EARLY DEVELOPMENT OF THE LOPHIID ANGLERFISH, *LOPHIUS GASTROPHYSUS*

YASUNOBU MATSUURA AND NELSON TAKUMI YONEDA[1]

ABSTRACT

Using larval specimens collected in bongo nets in southern Brazilian waters (between lat. 23° and 29°S), early development of the lophiid anglerfish, *Lophius gastrophysus*, is described and compared with other lophiid species. Larval morphology of *L. gastrophysus* is very similar to that of *L. americanus*, having three conspicuous melanophores on the trunk and caudal region, but the former can be easily distinguished from the latter by the presence of two melanophores on the preopercular and suborbital regions and positions of the melanophores on the elongate ventral fin.

The peculiar larvae of *Lophius* have been known since the description of the early developmental stage of *L. americanus* by Agassiz (1882). Their characteristic form with elongate dorsal and ventral fin rays makes them easily identifiable. Of the 25 species of the Lophiidae (Caruso 1981), larvae have been repeatedly described and discussed for *L. piscatorius* (Prince 1891; Williamson 1911; Stiasny 1911; Allen 1917; Lebour 1919, 1925; Bowman 1920; Tåning 1923; Arbault and Boutin 1968; Russel 1976) and for *L. americanus* (Agassiz 1882; Connolly 1920, 1922; Tåning 1923; Berrill 1929; Dahlgren 1928; Procter et al. 1928; Bigelow and Schroeder 1953; Martin and Drewry 1978; Fahay 1983; Pietsch 1984). The larvae of two other species also have been described: *L. budegassa* (Stiasny 1911; Padoa 1956) and *L. litulon* (Tanaka 1916; Mito 1966). There is no literature on larval morphology of *L. gastrophysus*.

During ichthyoplankton surveys along the southern Brazillian coast, many *Lophius* larvae were collected and identified as *L. gastrophysus*. This report gives a detailed comparative description of larval development based on 136 specimens collected during the past 13 years.

MATERIALS AND METHODS

Larval specimens used in this report were obtained from the collections of ichthyoplankton at the Instituto Oceanográfico da Universidade de São Paulo. These samples were collected from the southern Brazillian coast using a 61 cm bongo net following the sampling method of Matsuura (1979) and preserved in 10% Formalin[2] solution. Notochord length (NL) was taken from the tip of the upper jaw to the tip of the notochord. A total of 136 larvae (3.3-15.7 mm NL) of *L. gastrophysus* was used in this study. Specimens were measured with a micrometer in a stereoscopic dissecting microscope and illustrations were made with the aid of a camera lucida.

MORPHOLOGY OF LARVAE

The smallest identified specimens which were collected with plankton nets as free-living forms were about 3.3 mm NL, but they still had a large yolk sac. Fahay (1983) showed that the newly hatched larvae of *L. americanus* was as small as 2.5 mm long, and they were still encased in the egg veils (Fahay[3]). The reported size of newly hatched larvae of *L. piscatorius* was 4.5 mm TL (Lebour 1925).

Since the 3.3 mm larvae were not in perfect condition, we used larger specimens for the morphological description. Preflexion larvae of *L. gastrophysus* have a slender body (Fig. 1A, B, C, D), but they later become robust form (Fig. 1E, F). This change of body shape is partly a result of increase in body depth and partly due to enlargement of subepidermal space (Fig. 1C, D, E, F), which appears, firstly, on the head region and later becomes larger and extends posteriorly, giving the larvae a balloonlike appearance. This subepidermal space consists of transparent, gelatinous connective tissue and is considered an adaptation to planktonic life

[1]Instituto Oceanográfico da Universidade de São Paulo, Butantã, São Paulo 05508, Brasil.

[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

[3]M. P. Fahay, Northeast Fisheries Center Sandy Hook Laboratory, National Marine Fisheries Service, NOAA, Highlands, NJ 07732, pers. commun. July 1985.

Manuscript accepted August 1985.
FISHERY BULLETIN: VOL. 84, NO. 2, 1986.

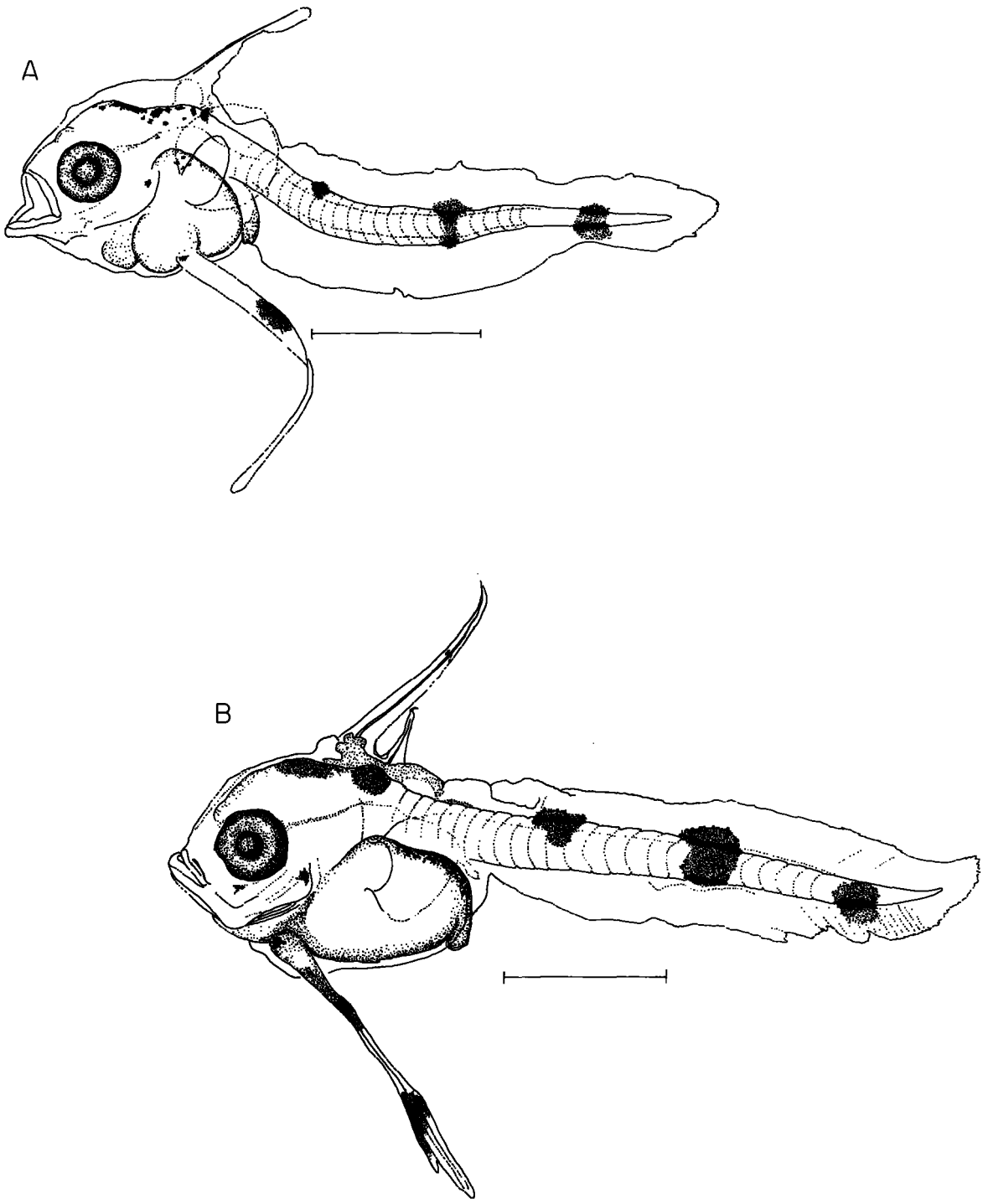

FIGURE 1.—*Lophius gastrophysus* larvae from southern Brazil: A. 3.8 mm NL, B. 4.5 mm NL. Scale bar is 1.0 mm.

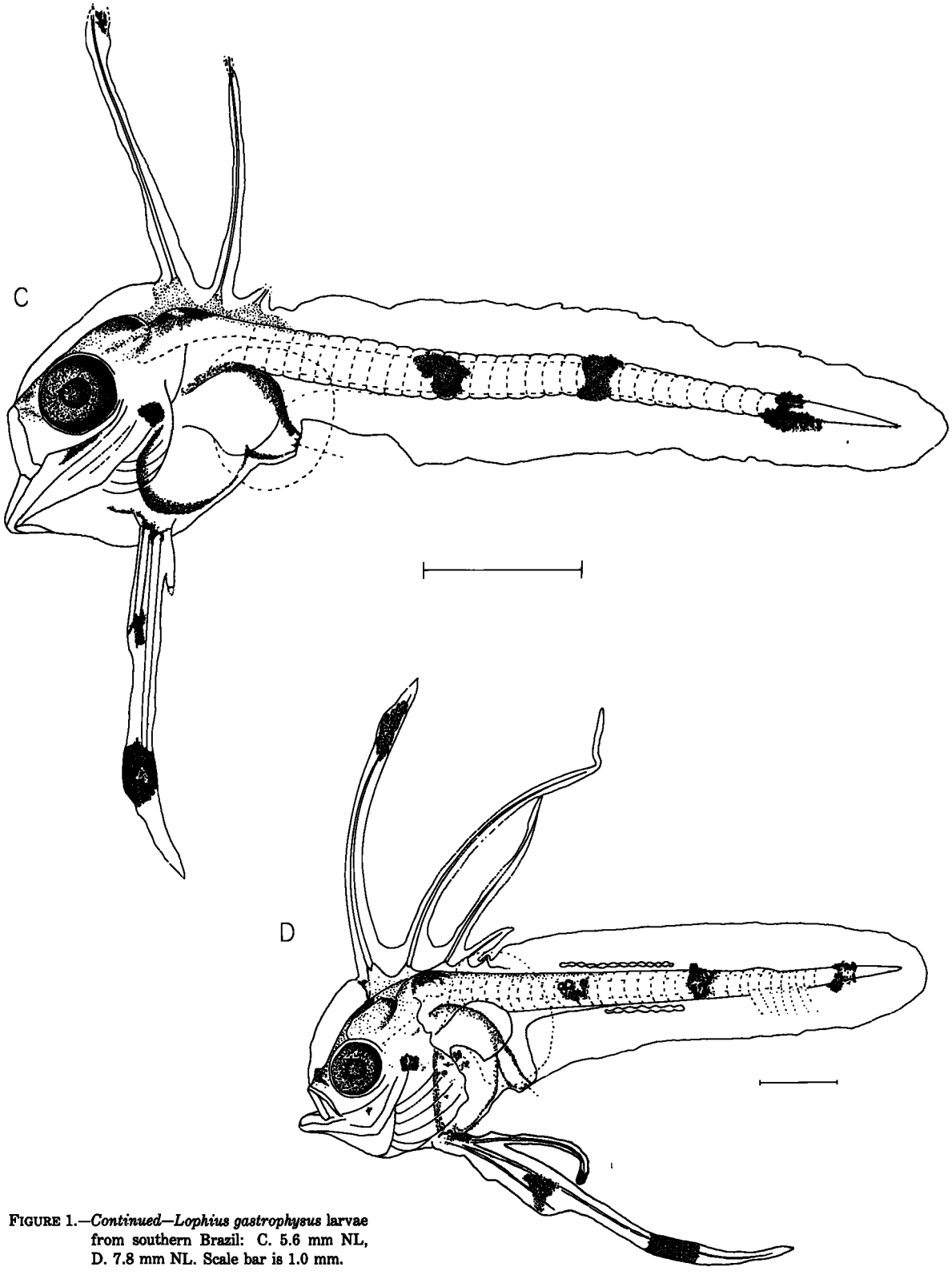

FIGURE 1.—*Continued—Lophius gastrophysus* larvae from southern Brazil: C. 5.6 mm NL, D. 7.8 mm NL. Scale bar is 1.0 mm.

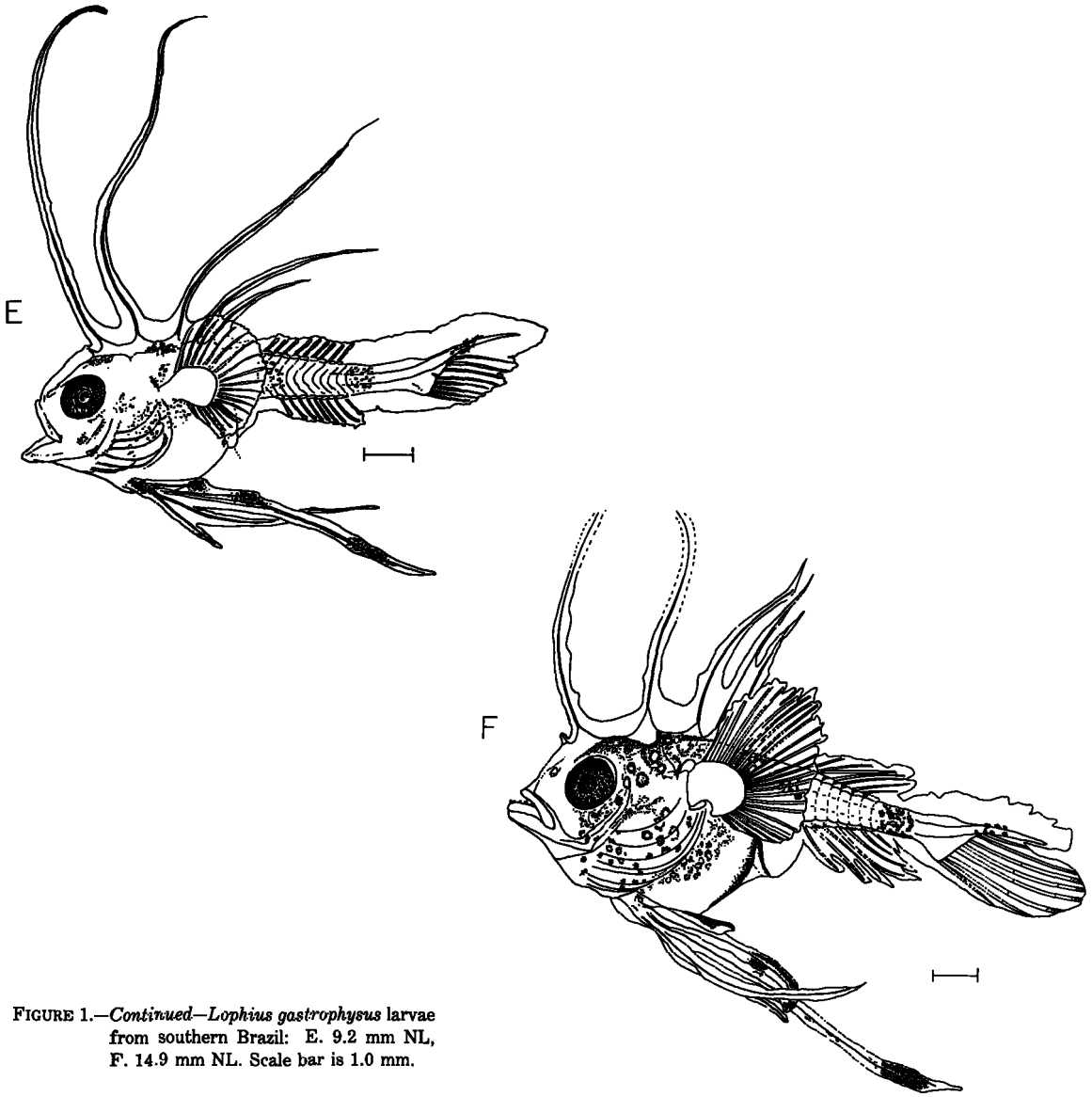

FIGURE 1.—*Continued—Lophius gastrophysus* larvae from southern Brazil: E. 9.2 mm NL, F. 14.9 mm NL. Scale bar is 1.0 mm.

(Tåning 1923). Notochord flexion starts at about 9 mm NL (Fig. 1E).

As shown in *L. piscatorius* larvae (Tåning 1923), the laterally compressed larval form changes gradually during their planktonic stage toward the dorsoventrally depressed shape of juvenile and adults. The largest larvae examined, 15.7 mm NL, had not yet achieved the juvenile stage, but a similar tendency was observed. For example, the maximal breadth of the head in 3.5 mm larva is only 22%, but that in 15.7 mm larva is about 40% of body length. The proportion of body depth also shows a similar tendency, i.e., it starts at 30% at 4 mm and attains 45% of body length at 15.7 mm. The proportion of head length starts at about 23% at 4.5 mm and attains almost 45% at 15.7 mm NL.

Statistics describing regressions of different body parts in relation to body length are shown in Table 1. The regressions lines of head length and body depth showed an inflexion at the size of 7.6 mm NL, while those of other body parts were linear for the size range 3.2-15.7 mm NL. Thus, the regressions

TABLE 1.—Statistics describing regressions relating notochord length with length of different body parts of *Lophius gastrophysus* larvae. *a* and *b* = constant ($y = a + bx$), *r* = correlation coefficient, *n* = number of specimens.

Characters (*x*)	Size range of notochord length (*y*) (mm)	*a*	*b*	*r*	*n*
Head length	3.2- 7.5	−0.18334	0.27117	0.68827	97
	7.7-15.7	−2.11501	0.56058	0.94483	27
Body depth	3.2- 7.5	0.10498	0.28333	0.74299	99
	7.7-15.7	−2.49286	0.65397	0.92825	27
Preanal distance	3.2-15.7	−1.54475	0.77254	0.96482	27
Predorsal distance	3.2-15.7	−1.65336	0.74641	0.96717	27
Eye diameter	3.2-15.7	−0.00095	0.10383	0.94353	124
Length of the second dorsal spine	3.2-15.7	−3.19397	0.99987	0.90707	96
Length of the third ventral fin ray	3.2-15.7	−3.47484	1.14083	0.90497	102

lines of the former were calculated in two size ranges.

PIGMENTATION

Lophius gastrophysus larvae develop a distinct pattern of melanophores. Since early stage (Fig. 1A), there are three large pigment bars on the trunk and caudal region and they remain at the same position during larval stage. The larva of 14.9 mm NL (Fig. 1F) has a heavily pigmented body, but the three large pigment bars on the trunk and caudal region are still visible. There are dense melanophores over the occipital region of the head and shoulder (Fig. 1A). Pigments on the elongate ventral fin ray is also visible in the smallest specimen, but the positions and number of them change gradually. In the earliest stage (3.8 mm NL) there are two melanophores on the ventral fin: one at the fin ray base and another at the middle of the ventral fin. At the size of 4.5 mm NL (Fig. 1B), there appears another small melanophore at one-third the length of the fin ray. The melanophore at the fin ray base remains at the same position, but the distal large one moves to the position three-fourths the length of the fin ray. After this size, positions and number of melanophores on the elongate third ventral fin ray remain the same up to 15.7 mm NL. When distal part of other ventral fin rays start to separate from the third one, there appears some melanophores on the distal edge of each fin ray.

There appears a patch of melanophores on the preopercular region at 3.8 mm NL and another small one appears on the suborbital region at 4.5 mm NL. The small melanophore, which appears on the tip of the elongate second dorsal spine at 4.5 mm NL, will later become a large pigment bar (Fig. 1C, D).

FIN DEVELOPMENT

The most remarkable change can be seen in lengths of the dorsal and ventral fins. Since the earliest stage (Fig. 1A), the larvae have elongate dorsal spine and ventral fin ray, which later become the second dorsal spine and the third ventral fin ray, respectively. The length of the second dorsal spine relative to body length changed from 28% at 3.3 mm NL to 90% at 8.3 mm NL (Fig. 2A). In larger larvae the proportion of the second dorsal spine length relative to body length decreased gradually to 70% at 15.7 mm NL. A similar tendency was observed for the length of the third ventral fin ray: it varied from 45% of body length at 3.3 mm NL to 121% at 11.6 mm NL (Fig. 2B). Unfortunately, these fin rays are in many cases lost or damaged at the distal tip, making it difficult to say whether we measured the total length of fin rays or the partial length of a damaged ray. In any case, the figure shows a clear tendency of rapid increase of fin rays during larval stage.

The number of fin rays increases during larval stage. For example, the origin of the first dorsal spine firstly appears anterior to the elongate second dorsal spine in 9.2 mm NL larva (Fig. 1E). The tip of the first dorsal spine which will transform into the illicium in the adult fish, emerges from the epidermal skin at about 10 mm NL. At this size, all fin rays are well developed and number of fin rays on the second dorsal, anal, and caudal fins attains the adult number.

Another remarkable change in fin development is a forward advancement of the dorsal spines. At 3.3 mm NL larva, the elongate second dorsal spine lies behind the head (Fig. 1A) and it moves gradually forward during larval stage; at 14.9 mm NL,

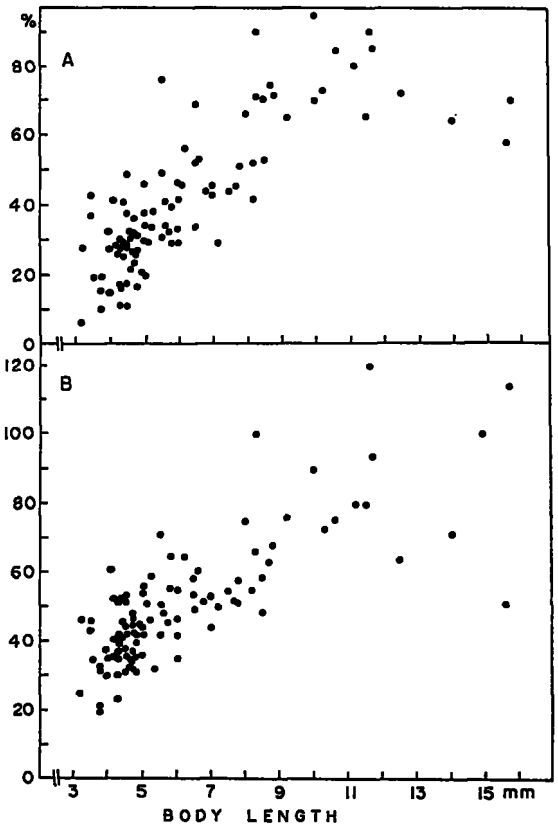

FIGURE 2.—Relationships between changes of proportion of second dorsal spine (A) and third ventral fin ray (B) and body length (NL) of *Lophius gastrophysus*.

it becomes the position anterior to the eyes (Fig. 1F).

DISCUSSION

Based on a study of world-wide collections, Caruso (1981, 1983) recently concluded that the Lophiidae is represented by 4 genera and 25 species, of which only 2 species inhabit the western Atlantic: *Lophius americanus* in the western North Atlantic and *L. gastrophysus* in the western Central and South Atlantic. The geographic ranges of the two species overlap between Cape Hatteras, NC, and Florida. The two western Atlantic species are very similar, but they can be easily distinguished by differences in dorsal and anal fin ray counts, size of the third and fourth dorsal spines, and differences in pigment pattern (Caruso 1983).

It is well known that lophiid anglerfishes spawn over deep water producing large gelatinous ribbons of spawn which often contain more than a million eggs (Berrill 1929). Spawning behavior is not known, but some authors have suggested that it may occur at or near the bottom (Tåning 1923; Dahlgren 1928). After hatching, the larvae emerge from the gelatinous capsules and pass a long planktonic stage. Upon attaining a length of about 60 mm TL, young fish probably take to the bottom (Connolly 1922; Tåning 1923; Bigelow and Schroeder 1953).

As shown previously, *Lophius* larvae can be easily distinguished from those of other species. Because there is only one species in the western South Atlantic, there is no doubt about the identification of our larvae as *L. gastrophysus*. Therefore, we have documented morphological differences in early developmental stages of our specimens and compared them with those of other well-known species (Table 2).

Meristic characters and adult forms of *L. americanus* and *L. piscatorius* are very similar, but their larval forms are quite different (Tåning 1923). The most remarkable difference is the presence of three large pigment bars on the trunk and caudal region in *L. americanus* from the yolk-sac stage. He also pointed out that the larval development of *L. americanus* was more rapid than that of *L. piscatorius*.

The larvae of *L. gastrophysus* are very similar to that of *L. americanus*. Both species have three large pigment bars on the trunk and caudal region from the very earliest stages. Larval development of *L. gastrophysus* is more rapid than that of *L. americanus*, e.g., formation of the bases of the second dorsal and anal fins and the five dorsal spines occurs at sizes 8.1 mm, 8.5 mm, and 11.5 mm, respectively, for *L. gastrophysus*, *L. americanus*, and *L. piscatorius*. In the same way, the first appearance of canine teeth on both jaws occurs at sizes of 4.2 mm, 6.5 mm, and 9.8 mm, respectively, in the same order for the three species.

Another difference is in the position of the melanophore of the ventral fin, present on the distal part of this fin in larvae of *L. americanus* and *L. piscatorius*, but at three-fourths the length of the fin in *L. gastrophysus* larvae. The presence of pigmentation in the preopercular and suborbital regions is also peculiar to *L. gastrophysus* larvae.

ACKNOWLEDGMENTS

The authors wish to thank Edward D. Houde of the University of Maryland for revision and critical reading of the manuscript.

They are also grateful to June Ferraz Dias and Kazuko Suzuki for sorting and drawing the larvae.

The financial support of this work came from the

TABLE 2.—Comparison of development stages of three Atlantic species of lophiid anglerfishes.

Characters	*L. gastrophysus*	*L. americanus*	*L. piscatorius*
General development			
Formation of bases of second dorsal and anal fins, the five dorsal spines, and the elongate ventral fin	8.1	8.5 mm[1]	11.5 mm[2]
First dorsal spine	about 10-11 mm	about 12-14 mm[1, 2]	about 15-16 mm[2, 3]
Completion of anal fin rays	9.3 mm	10.5 mm[2]	16 mm[3]
Completion of soft dorsal fin rays	9.3 mm	10.5 mm[2]	16 mm[3]
Size at first appearance of canine teeth in both jaws	4.2 mm	6.5 mm[2]	9.8 mm[2]
Size of newly hatched larva	about 3.5 mm	about 2.5 mm[4]	about 4.5 mm[3]
Pigment on distal edge of the second dorsal spine	since 5.2 mm	no pigment [1, 2]	since 6 mm[3, 5]
Position of pigment on distal part of the ventral fin	3/4 of ventral fin	far distal edge[2, 6]	far distal edge[5]
Pigment bars on the trunk and caudal region	three bars since early stage	three bars since[2] early stage	anterior two bars[5] since 11 mm
Meristic characters[7]			
Dorsal fin rays	9-11	11-12	11-12
Anal fin rays	8-9	9-10	9-10
Pectoral fin rays	22-26 (24.6)	25-28 (26.1)	23-27 (25.2)
Vertebrae	26-27 (26.2)	28-30 (29.1)	30-31 (30.4)

[1]Martin and Drewry 1978; [2]Tåning 1923; [3]Russel 1976; [4]Fahay 1983; [5]Lebour 1925; [6]Agassiz 1882; [7]Caruso 1983.
Note: For comparative purpose, the body length was given in total length for all species. Notochord length of *L. gastrophysus* larvae was converted to total length with an equation: TL = 1.024 mm NL + 0.1168 (r = 0.999), for larvae smaller than 10.0 mm NL.

Financiadora de Estudos e Projetos (FINEP). The senior author received the research fellowship of the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the junior author received the scholarship of the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP). This is contribution nº 620 of the Instituto Oceanográfico da Universidade de São Paulo.

LITERATURE CITED

AGASSIZ, A.
1882. On the young stages of some osseous fishes. Part III. Proc. Am. Acad. Arts Sci. 17:271-303.

ALLEN, E. J.
1917. Post-larval teleosteans collected near Plymouth during the summer of 1914. J. Mar. Biol. Assoc., U.K. 11:207-250.

ARBAULT, S., AND N. L. BOUTIN.
1968. Ichthyoplancton. Oeufs et larves de poissons téléostéens dans le Golfe de Gascogne en 1964. Rev. Trav. Inst. Pêches Marit. 32:413-476.

BERRILL, N. J.
1929. The validity of *Lophius americanus* Val. as a species distinct from *L. piscatorius* Linn., with notes on the rate of development. Contrib. Can. Biol. (N.S.) 4:145-151.

BIGELOW, H. B., AND W. C. SCHROEDER.
1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv., Fish. Bull. 53, 577 p.

BOWMAN, A.
1920. The eggs and larvae of the angler (*Lophius piscatorius*) in Scottish waters. A review of our present knowledge of the life history of the angler. Sci. Invest. Fish. Board Scotl. 1919, No. 1, p. 1-42.

CARUSO, J. H.
1981. The systematics and distribution of the lophiid anglerfishes: I. A revision of the genus *Lophiodes* with the description of two new species. Copeia 1981:522-549.
1983. The systematics and distribution of the lophiid anglerfishes: II. Revisions of the Genera *Lophiomus* and *Lophius*. Copeia 1983:11-30.

CONNOLLY, C. J.
1920. Histories of new food fishes. III. The angler. Bull. Biol. Board Can., Ottawa, No. 3, 17 p.
1922. On the development of the angler (*Lophius piscatorius* L.). Contrib. Can. Biol. 1921(7):113-124.

DAHLGREN, U.
1928. The habits and life history of *Lophius*, the angler fish. Nat. Hist. 28:18-32.

FAHAY, M. P.
1983. Guide to the early stages of marine fishes occurring in the western North Atlantic Ocean, Cape Hatteras to the southern Scotian shelf. J. Northwest Atl. Fish. Sci. 4:1-423.

LEBOUR, M. V.
1919. Feeding habits of some young fish. J. Mar. Biol. Assoc., U.K. 12:9-21.
1925. Young anglers in captivity and some of their enemies. A study in a plunger jar. J. Mar. Biol. Assoc., U.K. 13: 721-734.

MARTIN, F. D., AND G. E. DREWRY.
1978. Development of fishes of the Mid-Atlantic Bight: an atlas of eggs, larval and juvenile stages. Vol VI, Stromateidae through Ogcocephalidae. U.S. Fish Wildl. Serv. Off. Biol. Serv., 78/12, 416 p.

MATSUURA, Y.
1979. Distribution and abundance of eggs and larvae of the Brazilian sardine, *Sardinella brasiliensis*, during 1974-75 and 1975-76 seasons. Bull. Jpn. Soc. Fish. Oceanogr. 34: 1-12.

MITO, S.
1966. Fish eggs and larvae. [In Jpn.] *In* S. Motoda (editor), Illustrations of the marine plankton of Japan, Vol. 7, 74 p. Soyo-Sha, Tokyo.

PADOA, E.
1956. Triglidae, Peristediidae, Dactylopteridae, Gobiidae, Echneidae, Jugulares, Gobiesocidae, Heterosomata, Pediculati. [In Ital.] *In* Uova, larve, e studi giovanili di Teleostei, p. 627-880. Fauna Flora Golfo Napoli 38.

PIETSCH, T. W.
1984. Lophiiformes: development and relationships. *In* H. G. Moser et al. (editors), Ontogeny and systematics of fishes, p. 320-322. Am. Soc. Ichthyol. Herpetol., Spec. Publ. No. 1.

PRINCE, E. E.
1891. Notes on the development of the angler-fish (*Lophius piscatorius*). 9th Ann. Rep. Fish. Board Scotl., (1890), p. 343-348.

PROCTER, W., H. C. TRACY, E. HELWIG, C. H. BLAKE, J. E. MORRISON, AND S. COHEN.
1928. Fishes—a contribution to the life history of the angler (*Lophius piscatorius*). *In* Biological survey of the Mount Desert region, Part 2, p. 1-29. Philadelphia.

RUSSEL, F. S.
1976. The eggs and planktonic stages of British marine fishes. Acad. Press, Lond., 524 p.

STIASNY, G.
1911. Uber einige postlarvale Entwicklungsstadien von *Lophius piscatorius* L. Arb. Zool. Inst. Univ. Wien 19:57-74.

TANAKA, S.
1915-1919. Figures and descriptions of the fishes of Japan. J. Coll. Sci., Imp. Univ. Tokyo 24:419-440.

TÅNING, A. V.
1923. Lophius. Rep. Dan. Oceanogr. Exped. 1908-1910 Mediterr. Adjacent Seas 2, Biol. A. 10, 30 p.

WILLIAMSON, H. C.
1911. Notes on the eggs of the angler (*Lophius piscatorius*), halibut (*Hippoglossus vulgaris*), *Conger vulgaris* and tusk (*Brosmius brosme*), a young *Arnoglossus* sp.; abnormalities in *Lophius*, *Gadus*, Raia; diseases in *Gadus*, *Pleuronectes*, *Onos*, *Zoarces*; occurrence of *Himantolophus rheinhardti*, and *Clupea pilchardus*; the effectiveness of a seine-trawl in a small pond. 28th Ann. Rep. Fish. Board Scotl., (1909), Part III, p. 46-66.