specimens and are somewhat idealized (e.g., closed or frayed fins were drawn open and smooth, and curved bodies were straightened). To avoid confusion of pigmentation with other aspects of the drawings, only surface or near-surface melanophores were represented in black ink; the rest of each drawing was produced with various grades of graphite (Figures 2–9).

Results and Discussion

Specific data were recorded for 101 specimens measuring 6.2–136 mm TL. Most results for both species are similar to corresponding observations and data extracted from illustrations and descriptions by Pekovitch (1979), Taubert and Dadswell (1980), and Bath et al. (1981). The reported or suspected identity of collected specimens described or illustrated in these publications are verified by my results, except for recently hatched protolarvae. Verification of the identity of recently hatched protolarvae was inconclusive, but the results are supportive of most previously reported or suspected identities.

Morphometric Characters

Measurements for cultured and collected specimens of each species were combined for Tables 2 and 3. Data for collected protolarvae with yolk are presented separately because criteria for their identification are provisional.

In most cases, I considered morphometric characters to be diagnostically valuable if means between species were well separated and ranges were mutually exclusive, or nearly so. Statistical differences at lesser levels (e.g., 5% significance level; Student's *t*-test) are many, even between cultured and collected specimens of the same species, but most of these differences can be explained by differences in size within the developmental phase analyzed, absorption of yolk, regression of fin folds, or condition factor (depth and width measurements).

Mesolarvae and protolarvae without yolk.—Taubert and Dadswell (1980) suggested that mouth width, a diagnostic character for adult sturgeons (Ryder 1890; Vladykov and Greeley 1963), might distinguish the larvae of the two species once the mouth is formed. Bath et al. (1981) substantiated this observation for protolarvae between 14 and 21 mm TL from actual measurements on collected specimens (Table 4). However, because sample size was small and restricted to one river, and size range was very limited for specimens determined to be shortnose sturgeon, the authors called for further verification of the criteria by other researchers. Dadswell et al. (1984) cited the above papers and stated that "mouth width is the best character for separating all sizes of shortnose sturgeon and Atlantic sturgeon, including all larvae . . . ," except those bearing yolk.

The diagnostic value of mouth width is supported by my data, but, for most relationships, ranges between species do overlap (Table 4). Vladykov and Greeley (1963) considered width of the mouth opening to be a primary diagnostic character for adults. Although Bath et al. (1981) followed Vladykov and Greeley (1963) by measuring mouth width inside the lips (mouth opening, MO), their results tend to match my data better for mouth width including lips (mouth, M) than for width without lips (MO). For larvae at least up to 50 mm SL, I found width of mouth opening more difficult to measure, less consistent, and less discriminating than mouth width including lips. Some differences between my data and those of Bath et al. (1981) probably relate to their smaller sample size and use of greatest head width; I used head widths measured just behind the posterior margins of the eyes (BPE) and in line with the mouth (M). Bath et al. (1981) miscalculated their tabulated data for mouth width relative to interorbital width (a relationship used in adult keys) and actually presented the inverse, interorbital width as a percentage of mouth width (I recalculated the data for comparison in Table 4).

For larvae 15 mm to at least 50 mm SL, mouth width (hereafter the measurement includes lips) relative to head width measured at the mouth is somewhat more discriminating than mouth width relative to head length (anterior margin of snout, AS, to posterior margin of operculum, PO) and much more discriminating than mouth width relative to interorbital distance (IOR) or head width immediately behind the eyes (Table 4). Also, the character is more obvious (Figures 6, 7; Figure 7 in Dovel and Berggren 1983; Figure 4 in Dadswell et al. 1984) and easier to determine (both measurements are along the same line) than head width relative to head length. For protolarvae over 14 mm SL, mouth widths relative to head width measured at the mouth were 65% or less for Atlantic sturgeon (mean, 61%) and greater than

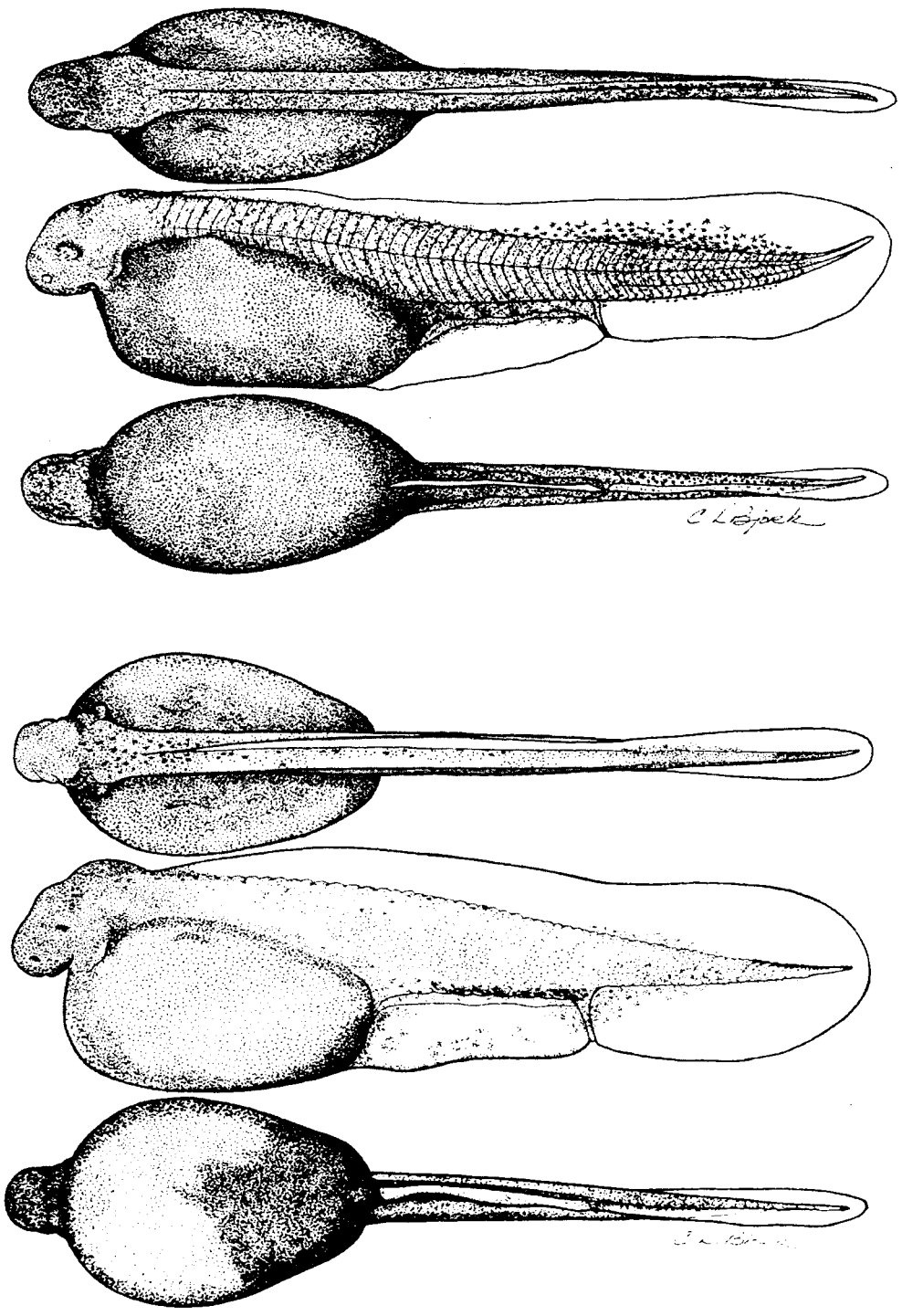

FIGURE 2.—Sturgeon protolarvae with yolk, reared at the Orangeburg National Fish Hatchery. Above: shortnose sturgeon, 10.9 mm standard length (SL), 11.1 mm total length (TL), preserved March 9, 1983, less than 12 h after hatching. Below: Atlantic sturgeon, 7.4 mm SL, 7.5 mm TL, preserved March 30, 1981, about 12 h after hatching.

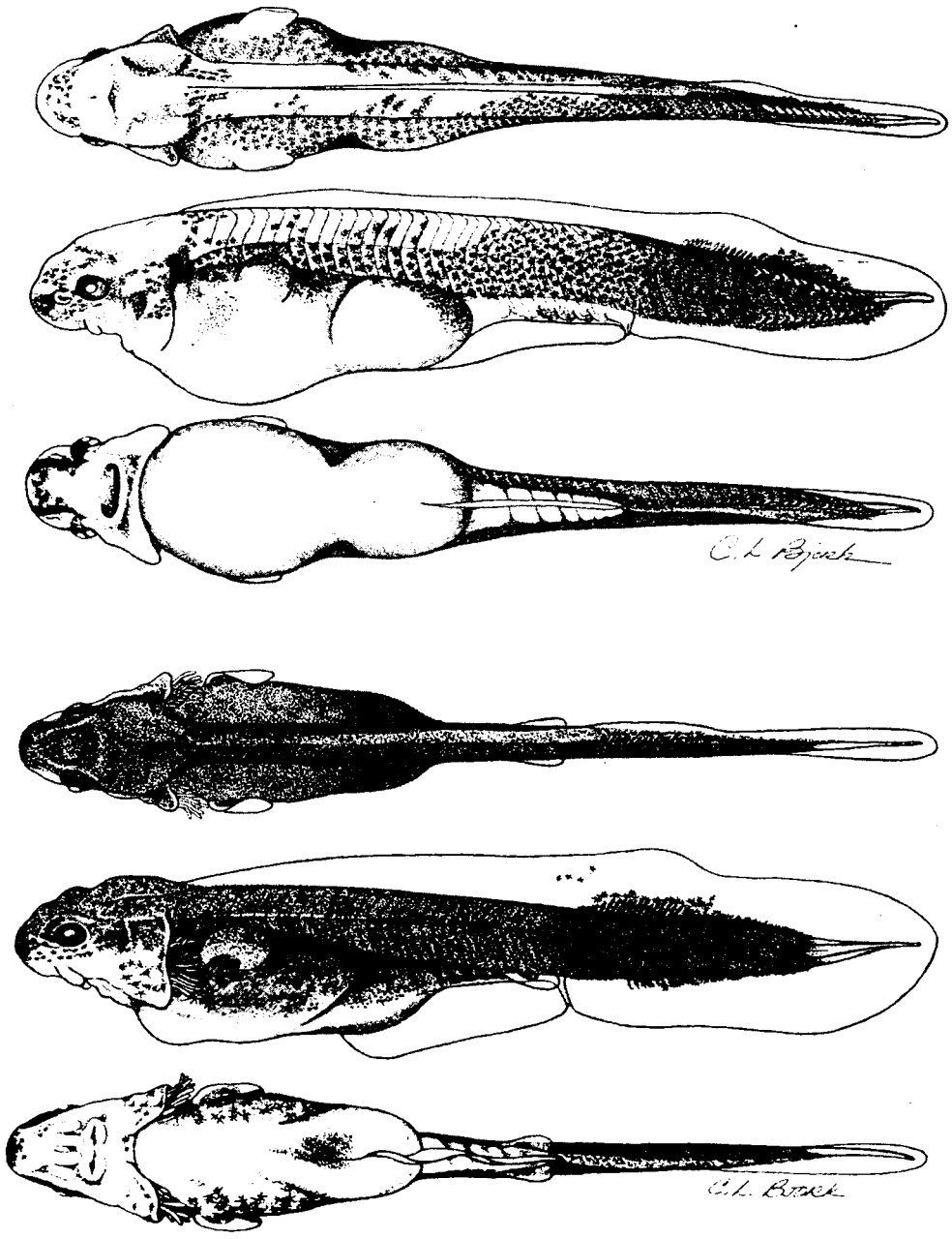

FIGURE 3.—Sturgeon protolarvae with yolk, reared at the Orangeburg National Fish Hatchery. Above: shortnose sturgeon, 12.0 mm standard length (SL), 12.1 mm total length (TL), preserved March 13, 1983, 4 d after hatching. Below: Atlantic sturgeon, 11.5 mm SL, 11.7 mm TL, preserved April 3, 1981, 4 d after hatching.

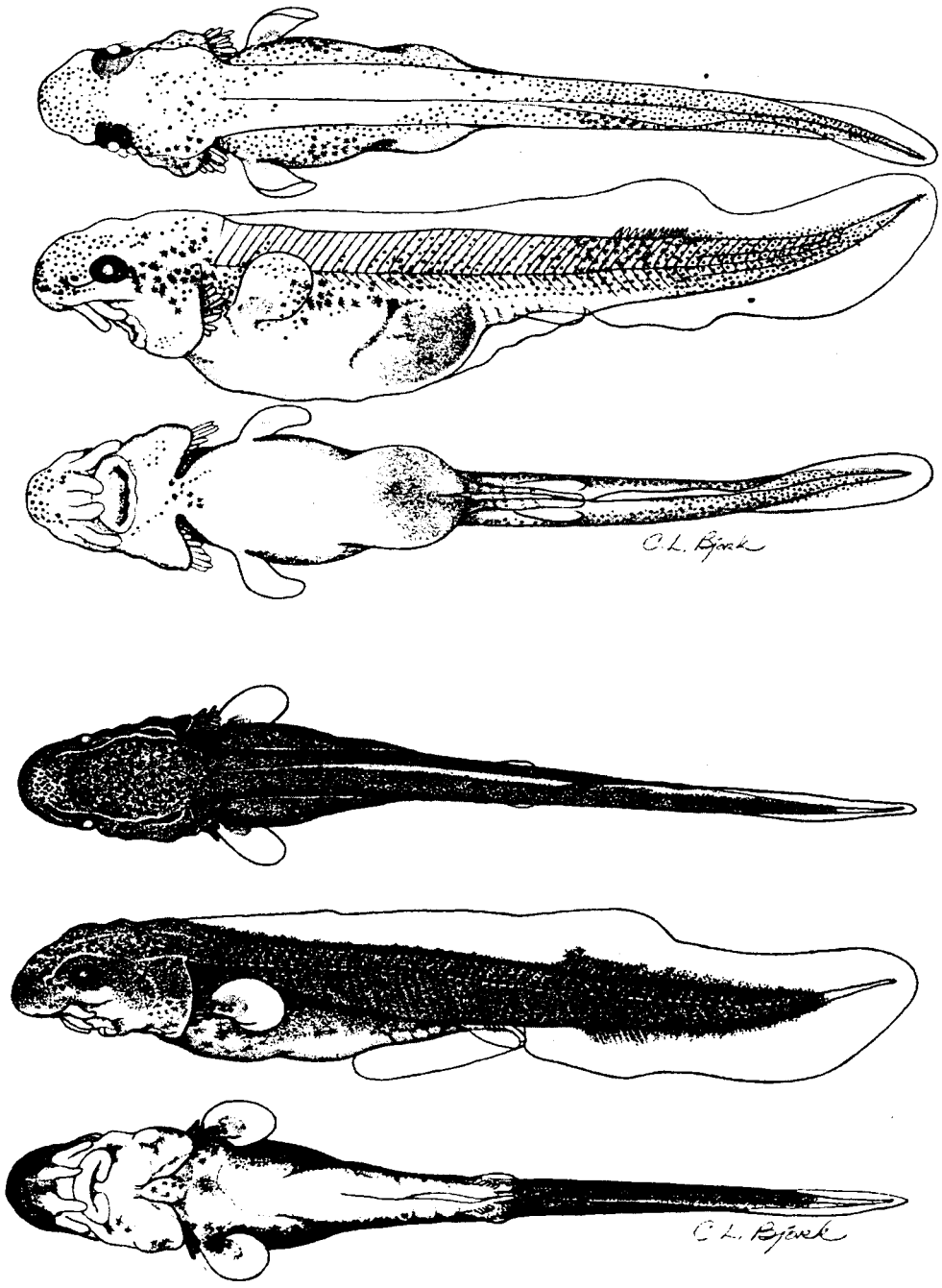

FIGURE 4.—Sturgeon protolarvae with little yolk, reared at the Orangeburg National Fish Hatchery. Above: shortnose sturgeon, 13.5 mm standard length (SL), 13.6 mm total length (TL), preserved March 15, 1983, 6 d after hatching. Below: Atlantic sturgeon, 12.9 mm SL, 13.1 mm TL, preserved April 5, 1981, 6 d after hatching.

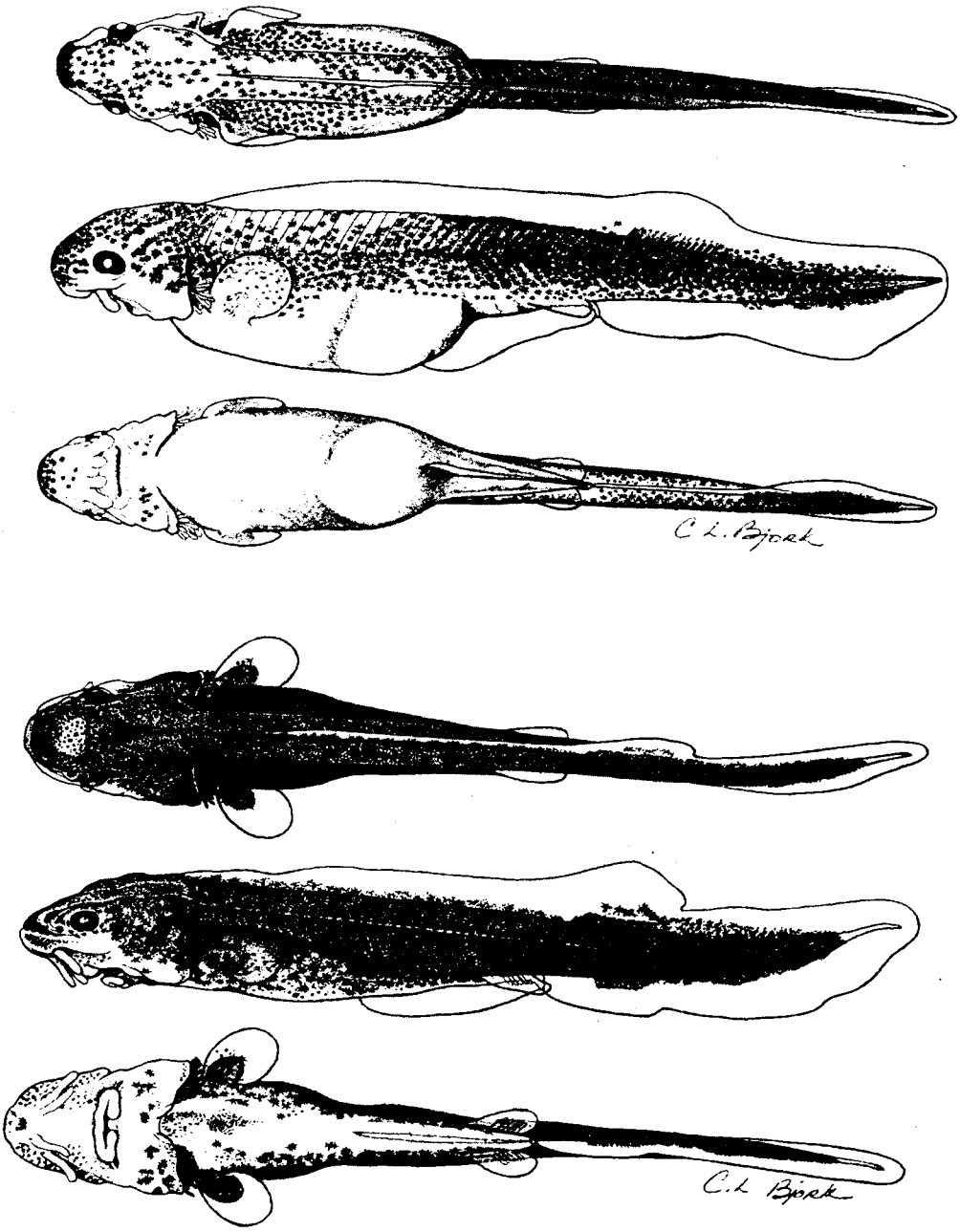

FIGURE 5.—Sturgeon protolarvae without yolk, reared at the Orangeburg National Fish Hatchery. Above: shortnose sturgeon (complete absorption of yolk is questionable), 15.1 mm standard length (SL), 15.2 mm total length (TL), preserved March 16, 1983, 7 d after hatching. Below: Atlantic sturgeon, 14.3 mm SL, 14.6 mm TL, preserved April 6, 1981, 7 d after hatching.

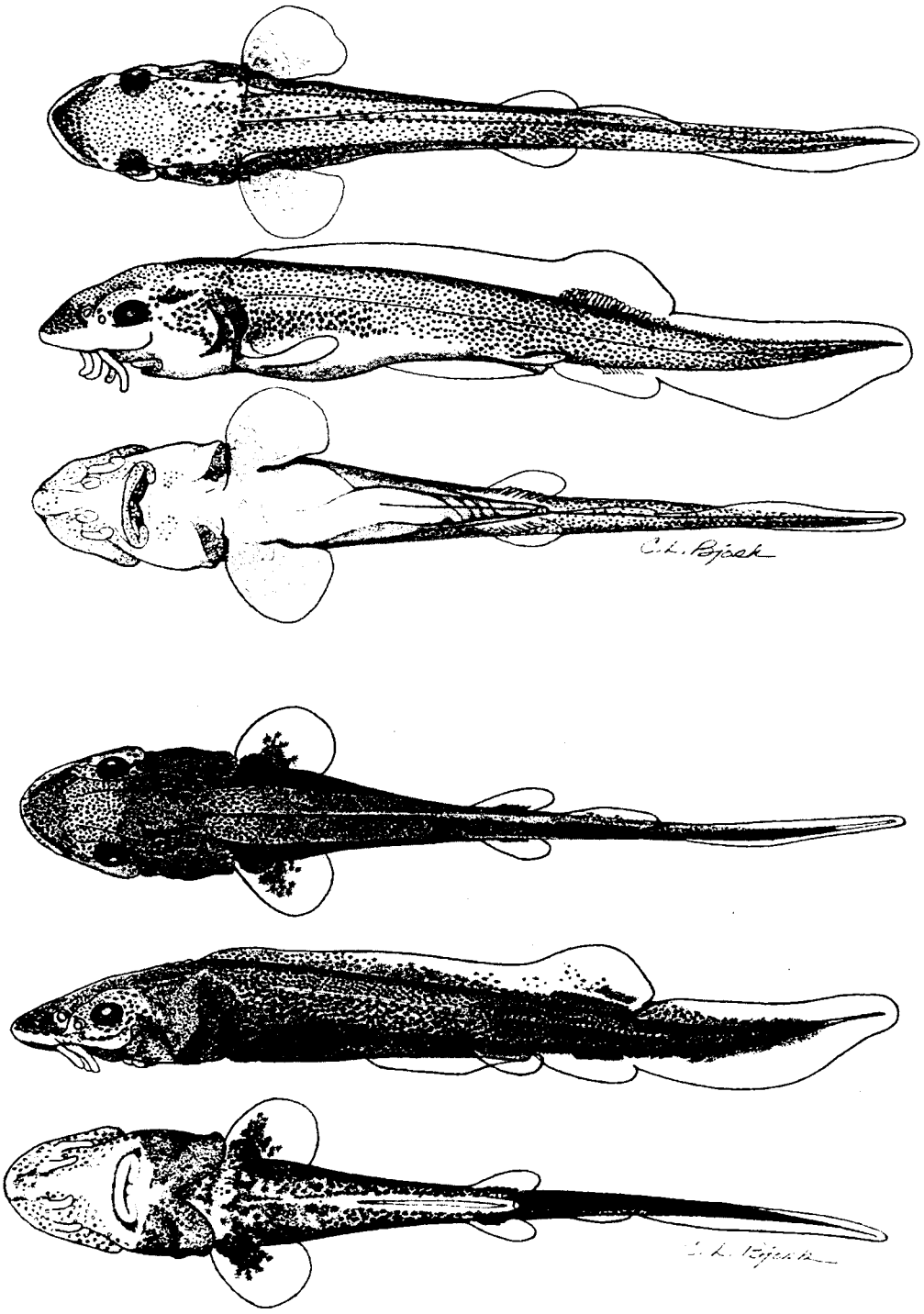

FIGURE 6.—Sturgeon protolarvae without yolk, reared at the Orangeburg National Fish Hatchery. Above: shortnose sturgeon, 17.7 mm standard length (SL), 18.0 mm total length (TL), preserved March 20, 1983, 11 d after hatching. Below: Atlantic sturgeon, 17.0 mm SL, 17.3 mm TL, preserved April 11, 1981, 12 d after hatching.

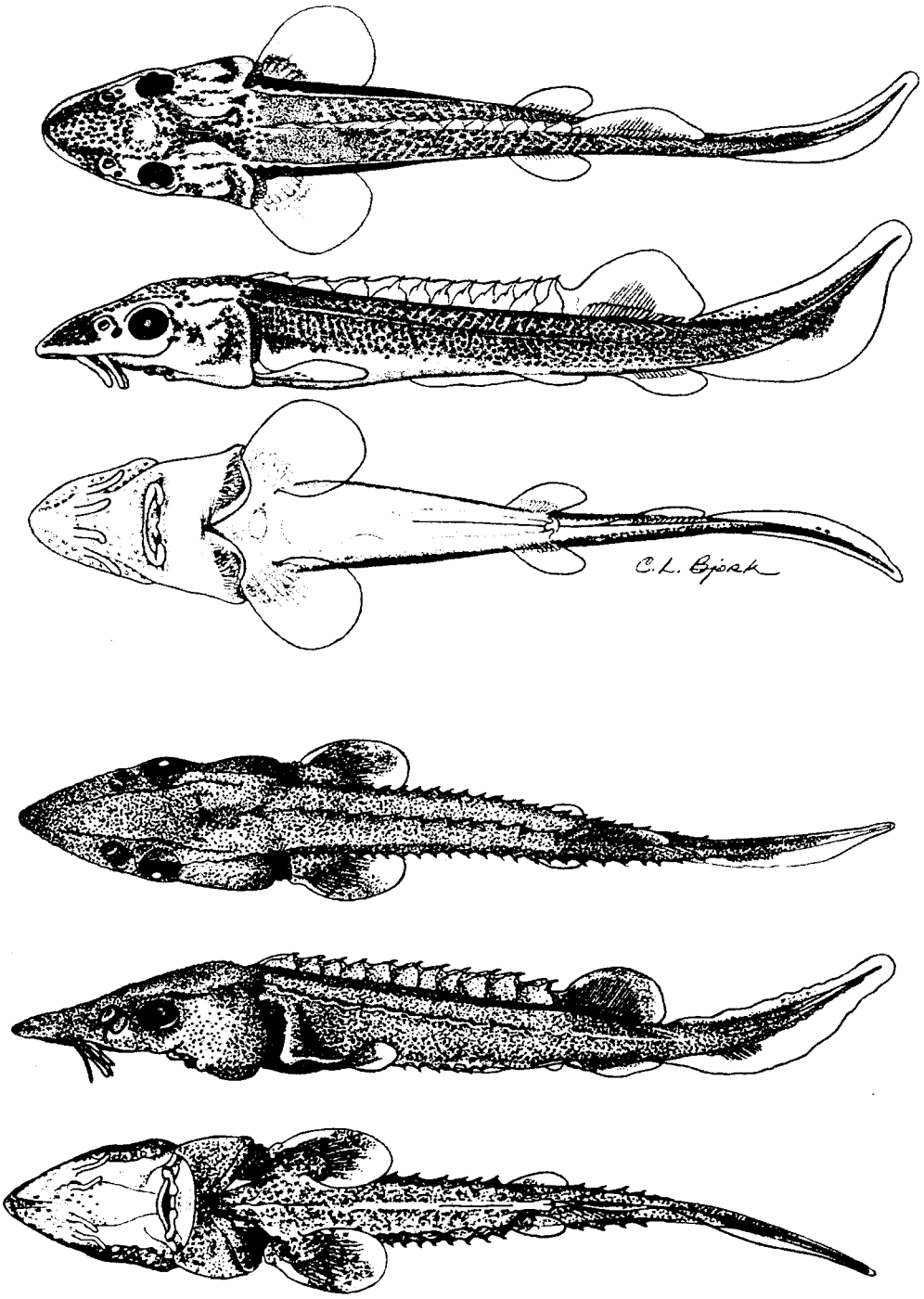

FIGURE 7.—Sturgeon mesolarvae reared at the Orangeburg National Fish Hatchery. Above, shortnose sturgeon, 24.4 mm standard length (SL), 24.9 mm total length (TL), preserved April 3, 1983, 25 d after hatching. Below: Atlantic sturgeon, 28.9 mm SL, 29.3 mm TL, preserved April 28, 1981, 29 d after hatching.

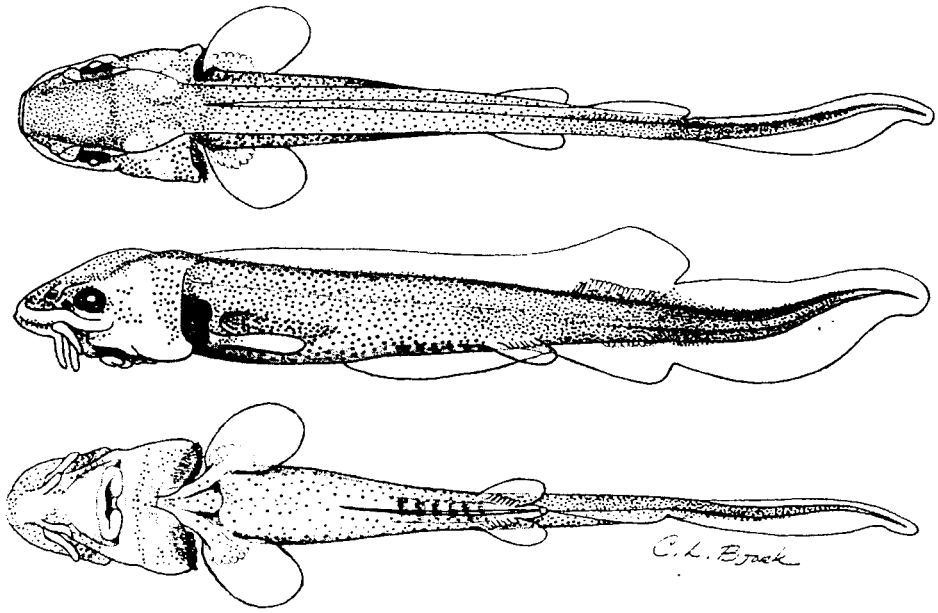

FIGURE 8.—Atlantic sturgeon protolarva without yolk, 14.0 mm standard length, 14.3 mm total length, collected and preserved from the Hudson River near Stony Point, New York (river kilometer 64), June 22, 1976 (specimen 14 in Bath et al. 1981).

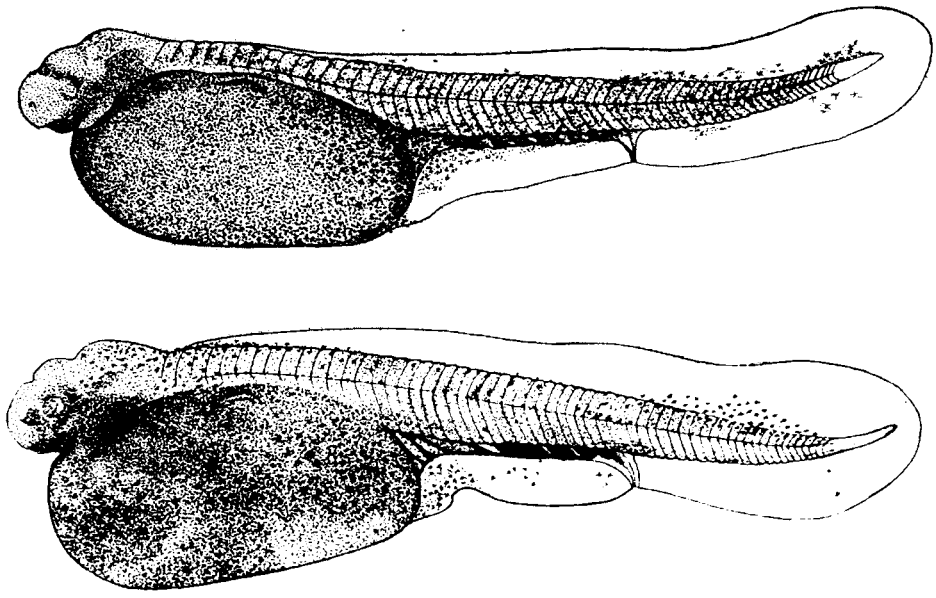

FIGURE 9.—Recently hatched sturgeon protolarvae collected 2 months apart from the same locality along the Savannah River near the U.S. Department of Energy's Savannah River Plant, South Carolina (Paller et al. 1984). Above: probable shortnose sturgeon, 9.6 mm standard length (SL), 9.7 mm total length (TL), collected and preserved March 12, 1982. Below: probable Atlantic sturgeon, 7.4 mm SL, 7.5 mm TL, collected and preserved May 21, 1982.

TABLE 2.—Summary of morphometric characters for shortnose sturgeon larvae. Protolarvae with yolk collected from the Savannah River, South Carolina and Georgia, are probable identities and, therefore, are tabulated separately from those cultured at Orangeburg National Fish Hatchery, South Carolina. Protolarvae without (obvious) yolk and mesolarvae include specimens reared at Orangeburg National Fish Hatchery and at Saint Andrews Biological Station, New Brunswick, Canada, and collected from the Hudson River, New York, the Savannah River, and Merrymeeting Bay, Maine. See Figure 1 for abbreviations and diagram of measurements. Values are rounded to nearest integer; "0" is 0 and ">0" is >0 to <0.50.

	Protolarvae, yolk						Combined sources					
	Collected			Cultured			Protolarvae, no yolk			Mesolarvae		
Measurement	Mean±SD	Range	*N*	Mean±SD	Range	*N*	Mean±SD	Range	*N*	Mean±SD	Range	*N*
SL, mm	10±1	9–11	8	12±1	10–14	9	16±2	14–21	19	42±12	24–57	9
TL, mm	10±1	9–11	8	12±1	10–14	9	17±2	15–21	19	43±12	25–58	9
Lengths, % of SL												
AS to AE	2±>0	2–3	6	4±1	2–6	9	7±1	5–9	19	13±2	10–14	9
to PE	6±>0	5–6	6	8±2	5–10	9	11±2	8–14	19	17±2	14–19	9
to AB	5±1	4–6	2	5±1	4–6	8	5±1	3–6	19	8±1	6–9	9
to AM	7±1	6–8	5	7±>0	7–8	8	10±2	7–14	19	15±2	12–17	9
to PO	11±>0	11–12	4	14±3	11–18	9	22±3	16–25	19	28±2	25–30	9
to OP1	21±1	20–23	7	20±1	19–21	9	23±3	18–27	19	28±2	25–30	9
to OP2				57±2	54–58	5	53±2	51–57	19	57±1	55–59	9
to IP2				62±2	60–64	5	58±1	57–60	19	60±1	58–61	9
to AY	8±2	6–12	8	10±4	7–18	7						
to PY	46±3	43–50	8	48±2	47–51	7						
to ODF	20±3	17–26	8	18±1	17–20	9	21±3	16–29	19	25±2	22–27	9
to OPAF	42±3	39–46	7	44±3	39–48	9	41±3	35–46	19	44±1	43–46	7
to PV	69±3	63–74	8	65±2	61–69	9	60±1	58–62	19	62±1	60–64	9
to OD				63	63	1	62±2	58–65	19	64±2	62–67	9
to ID							71±2	69–75	13	73±2	71–75	9
to OA							66±2	64–69	11	68±2	65–70	9
to IA							72±2	70–75	11	74±1	72–75	9
to OC										78±2	74–81	8
to PC	102±>0	101–102	8	101±>0	100–2	9	102±1	101–3	19	102±1	100–2	9
B	>0±>0	0–1	8	2±1	0–4	9	5±2	1–8	19	6±1	5–7	9
P1	2±2	1–6	7	7±2	5–11	9	13±2	9–15	19	14±1	13–15	9
P2	0±0	0–0	8	3±3	0–7	9	8±2	4–11	19	9±1	8–10	9
D							13±1	13–14	10	11±2	9–15	9
A							9±1	7–10	7	8±1	7–10	9
Depths, % of SL												
at BPE	10±1	8–11	7	10±1	9–12	9	11±1	9–13	19	10±1	9–12	9
at OP1,B	21±3	16–25	6	20±2	17–23	9	13±2	10–17	19	12±1	11–13	9
at OP1,T	21±3	17–25	5	21±2	17–24	9	14±2	12–18	19	13±1	13–14	9
at OP2,B	8±>0	7–8	8	10±1	9–11	9	8±1	7–10	19	9±1	7–9	9
at OP2,T	14±2	12–18	8	16±3	11–20	9	13±2	11–17	18	12±1	11–13	9
at BPV,B	5±>0	5–6	8	7±1	7–8	9	7±1	5–8	19	7±>0	7–8	9
at BPV,T	13±2	10–16	8	13±2	11–17	9	12±1	9–13	18	10±1	9–12	9
at OC,B	4±>0	3–5	7	4±1	4–6	9	4±1	3–5	19	4±1	3–5	9
at OC,T	14±2	12–18	7	14±2	12–17	9	10±1	8–12	17	5±2	4–10	9
at AMPM,B	2±>0	2–3	8	2±>0	2–3	9	2±>0	2–2	19	2±>0	1–2	9
at AMPM,T	14±2	11–17	8	14±2	11–17	9	10±1	9–13	18	7±1	5–8	9
DF at OP2	3±1	2–4	8	3±1	1–4	9						
Yolk, maximum	18±5	11–22	4	17±2	14–19	7						
Widths, % of SL												
at BPE	8±1	7–8	8	10±1	8–12	9	14±2	10–19	19	15±1	14–16	9
at M	20±5	13–25	7	10±2	8–12	8	14±2	10–17	19	14±1	13–16	9
at OP1	4±>0	3–5	8	16±4	11–21	9	11±1	9–13	19	14±1	11–17	9
at OP2,B				6±1	5–6	9	5±>0	4–6	19	6±1	6–7	9
at OP2,T	4±>0	3–4	8							9±1	8–10	8
at BPV,B				5±1	4–6	9	4±>0	4–5	19	5±>0	5–5	9
at BPV,T	3±>0	2–3	8							6±1	5–7	8
at OC	2±>0	2–2	8	4±1	3–5	9	3±>0	2–3	19	2±1	2–3	9
at AMPM				2±>0	1–2	9	1±>0	1–1	19	1±>0	1–1	9
M				8±1	8–9	5	10±1	8–14	18	10±1	9–11	9
MO				6±1	5–7	5	7±1	5–10	18	7±>0	6–7	9
IOR	4±>0	4–5	4	7±2	4–10	8	9±1	8–12	18	10±1	8–11	9
ILL				5	5	1	4±>0	4–5	14	3±1	2–5	9
Yolk, maximum	23±3	18–25	5	18±3	14–21	7						

TABLE 3.—Summary of morphometric characters for Atlantic sturgeon larvae. Protolarvae with yolk collected from the Savannah River, South Carolina and Georgia, are probable identities and, therefore, are tabulated separately from those cultured at Orangeburg National Fish Hatchery, South Carolina. Protolarvae without (obvious) yolk and mesolarvae include specimens reared at Orangeburg National Fish Hatchery and collected from Hudson River, New York, Savannah River, and Winyah Bay, South Carolina. See Figure 1 for abbreviations and diagram of measurements. Values are rounded to nearest integer; "0" is 0 and ">0" is >0 to <0.50.

	Protolarvae, yolk						Combined sources					
	Collected			Cultured			Protolarvae, no yolk			Mesolarvae		
Measurement	Mean±SD	Range	N	Mean±SD	Range	N	Mean±SD	Range	N	Mean±SD	Range	N
SL, mm	8±1	6–9	6	11±2	9–13	9	16±2	14–21	15	37±9	29–47	6
TL, mm	8±1	6–9	6	11±2	9–13	9	16±2	14–21	15	38±9	29–47	6
Lengths, % of SL												
AS to AE	3±1	3–4	5	4±1	3–5	8	7±2	4–10	15	14±2	12–16	6
to PE	7±>0	7–7	5	8±1	7–9	8	11±2	8–14	15	18±2	16–20	6
to AB	4±1	3–6	5	4±1	4–5	9	4±1	3–7	15	8±2	7–11	6
to AM	7±1	6–8	5	7±1	6–9	9	11±2	7–13	15	16±3	14–19	6
to PO	13±1	12–14	5	15±3	11–20	9	23±2	20–26	15	29±2	27–31	6
to OP1	24±3	21–27	5	20±2	17–24	9	22±2	20–26	15	30±2	27–32	6
to OP2				50±2	48–52	5	52±2	49–59	15	57±1	55–58	6
to IP2				58±2	55–60	5	57±2	55–62	15	60±1	59–61	6
to AY	8±1	7–10	6	12±5	6–21	9						
to PY	48±1	47–50	6	43±5	34–47	9						
to ODF	20±2	19–23	6	17±1	15–19	9	20±2	17–27	15	27±2	24–29	6
to OPAF	45±3	41–49	6	39±3	34–42	9	39±3	35–45	15	46±4	43–52	6
to PV	73±1	72–74	6	63±6	56–71	9	59±2	56–64	15	62±1	61–64	6
to OD				60±2	58–62	3	60±2	57–64	15	63±2	61–65	6
to ID							70±2	67–74	15	72±1	70–73	6
to OA				64±2	62–66	3	64±2	61–70	15	67±2	65–68	6
to IA							70±2	67–75	14	72±1	70–73	6
to OC										77±1	75–78	5
to PC	102±1	101–103	6	102±>0	101–102	9	101±1	101–102	15	101±1	100–101	6
B	1±>0	0–1	6	3±2	1–5	9	5±1	4–6	15	5±1	5–6	6
P1	5±1	4–6	5	7±2	5–10	9	12±2	10–15	15	13±1	12–14	6
P2	0±0	0–0	6	5±4	0–9	9	8±1	7–9	15	8±1	7–9	6
D							13±1	12–15	11	12±1	10–14	6
A							8±1	7–9	10	8±1	7–10	6
Depths, % of SL												
at BPE	11±2	10–14	6	10±1	9–11	9	11±1	10–14	15	11±1	9–12	6
at OP1,B	24±4	19–29	6	19±6	11–26	9	12±1	10–15	15	12±1	11–12	6
at OP1,T	25±4	20–30	5	20±7	12–27	9	13±1	11–16	15	13±1	12–14	6
at OP2,B	8±>0	7–8	6	9±1	8–9	9	8±1	7–10	15	8±2	5–9	6
at OP2,T	15±2	11–18	6	20±2	17–23	7	14±2	11–18	15	11±2	10–14	6
at BPV,B	5±1	5–6	6	7±1	6–7	9	7±1	6–8	15	6±1	6–8	6
at BPV,T	14±1	13–15	5	16±2	14–19	9	12±1	10–16	15	9±2	7–11	6
at OC,B	4±>0	4–5	6	4±1	3–5	9	4±0	3–5	15	3±>0	3–4	6
at OC,T	14±1	13–16	5	18±3	13–22	8	11±1	9–14	14	6±1	5–9	6
at AMPM,B	2±>0	2–3	6	2±>0	2–3	9	2±0	2–3	15	2±>0	1–2	6
at AMPM,T	14±2	11–16	6	16±1	13–18	9	10±2	8–14	14	7±1	6–8	6
DF at OP2	3±1	2–4	6	5±1	4–6	9						
Yolk, maximum	20±3	17–24	6	16±6	8–22	8						
Widths, % of SL												
at BPE	8±>0	8–9	6	9±1	7–12	9	13±2	10–16	15	13±1	12–14	6
at M				10±1	9–12	5	13±1	12–15	15	13±>0	13–14	6
at OP1	22±3	18–26	5	16±6	9–23	9	10±2	9–17	15	14±1	13–16	6
at OP2,B	4±1	3–5	6	4±1	3–5	9	4±1	3–6	15	5±>0	4–5	6
at OP2,T										7±1	6–8	6
at BPV,B	4±1	3–4	6	4±1	3–4	9	4±1	3–6	15	4±>0	4–5	6
at BPV,T										6±1	5–8	6
at OC	3±1	2–4	6	2±1	2–3	9	3±1	2–5	14	2±1	1–3	6
at AMPM	2±>0	2–2	6	2±>0	1–2	9	1±0	1–2	14	1±>0	1–1	6
M				7±>0	6–8	5	8±0	8–9	15	7±>0	7–8	6
MO				5±1	4–6	5	6±0	5–7	15	5±>0	5–6	6
IOR	4±1	3–5	3	6±1	4–8	8	9±1	8–10	15	9±1	9–10	6
ILL				1±>0	1–2	2	1±0	1–1	14	1±>0	1–1	5
Yolk, maximum	23±3	19–26	5	18±5	12–23	8						

TABLE 4.—Inter-lip-lobe distance, mouth width (with lips), and mouth-opening width as a percentage of selected head measurements for shortnose sturgeon and Atlantic sturgeon larvae without yolk and greater than 13 mm standard (SL) or total (TL) length. Data are based on both cultured and collected specimens. Data from Bath et al. (1981) for mouth-opening width are provided for comparison. Where the number and size range of specimens are adequate, the degree of difference between species means and ranges is indicative of a character's diagnostic value. Negative range differences represent overlap; asterisk (*) indicates one range is completely included within the other. Inter-lip-lobe distance (ILL) is width between lobes of lower lip; mouth width (M) includes lips; mouth-opening width (MO) excludes lips; head width was measured immediately behind eyes (W at BPE), at mouth (W at M), and at greatest width (GHW); head length was measured to posterior margin of opercula (AS to PO); interorbital distance (IOR) is least width between fleshy orbits of eyes.

Measurement	Shortnose sturgeon			Atlantic sturgeon			Difference	
	Mean±SD	Range	*N*	Mean±SD	Range	*N*	Mean	Range
Inter-lip-lobe distance								
Protolarvae >13 mmSL								
mm SL		14–21			14–21			
% M	46±7	34–58	14	14±3	6–18	14	32	16
% W at M	34±6	27–47	14	9±2	3–13	14	25	15
% W at BPE	33±6	25–47	14	9±2	3–14	14	24	11
% AS to PO	21±5	15–29	14	5±1	2–7	14	16	8
Mesolarvae								
mm SL		24–57			30–47			
% M	32±5	26–42	9	15±3	10–18	5	17	8
% W at M	22±4	17–31	9	8±2	6–10	5	14	7
% W at BPE	22±4	16–31	9	8±2	6–11	5	14	5
% AS to PO	11±3	9–18	9	4±1	2–5	5	7	4
Mouth width (with lips)								
Protolarvae >13 mm SL								
mm SL		14–21			14–21			
% W at M	75±5	66–88	18	63±4	57–72	15	12	−6
% W at BPE	75±9	59–100	18	64±6	55–79	15	11	−20
% AS to PO	47±4	38–55	18	38±3	33–42	15	9	−4
% IOR	107±11	87–140	17	93±7	79–105	15	14	−18
Protolarvae >14 mm SL								
mm SL		15–21			15–21			
% W at M	75±6	66–88	17	61±3	57–65	9	14	1
% W at BPE	75±9	59–100	17	60±4	55–68	9	15	−9
% AS to PO	46±4	38–55	17	36±3	33–42	9	10	−4
% IOR	107±11	87–140	16	92±4	87–100	9	15	−13*
Mesolarvae								
mm SL		24–57			29–47			
% W at M	69±4	62–74	9	57±1	56–59	6	12	3
% W at BPE	67±4	61–74	9	56±3	53–61	6	11	0
% AS to PO	35±3	31–43	9	26±2	24–28	6	9	3
% IOR	101±4	84–119	9	82±2	73–88	6	19	−4
Mouth-opening width								
Protolarvae >13 mm SL								
mm SL		14–21			14–21			
% W at M	50±6	42–67	18	44±4	37–50	15	6	−8
% W at BPE	51±9	40–76	18	45±5	35–52	15	6	−12
% AS to PO	31±4	25–42	18	26±3	22–31	15	5	−6
% IOR	72±11	57–107	17	65±6	57–75	15	7	−18
Protolarvae >14 mm SL								
mm SL		15–21			15–21			
% W at M	50±6	42–67	17	43±5	27–50	9	7	−8
% W at BPE	50±9	40–76	17	43±5	35–50	9	7	−10
% AS to PO	31±4	25–42	17	26±3	22–31	9	5	−6
% IOR	72±11	57–107	16	65±5	60–73	9	7	−13*
Mesolarvae								
mm SL		24–57			29–47			
% W at M	47±2	43–50	9	41±2	39–44	6	6	−1
% W at BPE	46±4	42–51	9	40±2	39–43	6	6	−1
% AS to PO	24±2	21–30	9	19±2	16–21	6	5	0
%IOR	70±7	61–83	9	58±2	53–64	6	12	−3
Mouth-opening width—from Bath et al. (1981)								
Protolarvae >13 mm TL								
mm TL		15–16			14–21			
% GWH	73±5	65–75	4	52±3	48–55	5	21	10
% AS to PO	44±2	43–47	4	36±3	33–41	7	8	2
% IOR	147±7	136–150	4	130±23	100–157	5	17	−14*
Protolarvae >14 mm TL								
mm TL		15–16			17–21			
% GHW	73±5	65–75	4	51±3	48–55	4	22	10
% AS to PO	44±2	43–47	4	34±1	33–36	4	10	7
% IOR	147±7	136–150	4	111±15	100–121	2	36	15
Mesolarvae								
mm TL					32–37			
% GHW				48		1		
% AS to PO				26±2	25–27	2		
% IOR				97±21	82–112	2		

65% for shortnose sturgeon (mean, 75%). However, the boundary between values for the two species (65–66%) might not hold in all cases because inclusion of 14-mm-SL specimens in the data set extends the range for Atlantic sturgeon up to 72%. For mesolarvae, mouth widths relative to head width measured at the mouth were less than 60% for Atlantic sturgeon (mean of 57%) and greater than 61% for shortnose sturgeon (mean of 69%).

The distance between lobes of the lower lip (inter–lip-lobe distance, ILL) is the most diagnostically valuable morphometric character considered in this study (Tables 2–4). The character was illustrated by Dovel (1979), noted by Bath et al. (1981) as a personal communication from Dovel, and specified by Dovel and Berggren (1983) as a better distinguishing character than mouth width.

Although diagnostically very strong regardless of the head dimension it is related to, differences in inter–lip-lobe distance are particularly obvious when compared to mouth width, even without actual measurement (Table 4; Figures 6–8; Figure 7 in Dovel and Berggren 1983; Figure 4 in Dadswell et al. 1984). Dovel and Berggren (1983) observed that for Atlantic sturgeon larvae this distance is usually "less than a third of the total width of the mouth." I found that this distance was less than 19% of mouth width for Atlantic sturgeon (means of 14% for protolarvae longer than 13 mm SL and 15% for mesolarvae) and greater than 25% for shortnose sturgeon (means of 46% and 32%, respectively).

Dovel and Berggren (1983) stated that there are differences between Atlantic and shortnose sturgeon larvae in the size and shape of their barbels. I observed no obvious differences in shape or consistent differences in size relative to developmental state (length B in Tables 2, 3)

Protolarvae with little yolk.—Protolarvae approaching yolk depletion (12–13 mm, rarely 11 mm SL) sometimes are distinguishable on the basis of mouth width and inter–lip-lobe distance criteria discussed. However, these characters must be used cautiously and, if possible, in combination with other criteria.

Position of recently formed pelvic fin buds also might have diagnostic value for larvae approaching yolk depletion. The origin of the bud (AS to origin of pelvic fin, OP2) was greater than 53% SL for shortnose sturgeon and equal to or less than 53% for Atlantic sturgeon protolarvae with yolk (Tables 2, 3). However, all measurements were from cultured specimens; verification with collected material is needed. Also, pelvic fin positions in protolarvae without yolk are nearly identical (Tables 2, 3), and in a few instances, the between-species relationship is reversed—48–51% of TL for shortnose sturgeon and 51–55% of TL for Atlantic sturgeon based on data from Pekovitch (1979) and illustrations from Bath et al. (1981).

Protolarvae with yolk.—Morphometric characters are of limited value in identifying recently hatched protolarvae of these sturgeons. The most obvious and consistent difference, dorsal fin-fold depth, is reflected somewhat in total depths, especially at the origin of future or recently formed pelvic fin buds for cultured specimens (OP2,T and DF at OP2, Tables 2, 3) and origin of pectoral fin buds for collected specimens (OP1,T). The anterior portion of the dorsal fin fold tends to be much shallower in yolk-bearing protolarvae of shortnose sturgeon than in Atlantic sturgeon (Figures 2, 9). In association with this difference, the anterior portion of the dorsal fin fold often tends to be slightly concave in shortnose sturgeon and convex in Atlantic sturgeon. For cultured specimens examined from hatching through 13 mm SL, dorsal fin-fold depth at origin of the future or recently formed pelvic fin buds (DF at OP2) is always 36% of body depth (OP2,B) or less for shortnose sturgeon and 45% or greater for Atlantic sturgeon (Figure 10). However, addition of corresponding data for collected protolarvae with yolk (believed to be accurately identified based on other criteria) obscures this distinction for specimens with fin-fold depths over 35% of body depth. Nearly all collected Atlantic sturgeon have intermediate fin-fold depths between 36 and 50% of body depth at the pelvic fin bud origin, and fin-fold depths for collected shortnose sturgeon varied between 22 and 56% of body depth.

Meristic Characters

Myomere counts were nearly identical for the two species and accordingly have no diagnostic value. Means for both species examined for this study were 38 preanal, 22 or 23 postanal, and 60 or 61 total myomeres (Table 5). Mean preanal and total myomere counts reported by Pekovitch (1979) for shortnose sturgeon were one to two units less, those reported by Taubert and Dadswell (1980) for shortnose sturgeon were four to five units less, and those reported by Bath et al. (1981) for Atlantic sturgeon were one to four units less. For specimens examined in this study, larvae from the Saint John and Hudson rivers have myomere counts similar to

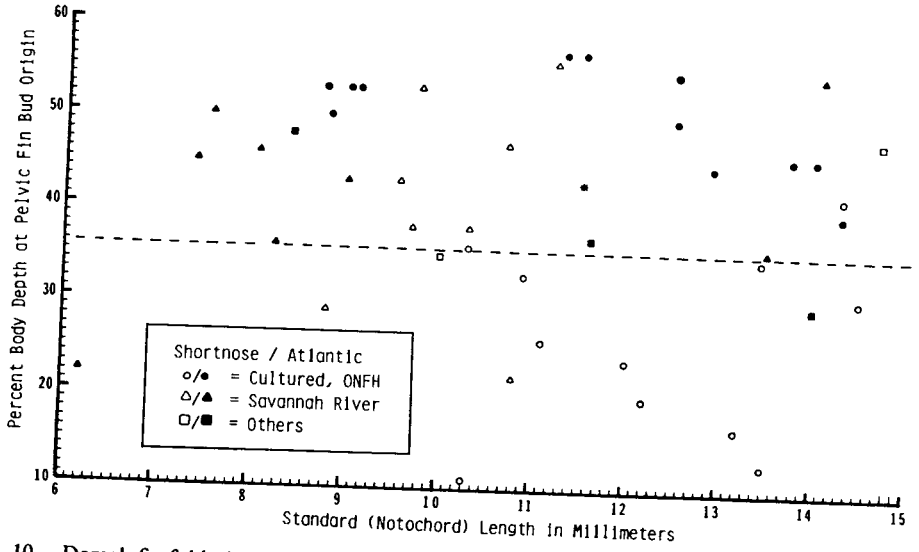

FIGURE 10.—Dorsal fin-fold depth as a percentage of body depth (fin folds excluded) at the origin (or approximated origin) of the pelvic fin buds for shortnose sturgeon and Atlantic sturgeon protolarvae before and shortly after complete yolk absorption. "Other" data were extracted from photographs in Taubert and Dadswell (1980) and Bath et al. (1981). The asterisk represents a datum extracted from a drawing reported to be of Atlantic sturgeon by Ryder (1890). Between 7 and 13 mm standard length, all data beneath the broken horizontal line represent only shortnose sturgeon; ONFH is Orangeburg National Fish Hatchery.

those from South Carolina populations. Accordingly, the discrepancies among authors probably reflect differences in criteria or technique for myomere counts rather than differences between species or geographically segregated populations. The most anterior and posterior myomeres are often difficult to discern and may be overlooked; some reported counts may exclude all anterior segments that are strictly epaxial or dorsal to the horizontal myoseptum. The number of myomeres illustrated for a recently hatched Atlantic sturgeon in Ryder (1890; 61 preanal, 35 postanal, and 96 total) is inaccurate.

Pelvic and anal fin ray counts effectively differentiate specimens larger than 50–60 mm SL (Table 6). Pelvic fin ray counts are discrete: 17–22 pelvic rays for shortnose sturgeon versus 26–35 for Atlantic sturgeon. In contrast, the diagnostic value of anal fin ray counts is limited by range overlap: 18–24 for shortnose sturgeon versus 22–32 for Atlantic sturgeon. These counts are based on original and published data and include rare or questionable observations.

Published reports of caudal fin ray counts, 60 for shortnose sturgeon and 90 for Atlantic stur-

TABLE 5.—Myomere counts for cultured and collected larvae of shortnose sturgeon and Atlantic sturgeon.

Myomere count	Shortnose sturgeon			Atlantic sturgeon		
	Mean±SD	Range	*N*	Mean±SD	Range	*N*
			Cultured			
Preanal	38±2	35–41	24	38±1	36–40	20
Postanal	22±2	20–26	22	23±1	22–24	19
Total	60±2	58–65	21	61±1	59–62	19
			Collected			
Preanal	38±1	36–40	13	38±1	36–40	13
Postanal	24±2	19–25	8	21±2	18–24	10
Total	62±2	58–65	8	59±2	56–61	10
			Combined			
Preanal	38±2	35–41	37	38±1	36–40	33
Postanal	23±2	19–26	30	22±2	18–24	29
Total	61±2	58–65	29	60±2	59–62	29

TABLE 6.—Selected meristic characters for shortnose sturgeon and Atlantic sturgeon as summarized from original observations and the literature. Original counts are believed to represent adult complements. Where appropriate and notable, mean or model values are underlined. Rare or questionable extremes are enclosed in parentheses.

Character	Shortnose sturgeon		Atlantic sturgeon	
	Count	Source[a]	Count	Source[a]
Fin rays				
Dorsal				
Original	32–34	2, 57–57	34–41	12, 39–136
Literature	33–42	A–C, F–I	30–46	A–C, E–H
Anal				
Original	18	1, 57	24–27	11, 47–136
Literature	18–19–22–24	A–D, F–I	(22)23–30(32)	A–H
Caudal				
Original			92[b]	1, 136
Literature	60	A, H	90	A
Pectoral[c]				
Original	25–27	6, 36–57	(27)28–36(38)	12, 39–136
Literature	30–31	A, H	35–41	A, H
Pelvic				
Original	19–22	3, 51–57	28–33(35)	9, 58–136
Literature	17–21	A, H	26–29	A, H
Fin ray supports				
Dorsal				
Original	17–19(23)	28, 14–57	15–16–17–18	33, 11–107
Literature	15–17	J	13	A
Anal				
Original	10–12(13)	13, 16–57	10–11–12–13	30, 13–136
Literature	10	J	10	A
Caudal				
Original	23–29	8, 34–57	(29)31–43	11, 29–107
Literature			25	A
Pectoral				
Original	7–8	25, 15–57	7–8(9)	20, 13–58
Pelvic				
Original	(7)8–9	22, 17–57	7–8–9(10)	28, 13–107
Literature	6–8	J		
Scutes series[d]				
Dorsal				
Original	10–11–14	8, 34–57	9–11–12	12, 39–136
Literature	(7)8–10–11–13	A–I	(7)10–11–14(16)	A–H
Lateral				
Original	24–31	3, 51–57	(23)24–27	12, 39–136
Literature	(21)22–25–32–34	A–I	24–26–29–35(36)	A–H
Ventral				
Original	6–7–8–9	8, 34–57	8–9–10(11)	12, 39–136
Literature	(3)6–7–9–11	A–I	8–9–11–12(14)	A–D, F–H
Gill rakers				
First arch				
Literature	22–25–28–32	E, G–I	15–22–27	E, G–I

[a]Number of specimens and size range (mm standard length) for original counts; literature sources: A, Ryder (1890); B, Jordan and Evermann (1896); C, Hildebrand and Schroeder (1928); D, Bigelow and Schroeder (1953); E, Vladykov and Greeley (1963); F, Moore (1968); G, Scott and Crossman (1973); H, Jones et al. (1978); I, Dadswell et al. (1984); and J, Pekovitch (1979, based on four specimens 16.3–18.2 mm total length).

[b]About 23 rays in lower lobe, 58 in upper lobe, and 11 at tip, which is separated from upper lobe by a narrow constriction; count at tip might not be complete.

[c]Original counts do not include rays incorporated in spinelike structure along anterior margin of fin.

[d]At least for original counts, dorsal series of scutes includes modified scute at anterior margin of dorsal fin. Original counts and most previously published counts of ventral or ventrolateral series end with a scute just anterior to pelvic fin. Some published counts might include paired scutes between vent and anal fin.

geon, indicate that this character also is discriminating (Table 6). However, acquisition of the adult count of caudal fin rays is the last criterion for transition to the juvenile period in sturgeons, so the character cannot be applied until very late in the larval period. Also, adult counts need further verification based on larger specimens.

Caudal fin ray supports, 23–29 for shortnose sturgeon and 29–43 for Atlantic sturgeon, might be diagnostic even for larvae as small as 29 mm SL (Table 6). However, Ryder (1890) reported 25 caudal fin ray supports for Atlantic sturgeon. If the latter observation is accurate, the diagnostic value of the character must, at least for the

present, be limited to counts well over 29, which would represent Atlantic sturgeon.

The number of scutes (bony shields and plates) in major series or rows is similar for both species (Table 6). However, other more posteriorly located scutes differ in number and position (Scott and Crossman 1973). Atlantic sturgeon larvae 50 mm or larger are characterized by a ridge along each side of both the dorsal midline, between the dorsal and caudal fins, and one along the ventral midline, between the anal and caudal fins. The dorsal ridges are replaced in larger larvae by (typically) three scutes on each side. Between the anal and caudal fins, the ridges are replaced by one or two scutes on each side followed by an elongate median scute that extends onto the anterior margin of the caudal fin. In contrast, 51-mm-SL shortnose sturgeons have single median ridges posterior to the dorsal and anal fins. By 57-mm SL, these ridges are replaced by two or three median scutes, including those that extend onto the anterior margins of the caudal fin. One 57-mm-SL shortnose sturgeon also possessed two scutes along each side of the midline between the vent and anal fin with one median scute bordering the anterior margin of the anal fin. These paired vent-to-anal-fin scutes often fail to develop because they are often absent from many adults (Dadswell et al. 1984).

My fin ray and scute counts were not always consistent with those previously reported (Table 6). In particular, apparently complete pectoral fin ray counts observed for the larger larvae of both species were much lower than those previously reported for juveniles or adults. A difference of a few rays might be attributed to differing criteria if previous counts included the pectoral spine or individual rays incorporated in or associated with the spine. Despite the apparent completeness of pectoral fin ray counts by 30 mm SL, not all rays of the adult complement may be present yet, even for the largest larvae I examined. I observed considerable variation in pectoral fin ray counts for Atlantic sturgeon (27–38 irrespective of size between 30 and 136 mm SL) including differences of as many as 6 rays between right and left fins on some specimens. Counts of dorsal and caudal pterygiophores (fin ray supports) for Atlantic sturgeon were much higher than those reported by Ryder (1890) for juveniles or adults. Perhaps some fin supports fuse as the fish grow.

Size Relative to Developmental State

From the specimens studied, shortnose and Atlantic sturgeons are developmentally similar at hatching, but shortnose sturgeons are larger than Atlantic sturgeons, about 9–10 mm SL versus 7–9 mm SL. Shortnose sturgeons generally continue to be slightly larger at the same state of development than Atlantic sturgeons, at least through 60 mm SL (Table 7; Figures 2–7, 9).

The size difference at hatching was corroborated by recent hatchery experiments. For Atlantic sturgeons incubated at a mean temperature of 18°C, Smith et al. (1980) reported hatching in 5–6 d at a mean of 7.1 mm TL (1.9 mm SE). For shortnose sturgeons reared at 17°C, Buckley and Kynard (1981) reported hatching in 8 d at 9.5 mm TL. Dadswell et al. (1984) reported that Washburn and Gillis Associates (Fredericton, New Brunswick) reared shortnose sturgeons and observed hatching sizes of 7.3–11.3 mm, but that no specimens less than 8.0 mm survived. Taubert and Dadswell (1980) measured newly hatched (within 2 to 3 d) shortnose sturgeons collected from the Connecticut River at 8.0–12.5 mm TL.

Contrary to other observations of hatching size, Ryder (1890) reported that reared Atlantic sturgeons hatched at 11 mm TL. He illustrated a just-hatched specimen reported to measure 11.5 mm TL (Ryder's Figure 18). From total length and the concave shape of the dorsal fin fold, the illustrated specimen appears more typical of a recently hatched shortnose sturgeon. However, no other evidence in Ryder's report suggests that he might have reared shortnose sturgeons. For example, the diameter he reported for deposited unfertilized eggs, 2.6 mm, is consistent with observations for Atlantic sturgeons by Smith et al. (1980), 2–3 mm for unfertilized eggs, and by Jones et al. (1978), 2.0–2.9 mm for fertilized eggs. Shortnose sturgeon eggs are larger: Dadswell et al. (1984) and Buckley and Kynard (1981) reported diameters of 3.0–3.2 for ripe eggs and 3.5 mm for fertilized eggs, respectively. Yet, the hatching size Ryder reported is 2–5 mm larger than Smith et al. (1980) and I observed for Atlantic sturgeons, 1.5 mm larger than Buckley and Kynard (1981) reported for shortnose sturgeons, and at the upper end of the ranges Taubert and Dadswell (1980) and I observed for shortnose sturgeons. The hatching size reported by Ryder might have been an error. However, Ryder's emphasis on the size of his specimens relative to that of recently hatched *Acipenser ruthenus* suggests that he would have been particularly careful about this measurement. Vladykov and Greeley's (1963) remark that Atlantic sturgeons hatch at 11 mm was

TABLE 7.—Size (standard length, SL) and age at apparent onset of selected developmental events for shortnose sturgeon and Atlantic sturgeon, based on original observations at low-power magnification except as footnoted. Age from hatching is based on specimens reared at the Orangeburg National Fish Hatchery and might differ from similar observations on fish reared under other conditions. Observations on mesolarvae were limited and often size or age or both are reported only as greater than or less than that of available specimens. Rare or questionable values are enclosed in parentheses.

Developmental event	Shortnose sturgeon		Atlantic sturgeon	
	Size (mm SL)	Age (d)	Size (mm SL)	Age (d)
Hatching	(8[a])9–10(11)	0	(6)7–9(11[b])	0
Eyes pigmented	11–12(13[a])	1–3	10(11)	>1, 4
Pectoral bud formed	Prehatch	Prehatch	6, prehatch	0, prehatch
Pelvic bud formed	(11)12	3–4	10–11(12[c])	>1, 4
All yolk absorbed[d]	(13)14(15[a])	6	13(14[c])	6–7
All fin fold absorbed	~57	>30	>58, <67	~100
		First element(s) present		
Fin ray supports				
Dorsal	11–(12)	1–3–(5)	10–11(12[c])	>1, 4
Anal	12–13	4–8	10–11	>1, 4
Caudal	>21, 24	>21, <25	20–21	>13, <29
Pectoral	(12)–14(15)	6–(8)	12–(13)	4–5
Pelvic	15–16	7–10	12	4–5
Fin rays				
Dorsal	>21, <24	>21, <25	>19[c], <29	>13, <29
Anal	34–37	>30	29–32	~29
Caudal	>24, <34	>30	>21, <29	>13, <29
Pectoral	>21, <24	>21, <25	(17)19[c], <29	(12)>13, <29
Pelvic	>24, <34	>30	>21, <29	>13, <29
Scute series				
Dorsal	>21, <24	>21, <25	>17, <20	>13, <29
Lateral	>21, <24	>21, <25	20–21	>13, <29
Ventral	>21, <24	>21, <25	>21, <29	>13, <29
		Full complement present		
Fin ray supports				
Dorsal	(13)14–15	6–8	11–12	4
Anal	16–17	9	12–13	4–5
Caudal	>24, <34	>30	29–30	29
Pectoral	15	7–9	13–16	5–9
Pelvic	16–17	9–10	13–14	5–7
Fin rays				
Dorsal	>51, 57	>30	~29–30	~29
Anal	57	>30	>39, <47	>29, <100
Caudal	>57	>30	>116, <136	120
Pectoral	~36–37[e]	>30[e]	(30)~39–47[e]	>29, <100[e]
Pelvic	>41, <51	>30	>47, <58	>29, <100
Scute series				
Dorsal	>21, <24	>21, <25	20–21	>13, <29
Lateral	>41, <51	>30	>32, <39	~29
Ventral	>24, <34	>30	>21, <29	>13, <29

[a]Data modified or extended according to observations by Taubert and Dadswell (1980).
[b]Reported by Ryder (1890); inconsistent with other observations.
[c]Data modified or extended according to observations by Bath et al. (1981).
[d]Obvious yolk. Some yolk is probably retained in larger specimens but would require dissection to detect.
[e]Adult complement might not be acquired until larvae are larger and older.

not documented as to source but was probably based on Ryder (1890).

My observations on size at the onset of selected developmental events generally agree with those of Taubert and Dadswell (1980) and Bath et al. (1981). Among the differences incorporated in Table 7, Taubert and Dadswell (1980) reported that shortnose sturgeons acquire eye pigment and complete yolk absorption at larger sizes. Also, Bath et al. (1981) reported that Atlantic sturgeon larvae acquired pelvic fin buds and complete absorption of yolk at larger sizes and acquired first dorsal fin rays at smaller sizes than I observed.

Both Pekovitch (1979) and Taubert and Dadswell (1980) mistook median fin pterygiophores or basal structures (as in Figures 3–7) for incipient fin rays (see dorsal fins in Figure 7). The misrepresented fin ray counts were reiterated in a table

of morphological and meristic parameters by Dadswell et al. (1984). Based on this misinterpretation of fin structure, Taubert and Dadswell (1980) also referred to 13–15-mm-TL shortnose sturgeons as mesolarvae, a developmental state not attained until the first median fin rays actually appear between 21 and 24 mm SL (Table 7).

In another instance of misapplication of developmental phase terminology, Bath et al. (1981) referred to 31.5–37-mm-TL Atlantic sturgeons as prejuveniles. However, the prejuvenile phase requires possession of the adult complement of fin rays in all fins (Mansueti and Hardy 1967). It is unlikely that the full complement of fin rays is present in any but the dorsal and possibly pectoral fins of specimens less than 40 mm TL (Table 7).

By 57 to 67 mm, both species have met all criteria for transition to the juvenile period (Snyder 1976, 1983) except attainment of the adult complement of caudal fin rays (Table 7). A full complement of caudal fin rays does not occur on Atlantic sturgeons until nearly twice that size (greater than 116 mm SL) but might be achieved by shortnose sturgeons at a much smaller size. Both species remain mesolarvae until the juvenile period; by definition, they do not pass through the metalarval phase typical of teleosts.

Pigmentation

Although pigmentation is similar for recently hatched protolarvae of both species (Figures 2, 9), it is the most obvious diagnostic character for confidently segregating all shortnose and Atlantic sturgeon larvae more than (and sometimes equal to) 12 mm SL (Figures 3–8). The ventral surface of the abdomen of shortnose sturgeon larvae, at and below the level of the pectoral fins or fin buds, is white (practically no melanophore pigmentation). This includes the ventral surface of the pectoral fin and later the ventral series of scutes. On Atlantic sturgeon larvae with partially assimilated yolk, melanophores cover the ventrolateral surfaces of the abdomen and the base of the pectoral fin. After the obvious yolk supply is exhausted, melanophores rapidly spread over most of the ventral surface of the abdomen, pectoral fins, and gill covers. As Atlantic sturgeons grow beyond 30 to 40 mm, melanophores on the ventral abdomen become more widely spaced. The surface becomes quite pale but remains at least sparsely pigmented with a uniform speckling of melanophores, even on specimens as large as 136 mm SL. The appearance of pigmentation (density and degree of melanophore expansion) can vary considerably on both species (compare Figure 5, bottom, with Figure 8), but the specific generalized pattern of distribution is consistent at least through the larval period. Scott and Crossman (1973) and Vladykov and Greeley (1963) described adults of both species as white on the ventral surface of the body.

As a diagnostic character for identifying protolarvae without yolk and mesolarvae, abdominal pigmentation was overlooked or unspecified in previous descriptions. Pekovitch (1979) noted that for 16–18-mm-TL shortnose sturgeon, "pigmentation was absent ventrally from the mouth to the anus. . . ." However, his three-view drawings of 16- and 32-mm shortnose sturgeons do not clearly illustrate the white ventral surface and might be misleading because pigmentation cannot be readily distinguished from dot-pattern shading that covers all surfaces. Taubert and Dadswell (1980) also noted that shortnose sturgeon larvae, 13–15 mm TL, had a "light ventrum", but Bath et al. (1981) made no mention of ventral pigmentation. Still, lateral-view photographs of both species in Bath et al. (1981) and of shortnose sturgeons in Taubert and Dadswell (1980) illustrate the difference in ventrolateral pigmentation. A lateral-view photograph in Buckley and Kynard (1981) also illustrates the distinctly white ventrolateral surface of shortnose sturgeon mesolarvae. Finally, Dovel and Berggren (1983) noted that there are differences in pigmentation but did not elaborate on the nature of these differences and suggested the character could be confusing. However, the ventral-view photographs of both species in Dovel (1979) and Dovel and Berggren (1983) clearly illustrate the differences.

Correlation with Capture Date and Location

In at least some cases, identity of recently hatched sturgeon larvae can be corroborated with information on date and location of capture. Depending on the specific river system, shortnose sturgeons usually begin spawning about a month earlier, have a shorter spawning period, spawn at cooler water temperatures (9–15°C versus 13–18°C), and, in some rivers, use more upstream locations for spawning than Atlantic sturgeons (Borodin 1925; Vladykov and Greeley 1963; Scott and Crossman 1973; Jones et al. 1978; Dadswell 1979; Taubert 1980; Bath et al. 1981; Dovel and Berggren 1983; Dadswell et al. 1984).

The value of capture date and location for

identification of larvae in the Hudson River was documented by Bath et al. (1981). Using primarily mouth width characters, they identified shortnose sturgeon protolarvae without yolk only in collections from an upstream, freshwater portion of the river at river kilometer 235 (near Albany) during May and similar-size Atlantic sturgeons only in downstream collections from oligohaline waters from km 64 to 106 (Stony Point to Chelsa) during June and July. Based on these results and other information on species distributions, movements, and probable spawning seasons and grounds in the Hudson River, they tentatively identified yolk-bearing larvae collected in the oligohaline portion of the river from km 60 to 126 (Haverstraw to Hyde Park) during June and July as Atlantic sturgeons.

Recently hatched protolarvae from the Savannah River also were segregated by collection date (Figure 9). All those suspected to be shortnose sturgeons, based on larger size relative to state of development and, in some cases, dorsal finfold depth and shape, were collected in March of 1982 and 1983 at river temperatures usually between 11 and 13°C. Those suspected to be Atlantic sturgeons were taken, with one exception, in April and May at river temperatures usually between 15 and 22°C. The single exception was a specimen captured in August at 21°C. Based on observations of running-ripe fish in the Savannah and other rivers in South Carolina, there appeared to be a second population of Atlantic sturgeon that spawns in August to October (Smith, personal communication). Unlike sturgeon larvae in the Hudson River, recently hatched larvae of both species were collected in the same portions of the Savannah River, mostly adjacent to the Savannah River Plant (km 242 to 253), but some were taken as far downstream as Porter's Landing (km 113) (Paller et al. 1984; note that in their Table 2–22, the larva collected on March 29, 1983, should be listed as shortnose sturgeons, not Atlantic sturgeons).

Conclusions

Although larval development is similar for both species, shortnose sturgeon larvae at a given developmental state are usually larger than Atlantic sturgeon larvae, at least through 60 mm SL. Both species absorb most of their yolk by 13 or 14 mm SL and remain protolarvae until the first median fin rays appear in the dorsal fin between 19 and 24 mm SL. By 60–70 mm SL, all fin fold is lost and, if one assumes that ray formation in the pectoral fins is complete, the adult complement of fin rays is present in all but the caudal fin. As a result, the metalarval phase typical of teleosts is eclipsed. Transition from the mesolarval phase to the juvenile period occurs when the adult complement of caudal rays is acquired, probably between 116 and 136 mm SL for Atlantic sturgeons and possibly at a smaller size for shortnose sturgeons.

Morphological criteria for separation of recently hatched sturgeon larvae consist of size relative to state of development and depth and shape of the dorsal fin fold. However, these criteria might not be conclusive, and identities based on them should be considered tentative. Shortnose sturgeons hatch at a larger size than Atlantic sturgeons, usually at 9–10 mm SL (full range, 8–11 mm SL) versus 7–9 mm SL (full range, 6–9 mm SL exclusive of one questionable report of 11 mm TL). The anterior portion of the dorsal fin fold of yolk-bearing shortnose sturgeon protolarvae is often slightly concave in shape and shallower than the typically convex fin fold of Atlantic sturgeons. Specimens measuring 8–12 mm SL with a dorsal fin fold about a third or less of body depth (excluding fin folds) at the future origin of the pelvic fin buds (about two-thirds the distance from yolk sac to vent) are shortnose sturgeons. Specimens with dorsal finfold depths greater than a third of body depth could be either species. Many sturgeon larvae approaching yolk depletion can be identified on the basis of ventrolateral pigmentation, inter–lip-lobe distance, or both.

Suspected identity of recently hatched larvae should be corroborated with information on the date and, in some cases, location of capture. Shortnose sturgeons typically begin spawning about a month earlier and, in some rivers, much farther upstream than Atlantic sturgeons.

After the yolk is consumed, Atlantic sturgeon larvae are easily distinguished from shortnose sturgeons (barring possible hybrids) by the presence of melanophore pigmentation on the ventrolateral to ventral surfaces of the abdomen and an inter–lip-lobe distance less than 20% of mouth width (lips included). Shortnose sturgeon larvae are white (with almost no melanophores) on the ventrolateral and ventral surfaces of the abdomen and have an inter–lip-lobe distance greater than 25% of mouth width.

Although not as definitive as the above characters, mouth width (including lips) is diagnostic for specimens over 14 mm SL. For protolarvae, mouth width as a percentage of head width,

measured in line with the mouth, is greater than 65% (66–88%) for shortnose sturgeons and less than 66% (57–65%) for Atlantic sturgeons. For mesolarvae, the same criteria are greater than 60% (62–74%) and less than 60% (56–59%), respectively.

The number of pelvic fin rays and, to a lesser extent, number of anal fin rays are also diagnostic for larvae over 50–60 mm SL. Pelvic fin ray counts are 17–22 for shortnose sturgeons and 26–33 for Atlantic sturgeons. Anal ray counts are 18–24 and 23–30, respectively.

The most diagnostic morphometric and meristic characters for mesolarvae of shortnose sturgeons and Atlantic sturgeons should be equally definitive and obvious for distinguishing juvenile and adult specimens. In particular, inter–lip-lobe distance relative to mouth width (specific percentages might differ) and pelvic ray counts should be considered as supplements or alternatives to primary characters used in recent keys (e.g., Vladykov and Greeley 1963; Moore 1968; Scott and Crossman 1973; Dadswell et al. 1984).

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