DEVELOPMENT AND EARLY LIFE HISTORY OF THE NORTHERN SENNET, *Sphyraena borealis* DeKAY (PISCES: SPHYRAENIDAE) REARED IN THE LABORATORY[1, 2]

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ABSTRACT

Eggs and larvae of the northern sennet, *Sphyraena borealis* DeKay, are described from laboratory-reared specimens. Fertilized eggs were collected on the edge of the Florida Current near Miami in December 1969. Larvae were 2.6 mm SL (standard length) at hatching and 13.5 mm SL at 21 days after hatching. Head and snout length increased rapidly relative to standard length as larvae grew. A fleshy tip developed on the lower jaw when larvae were longer than 5 mm SL. Teeth also first appeared at about 5 mm SL. Myomere and vertebral numbers were constant at 24. Ossification of the axial skeleton began in the cephalic region and proceeded caudad as growth occurred. Fin ray complements were complete at about 13.5 mm SL. Pigmentation during development is described and illustrated. Behavior of laboratory-reared *S. borealis* larvae is discussed. Several wild-caught post-larvae were used to extend the descriptive series and helped to validate the identification of the laboratory-reared larvae.

Little is known about early development of barracudas (Sphyraenidae) in the Western Atlantic Ocean. Larvae of the northern sennet (also called northern barracuda), *Sphyraena borealis* DeKay, recently were reared in the laboratory, and the eggs, yolk-sac larvae, and early post-larval stages are described in this report from a series of preserved specimens, providing the first description of this species in its earliest life stages. De Sylva (1963) described some post-larval *S. borealis* and presented keys to identify the postlarvae of western North Atlantic sphyraenids longer than 5.5 mm SL (standard length).

Some confusion exists regarding the systematic relation of *S. borealis* and the similar *S. picudilla* Poey (southern sennet). The two species are regarded by de Sylva (personal communication) as valid species, separable on minor morphometric characters in adults. Briggs (1958) reported *S. borealis* to be distributed nearshore from Bermuda and Massachusetts to Panama, including the north central Gulf of Mexico. Adults of *S. borealis* from southern Florida intergrade in many characters toward those of *S. picudilla* (de Sylva, personal communication). Postlarvae reared in the laboratory during this study always closely resembled the *S. borealis* described by de Sylva (1963).

The eggs and yolk-sac larvae of *Sphyraena argentea* Girard from the eastern Pacific were described by Barnhart (1927). Orton (1955) also described *S. argentea* eggs and yolk-sac larvae as well as older larvae of about 4 and 7 mm TL (total length). Eggs and young larvae of *S. pinguis* Günther from the western Pacific were described by Shojima, Fujita, and Uchida (1957), and their development was reviewed by Uchida et al. (1958). Development of *S. sphyraena* Linnaeus collected in the Mediterranean was summarized by Vialli (1956), and illustrations of some stages were presented by Lo Bianco (1956). Development of *S. barracuda* (Walbaum), commencing with postlarval stages, was discussed by de Sylva (1963). Except for the material on *S. sphyraena,* complete developmental series appear to be lacking for barracudas. My specimens of *S. borealis* provide a

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complete series of egg and larval development of this species. In addition to the reared specimens, some postlarvae and juveniles of *S. borealis* were collected in nets, helping to extend the series beyond the lengths of the longest specimens reared in the laboratory.

MATERIALS AND METHODS

REARING TECHNIQUES

Pelagic eggs of *S. borealis* were collected in a 1-m, 505-μ mesh plankton net at the sea surface in the Florida Current, about 8 km east of Miami Beach on December 11, 1969, at 10:00 AM EST. Surface temperature was 23.6° C at time of collection. A total of 78 eggs were isolated from the catch. They were incubated and the larvae reared in a 55-liter aquarium. Temperature ranged from 23.2° to 24.5° C and salinity from 33.0 to 34.6‰ during the experiment. Larvae were fed zooplankton collected from Biscayne Bay and nauplii of brine shrimp (*Artemia salina*). Some pelagic fish eggs were added to the rearing tank beginning the 7th day after hatching to provide newly hatched fish larvae as a food source for the sennets. Constant illumination was provided to allow the larvae to feed continuously, both by day and night. Many details of methods used to rear fish larvae were described by Houde and Palko (1970).

PRESERVATION OF LARVAE

Only a small series of eggs and larvae were obtained during development because of the small number (78) of eggs available. Two eggs and 18 larvae were preserved in 5% buffered Formalin during the 23 days of the rearing experiment.

WILD-CAUGHT POSTLARVAE AND JUVENILES

Plankton collections in the Florida Current near Miami Beach between January 13 and January 27, 1970, provided 10 postlarval and young juvenile specimens of *S. borealis* from 7.4 to 30.6 mm SL. In addition, two juveniles, 59.6 and 62.9 mm SL, were collected from Biscayne Bay in a 20-ft beach seine in January 1970. These wild-caught specimens provided data to extend the descriptive series and helped to validate the identification of the laboratory-reared larvae as *S. borealis*.

MERISTICS AND MORPHOMETRICS

Fin rays and spines were enumerated for each of the fins. Myomeres (preanal plus postanal) were counted on each larva when they could be distinguished.

The following measurements were made:

Total length (TL): tip of snout to tip of caudal fin.

Standard length (SL): tip of snout to tip of notochord or, in more developed larvae, to base of caudal rays.

Body depth: height of body, exclusive of finfold, at base of pectoral fin.

Head length: tip of snout to posterior margin of otic capsules in yolk-sac larvae and tip of snout to opercular margin in postlarvae.

Snout length: tip of snout to anterior margin of the fleshy orbit.

Preanal length: tip of snout along midline to vertical from anus.

Eye diameter: horizontal distance from anterior to posterior margin of the fleshy orbit.

Tip of lower jaw: length of fleshy extension on tip of lower jaw.

1st predorsal length: tip of snout to anterior insertion of spinous dorsal fin, measured along the body midline.

2nd predorsal length: tip of snout to anterior insertion of second dorsal fin, measured along the body midline.

All counts and measurements were made using a binocular dissecting microscope and ocular micrometer.

OSTEOLOGY

Six larvae, 7.4 to 17.0 mm SL, were cleared with trypsin and stained with alizarin (Taylor, 1967) to determine the sequence of ossification and to accurately assess the lengths at which fin

rays first develop. A complete study of osteology was not undertaken, but development of teeth and caudal skeleton were examined in detail.

DEVELOPMENT

EMBRYO

Two preserved eggs of *S. borealis* were 1.22 and 1.24 mm diameter. They had single, clear yellow oil globules 0.27 and 0.29 mm diameter. The perivitelline space was narrow and the transparent yolk was vaguely segmented. In eggs that I preserved about 2 hr after collection, the embryo was not well developed and no pigment was visible (Figure 1A). Later stage embryos developed both melanophores and xanthophores on the body, giving the living embryo a greenish appearance to the naked eye. The eggs hatched about 20 hr after collection at an incubation temperature of 24° C.

MORPHOLOGY OF LARVAE AND JUVENILES

Larvae of *S. borealis* were 2.6 mm SL at hatching and were robust due to the large yolk sac (Figure 1B) but became characteristically slender after its absorption (Figures 2 and 3). Body depth averaged 12% SL for larvae from immediately after yolk absorption to juveniles of 21.0 mm SL. Gut length was moderately long in *S. borealis* larvae. Jaws were not elongated on newly hatched larvae but became so shortly after the yolk sac was absorbed and mouth parts became functional. Growth in length of laboratory-reared larvae is given in Figure 4.

Yolk Absorption

The yolk sac was large and nearly spherical at hatching, with its oil globule at the anterior end (Figure 1B). Some yolk and the oil globule remained up to 4 days after hatching (Figures 2A and 2B). Feeding began shortly before the yolk was completely absorbed.

Head Length

The head of recently hatched *S. borealis* was short (Figures 1 and 2), but increased rapidly in length as larvae developed. Head length increased relative to body length from 13% SL for newly hatched larvae to a constant value of about 33% SL for larvae 9 mm SL and longer (Table 1). Over half the head length increase was related to an increase in length of the snout during development.

Snout Length

Snout length increased on developing larvae from about 3% SL 1 day after hatching to a value of about 12% SL at 9 mm and gradually to 14% SL for juveniles (Table 1).

Tip of Lower Jaw

A fleshy tip began to develop on the lower jaw at about 5.0 mm SL (Table 1). Its relative length increased from less than 1% SL to about 3% SL when larvae had grown to 14.5 mm SL (Figures 2 and 3). The structure ranged from 3 to 6% SL on 17 to 30 mm SL wild-caught specimens. On two juveniles, 59.6 and 62.9 mm SL, the length of the fleshy tip was only 3% SL. The length of this structure on both laboratory-reared and wild-caught specimens varied rather markedly.

Jaws and Teeth

The mouth was not developed until larvae were 4.0 mm SL, about 3 days after hatching (Figure 2B). Teeth first appeared on the premaxillary bones at 5.3 mm SL when the jaws became barracuda-like (Figures 2C and 2D). Initially, the teeth appeared bluntly conical but became caninelike when larvae grew to 7.0 mm SL. Teeth were developed on the lower jaw and were developing on the palatine bones at 7.4 mm SL. The palatine bones on larvae longer than 12 mm SL bore the largest teeth, except for the second and third pairs of premaxillary teeth; these were long and directed posteriorly. All

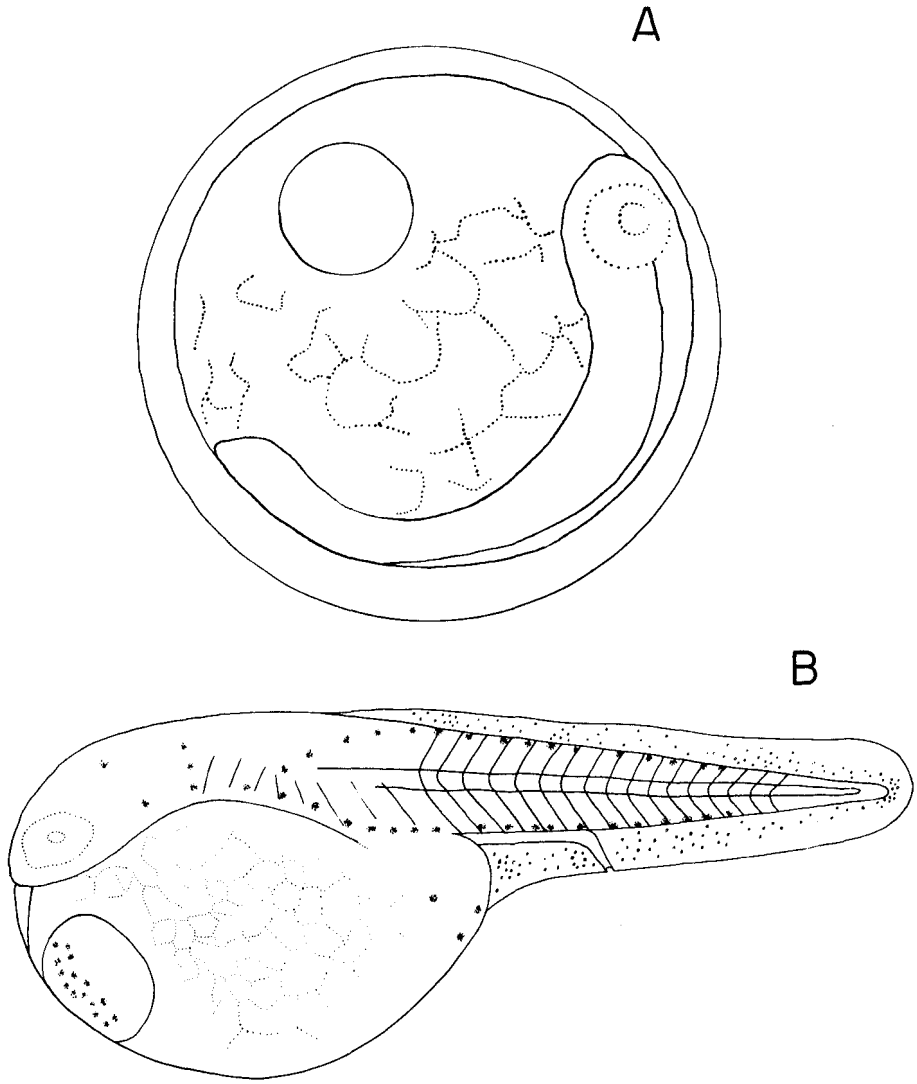

FIGURE 1.—Embryo and newly hatched larva of *Sphyraena borealis*. A. Embryo; B. Newly hatched larva, 2.6 mm SL. Inclusions in the finfold are not pigment.

teeth were strong and caninelike; most were slightly curved and directed backward at their tips. The number of premaxillary teeth increased from 4 at 5.3 mm SL to about 20 at 21.5 mm SL. Lower jaw teeth increased from 11 at 9.4 mm SL to about 15 on specimens from 12.1 to 21.5 mm SL. Palatine teeth numbered 6 at 9.4 mm SL and increased to about 10 at 21.5 mm SL.

Eye Diameter

Eye diameter decreased slightly, from 8% SL on newly hatched larvae to 7% SL for most individuals longer than 16.9 mm SL (Table 1).

Myomeres

The number of myomeres was constant at 24 (14 preanal plus 10 postanal) throughout development.

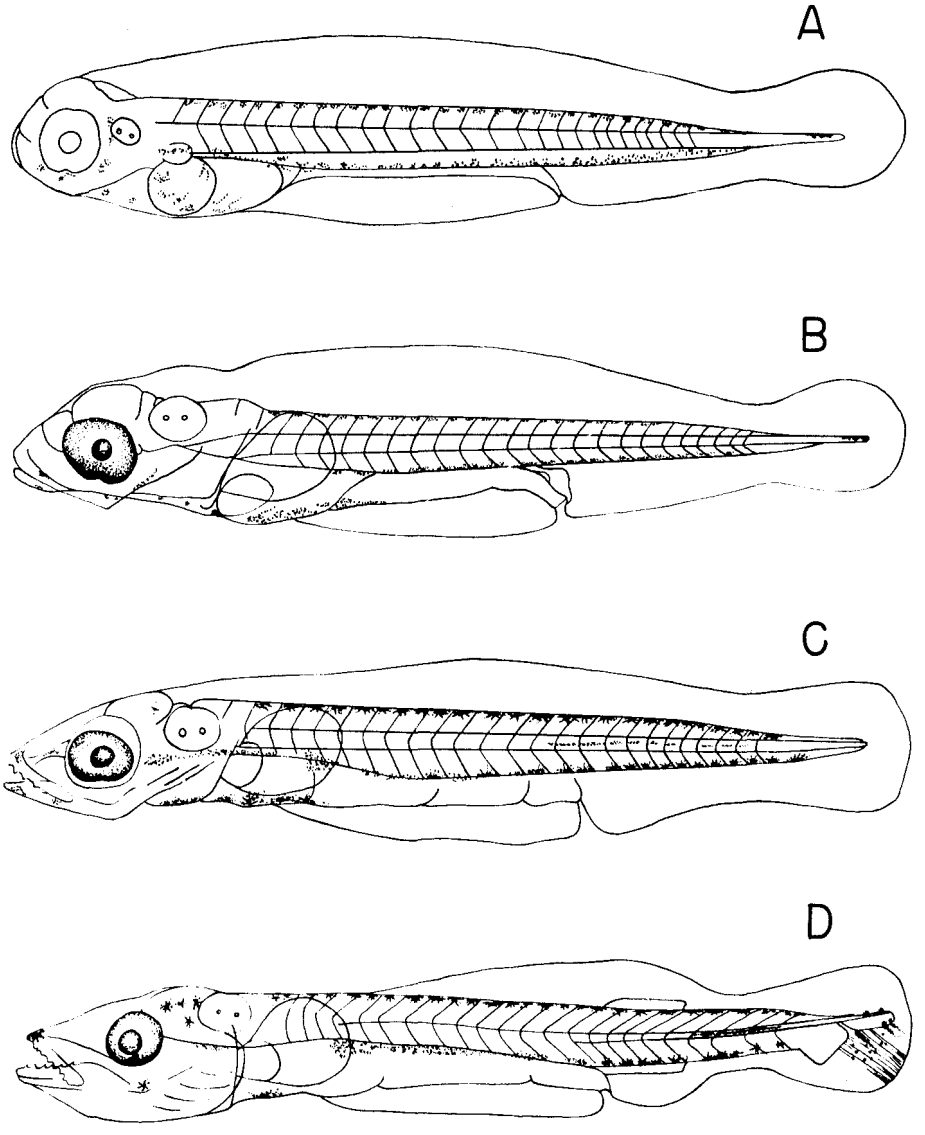

FIGURE 2.—Developmental stages of *Sphyraena borealis* reared in the laboratory. A. 3.8 mm SL; B. 4.3 mm SL; C. 5.3 mm SL; D. 7.4 mm SL.

Keeled Scales

Keeled scales appeared along the lateral line on the caudal peduncle when specimens were about 14.5 mm SL (Figure 3C).

Osteology

Ossification of the axial skeleton proceeded from the cephalic region caudad as growth occurred. A 7.4-mm SL specimen appeared to have nearly complete skeletal development of the head region, but little development posteriorly. Vertebral development was restricted to incomplete neural and haemal arches in the 7.4-mm SL larva. Centra were forming in a 9.1-mm SL larva and appeared to be completely developed

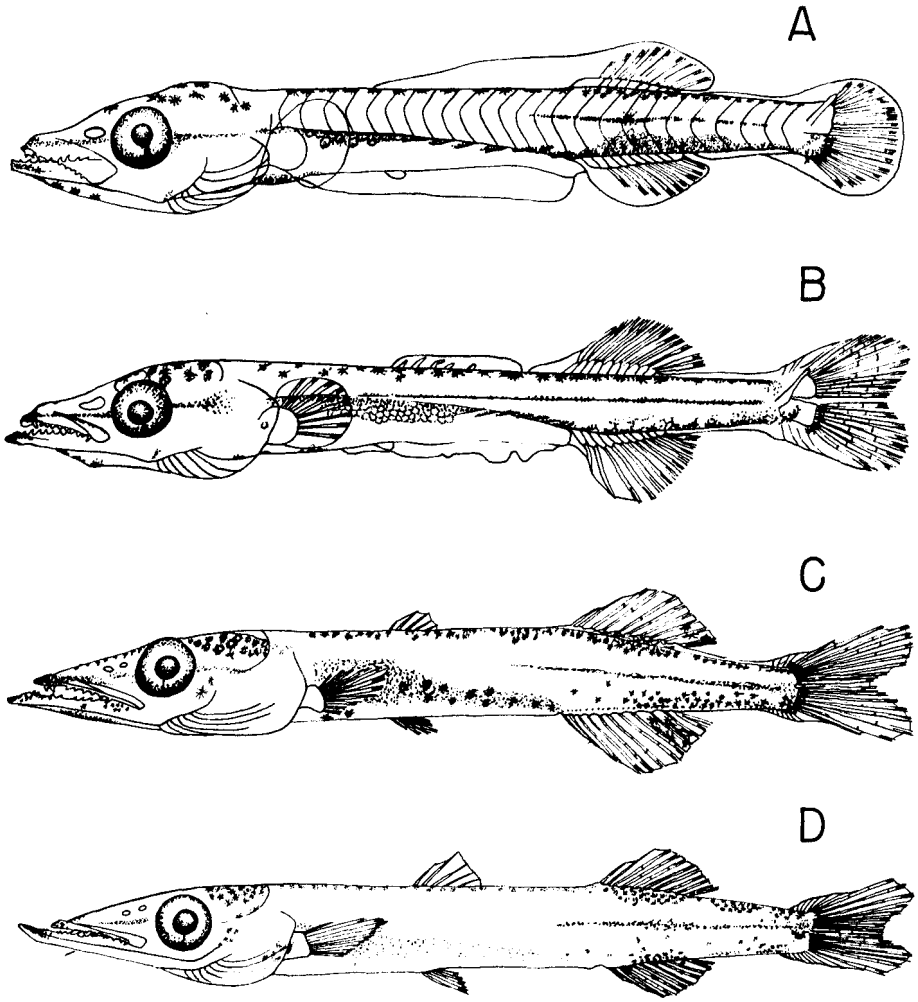

FIGURE 3.—Developmental stages of *Sphyraena borealis*. Specimens A, B, and C were laboratory reared; specimen D was collected in a plankton net. A. 9.4 mm SL; B. 12.3 mm SL; C. 14.5 mm SL; D. 21.0 mm SL.

in a 10.9-mm SL larva. All specimens had 24 vertebrae.

Six branchiostegals were present on the 7.4-mm SL larva and a seventh had developed on the 9.1-mm SL specimen. Cleithra were present but poorly ossified at 7.4 SL; they were well developed at 9.1 mm SL.

Ossification of the caudal region began at 7.4-mm SL. At this size, the hypural bones were developing and some rays could be distinguished in the ventral half of the caudal finfold. All caudal elements were beginning to develop by 10.9 mm SL and were easily recognized on a 12.1-mm SL specimen. The last three vertebrae (including the urostyle) contributed to support of the caudal fin; both neural and haemal spines of the antepenultimate vertebra (22nd) supported developing accessory rays of the caudal fin, as did the haemal spine of the penultimate (23rd) vertebra. A total of 6 hypural bones

TABLE 1.—Summary of morphometric data from laboratory-reared (L) larvae and from wild-caught (W) larvae and juveniles of *Sphyraena borealis*. (Specimens between broken lines are undergoing notochord flexion.) Except for total and standard lengths, measurements are proportional values, the ratio of the character relative to standard length.

Specimen No.	Total length	Standard length	Preanal length	1st predorsal length	2nd predorsal length	Head length	Snout length	Tip lower jaw	Eye diameter
	mm	*mm*							
3 (L)	2.6	2.6	0.68	--	--	0.13	--	--	--
4 (L)	4.0	3.8	.66	--	--	.14	0.03	--	0.08
5 (L)	4.2	4.1	.63	--	--	.19	.04	--	.08
7 (L)	4.3	4.2	.56	--	--	.19	.04	--	.08
6 (L)	4.5	4.3	.66	--	--	.21	.05	--	.08
9 (L)	5.2	5.0	.65	--	--	.26	.07	<0.01	.08
10 (L)	5.5	5.3	.67	--	--	.26	.07	<.01	.08
8 (L)	5.8	5.6	.68	--	--	.27	.08	<.01	.07
11 (L)	7.7	7.4	.66	--	--	.28	.10	<.01	.07
27 (W)	7.9	7.4	.71	--	--	.30	.12	.02	.08
12 (L)	9.5	9.0	.69	--	0.67	.31	.12	.01	.08
13 (L)	10.2	9.4	.70	--	.68	.32	.13	<.01	.09
14 (L)	12.2	10.9	.70	--	.68	.33	.14	.02	.08
17 (L)	12.9	11.3	.71	0.50	.70	.36	.12	--	.08
15 (L)	13.4	11.9	.69	--	.68	.31	.13	.02	.08
18 (L)	13.7	12.1	.69	.44	.68	.33	.12	.01	.08
16 (L)	13.7	12.3	.66	.44	.66	.32	.13	.03	.08
19 (L)	14.7	12.7	.68	.47	.70	.34	.13	.02	.08
24 (W)	15.9	13.7	.72	.49	.71	.32	.12	.05	.07
23 (W)	16.5	14.4	.72	.48	.70	.36	.15	.04	.08
20 (L)	16.7	14.5	.63	.47	.71	.35	.14	.03	.08
28 (W)	19.4	16.9	.70	.47	.70	.33	.14	.04	.07
26 (W)	19.1	17.0	.69	.48	.70	.32	.14	.04	.06
30 (W)	19.7	17.1	.70	.46	.70	.32	.13	.04	.06
29 (W)	21.2	18.4	.70	.47	.70	.33	.14	.05	.07
21 (W)	24.2	21.0	.71	.49	.72	.34	.15	.06	.08
25 (W)	24.6	21.5	.70	.46	.69	.32	.14	.03	.07
22 (W)	33.9	30.6	.70	.46	.70	.32	.14	.06	.07
32 (W)	66.8	59.6	.71	.46	.70	.32	.14	.03	.06
31 (W)	70.0	62.9	.72	.45	.71	.32	.14	.03	.06

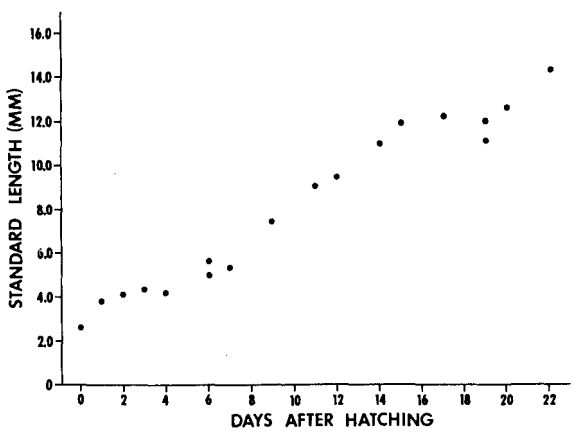

FIGURE 4.—Growth of *Sphyraena borealis* larvae reared in the laboratory at an average temperature of 24.0° C.

were formed near the posteroventral surface of the urostylar vertebra. There were 3 epurals and 2 pairs of uroneurals ossifying dorsal to the urostyle. The 17 principal caudal rays were supported by the hypural bones. Principal caudal ray support was as follows: hypural 1 supported rays 1 to 3; hypural 2 supported rays 4 to 7; hypural 3 supported ray 8; hypural 4 supported rays 9 to 11; hypural 5 supported rays 12 to 15; hypural 6 supported rays 16 and 17. A 17.0-mm SL specimen differed from smaller specimens only in having the first principal caudal ray partially supported by the haemal spine of the penultimate vertebra as well as the first hypural bone. All elements were at least partially ossified at 17.0 mm SL; both the epurals and uroneurals were the most poorly ossified bones of the caudal skeleton at this stage. Hollister (1937) examined caudal skeletons of adult and

TABLE 2.—Summary of meristic data (spines and rays) from laboratory-reared (L) and wild-caught (W) larvae of *Sphyraena borealis*. (Dashes indicate elements were present but could not be accurately counted.)

Specimen No.	Standard length	Principal Caudal rays	Anal fin	2nd dorsal fin	1st dorsal fin	Pelvic fin		Pectoral fin	
						Left	Right	Left	Right
	mm								
3 (L)	2.6	0	0	0	0	0	0	0	0
4 (L)	3.8	0	0	0	0	0	0	0	0
5 (L)	4.1	0	0	0	0	0	0	0	0
7 (L)	4.2	0	0	0	0	0	0	0	0
6 (L)	4.3	0	0	0	0	0	0	0	0
9 (L)	5.0	0	0	0	0	0	0	0	0
10 (L)	5.3	0	0	0	0	0	0	0	0
8 (L)	5.6	0	0	0	0	0	0	0	0
27 (W)	7.4	0	0	0	0	0	0	0	0
11 (L)	7.4	7	0	0	0	0	0	0	0
12 (L)	9.0	16	8	8	0	0	0	0	0
13 (L)	9.4	16	9	9	0	0	0	0	0
14 (L)	10.9	17	10	10	3	0	0	0	0
17 (L)	11.3	17	11	10	5	5	--	8	6
15 (L)	11.9	17	11	10	3	--	--	--	--
18 (L)	12.1	17	11	10	5	--	--	8	8
16 (L)	12.3	17	11	10	4	5	--	8	6
19 (L)	12.7	17	10	10	5	--	--	10	--
24 (W)	13.7	16	11	10	--	5	--	12	12
23 (W)	14.4	17	--	10	5	5	6	--	12
20 (L)	14.5	17	11	10	5	--	6	12	10
28 (W)	16.9	17	11	10	--	--	--	--	--
26 (W)	17.0	17	11	10	5	6	6	11	12
30 (W)	17.1	17	10	10	5	--	--	--	--
29 (W)	18.4	17	11	10	--	--	--	--	--
21 (W)	21.0	17	11	10	--	--	--	--	--
25 (W)	21.5	16	11	10	5	6	6	12	12
22 (W)	30.6	17	11	10	5	6	6	12	12

juvenile *S. borealis*, *S. picudilla*, and *S. barracuda*. She found that all were similar and showed that a progressive fusion of caudal elements occurred in barracudas as they grew. Fusion of hypurals 2 and 3, 4 and 5, and of the urostyle with hypural bones was apparent in her large specimens.

Fin Development

Newly hatched larvae had a prominent larval finfold (Figures 1 and 2) that appeared granular because of many bubbles or small inclusions distributed throughout. These inclusions were not illustrated, except in the newly hatched larva (Figure 1B), but were present until larvae grew to about 9.5 mm SL.

Fin ray development essentially was completed at 13.5 mm SL (Table 2). Fan-shaped pectoral fins without rays developed at 3.8 mm SL 1 day after hatching (Figure 2A). Rayed fins developed in the following sequence: caudal, anal and second dorsal, first dorsal, pelvics, and pectorals. The caudal fin rays began to develop at 7.4 mm SL when the notochord started to flex (Figure 2D). All 17 principal caudal rays were present on a 10.9-mm SL larva. Accessory caudal rays (raylets) also were developing at 10.9 mm SL. Their number varied from 6 to 8 dorsally and 6 to 9 ventrally on specimens up to 30.6 mm SL. The anal and second dorsal fins were represented only by opaque areas in the finfold at 7.4 mm SL, but rays of these fins were developing at 9.0 mm SL; posteriormost rays developed before the more anterior rays and 9 rays were present in each fin at 9.4 mm SL (Figure 3A). A full complement of 2nd dorsal (I, 9) and anal (I, 9 or 10) elements was present at 10.9 mm SL. Spines of the first dorsal fin appeared at 10.9 mm SL and a full complement of 5, located over vertebrae 5 to 7, was present on a 12.1-mm SL larva. The 5 spines were more heavily ossified and located over vertebrae 6 to 8 on a 17.0-mm SL specimen. Pelvic fin buds formed on larvae as small as 9.4 mm SL, but rays did not begin to develop until 11.3 mm SL. Pectoral fin rays also began to develop at this length. All pelvic (I, 5) and pectoral (12) elements were not present on

all larvae until about 13.5 mm SL. Remnants of the larval finfold persisted until 12.5 mm SL (Figure 3B).

Pigmentation

Except where specifically mentioned, references to pigment are to melanophores. Xanthophores were common on larvae, and both silver iridophores and blue chromatophores were present. (See Fujii, 1969, for chromatophore terminology.) Some variations in melanophore patterns were present among *S. borealis* larvae of similar size but the following description gives the typical sequence of development.

Melanophores and xanthophores were present on newly hatched larvae but the latter faded after preservation. Small melanophores were distributed in a dorso-lateral and ventro-lateral row on each side of the larva (Figure 1B). The two rows converged just above the yolk sac and ran anterior as a single row to the posterior cephalic region, joining a series of melanophores located over the hindbrain. Other melanophores were present on the anterior half of the oil globule and near the posterior of the yolk sac.

One to two days after hatching (about 3.8 mm SL), melanophores became larger and more numerous (Figure 2A). Those located in the lateral rows and on the cephalic region became stellate. They were more numerous on the yolk sac and two small melanophores appeared near the developing mouth. A series of two to six small, contracted melanophores were noted near the tip of the notochord. The eye became pigmented at 2 days after hatching.

As larvae developed, both melanophores and xanthophores became more numerous. Xanthophores were distributed over much of the body and consisted of elongate yellow cells forming a loose network on the body. In life, larvae appeared green because of the presence of both yellow and black pigments. Blue iridophores on the hindgut and some iridescent pigment in the eyes also were present.

By 7 days after hatching (about 5.3 mm SL, Figure 2C) stellate melanophores had appeared over the brain, on the tip of the upper jaw, lower jaw, angle of the jaw, ventral margin of the opercular region and over the foregut. Each dorso-lateral row of stellate melanophores was well developed while the ventro-lateral rows were condensing into a single ventro-medial row, posterior to the anus. A mid-lateral series of melanophores was developing posterior to the anus.

At 9 days after hatching (about 7.4 mm SL) pigmentation became more intense (Figure 2D). About 5 melanophores were present in the developing caudal fin. The fleshy tip of the lower jaw began to become darkly pigmented on some specimens at this stage. The extent and intensity of pigmentation continued to increase on older larvae (Figures 3A and 3B). No changes in pattern were observed, except for development of a line of pigment that bisected the eye, and a migration of melanophores from the tip of the developing urostyle to the ventral margin of the hypural plate.

When specimens were 20 to 22 days old (about 12.5 to 14.5 mm SL), the juvenile pattern of dorsal and lateral blocks of pigment began to appear (Figure 3C). Stellate melanophores also developed in the second dorsal and anal fins of individuals of this size. Longer specimens from plankton collections had the typical juvenile pigment pattern (Figure 3C) (cf. de Sylva, 1963; Figure 4).

GROWTH AND MORTALITY

Larvae of *S. borealis* grew most rapidly during the first 14 days after hatching, but more slowly during the next 7 days (Figure 4). Larvae were 2.6 mm SL at hatching, averaged 5.5 mm SL at 7 days after hatching, 11 mm at 14 days, and about 13.5 mm at 21 days. The decrease in growth rate of the sennets during the third week may have been caused by the scarcity of fish larvae in their diet. Average growth rate during the rearing experiment was about 0.5 mm per day.

A total of 78 sennet eggs were incubated but only about 50% hatched. From this small number of hatched larvae, 9 survived until 14 days after hatching, when they had developed most of the characters of juvenile sennets. Mortality in the first 14 days included 11 larvae preserved

for describing larval development. No larvae survived beyond 22 days after hatching, probably because of the inadequate diet.

TRANSFORMATION

Transformation from the larval to the early juvenile stage occurred at about 13.5 mm SL for *S. borealis*. At that size, fin ray development was complete and there were no remnants of the larval finfold. Additional evidence that this size marked the end of the larval period was the occurrence of keeled scales on specimens at 14.5 mm SL and the appearance of juvenile pigment patterns between 12.5 and 14.5 mm SL.

COMPARISONS

Among the four early life history series of barracudas that have been described in the literature, newly hatched larvae of *S. borealis* most closely resemble those of *S. pinguis* from Japanese waters (Shojima et al., 1957; Uchida et al., 1958), except for size at hatching. In both species, the oil globule, at hatching, is located at the anterior end of the yolk mass; neither develop melanophores in the finfold. In contrast, the oil globule is located at the posterior end of the yolk mass in newly hatched larvae of *S. sphyraena* (Vialli, 1956) and *S. argentea* (Orton, 1955) and both have melanophores in the finfold.

Eggs of *S. pinguis* (0.69 to 0.82 mm diameter) were considerably smaller than those of *S. sphyraena* (1.11 to 1.15 mm), *S. borealis* (1.22 to 1.24 mm), and *S. argentea* (about 1.5 mm). It is not surprising that at hatching, larvae of *S. pinguis* were smaller than those of *S. borealis*, measuring 1.75 mm as compared to 2.6 mm. Both species were similarly pigmented at hatching, but differed significantly by 45 and 66 hr. Melanophores were larger and more concentrated in *S. pinguis* larvae than in *S. borealis* at the same stage of development.

Older larvae of *S. borealis* and *S. sphyraena* had similar pigment patterns, but those of *S. sphyraena* had a more developed lower jaw tip. Three-day-old larvae of *S. argentea* from California waters had a distinctive band of melanophores on the tail portion of the body just posterior to the anus that was lacking in *S. borealis*. Postlarvae of *S. barracuda* were described and illustrated by de Sylva (1963). They differ substantially from *S. borealis* in being deeper bodied and having a relatively longer snout. Pigmentation of *S. barracuda* and *S. borealis* larvae between 5.5 and 11.9 mm SL also differs somewhat in its detail.

BEHAVIOR

Newly hatched larvae of *S. borealis* drifted about the rearing tank making only occasional feeble swimming attempts when disturbed. At 2 days after hatching, larvae maintained a horizontal position and began swimming actively with short darting motions. Feeding activity was first observed 3 days after hatching. Sennet larvae usually fed using the *S*-flex behavior previously described for many species of clupeiform larvae (e.g., Rosenthal, 1969; Schumann, 1965). Occasionally, however, a sennet larva would strike at a food organism without first flexing its body and examining the item. Zooplankton organisms less than 100 μ in body width were the initial food of larvae. No stomach analyses were carried out on sennet larvae, but most of the food which was placed in the tank were copepod nauplii and copepodites.

Sennet larvae continued to feed on small zooplankton organisms until 10 days after hatching, even though larger plankton, including fish larvae, and nauplii of brine shrimp were present in the tank beginning 7 days after larvae hatched. At 10 days, large plankton (about 300 to 400 μ body width) was accepted as food, as were some unidentified, newly hatched fish larvae about 2 mm in length. A sennet larva would approach a tiny fish larva, assume an *S*-flex position and dart out at the larva, usually seizing it crosswise. Before swallowing it, a sennet would shake the larva and turn it so that its long axis was parallel to the sennet's alimentary tract. Sennets would swallow fish larvae either head or tail first. Fish larvae were the preferred food of sennets longer than 9 mm SL, but this food was not provided in sufficient quantities to satisfy the sennets. Cannibalism was not observed, but sennets became aggressive toward one an-

other at 11 days after hatching. If size variation had been great or if the sennet larvae had been crowded in the rearing tank, cannibalism likely would have occurred.

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