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DEVELOPMENTAL ABNORMALITIES OF THE FLATFISH *Achirus lineatus* REARED IN THE LABORATORY¹

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ABSTRACT

Of 31 *Achirus lineatus* juveniles reared in a single experiment, 26 were abnormal. Abnormalities included incomplete eye migration, hooked dorsal fins, the presence of a left pectoral fin, ambicoloration, and partial albinism. The abnormal specimens have been described and photographed. A single reversed specimen, preserved as a nearly metamorphosed individual, also is described. Most of the abnormal conditions were interrelated. Possible effects of the rearing tank environment on abnormal development are discussed.

Larvae of lined soles, *Achirus lineatus* (Linnaeus), were reared in the laboratory from fertilized eggs collected in plankton tows from Biscayne Bay, Fla. Development and details of metamorphosis were described by Houde, Futch, and Detwyler (1970). No developmental abnormalities were detected until metamorphosis was nearly complete. At 50 days after hatching, the 31 survivors were examined and 26 (84%) were found to be abnormal.

The unique metamorphosis of flatfishes (Pleuronectiformes) may be responsible for the high percentage of abnormal specimens reported for this group in the literature (Norman, 1934; Hubbs and Hubbs, 1945; Dawson, 1962). Most of the described abnormal conditions in flatfishes were encountered in lined soles from this rearing experiment. Abnormalities included, in order of frequency, (1) ambicoloration (25 specimens), (2) retention of left pectoral fin, normally lost after metamorphosis (23 specimens), (3) partial or no migration of the left eye (17 specimens), (4) hooked dorsal fin, (same 17 specimens), (5) partial albinism (1 specimen), and (6) reversal (1 specimen). Similar abnormalities have been described previously in

flatfishes, but are rare in the family Soleidae (Dawson, 1962). None have been reported previously for *A. lineatus*. The extremely high percentage of abnormal individuals among laboratory-reared specimens from this experiment apparently reflects some effect of the aquarium environment on the development of *A. lineatus*. A high proportion of pigment-deficient individuals of plaice (*Pleuronectes platessa*) was associated with high densities of metamorphosed specimens in rearing tanks and with low food levels in the tanks (Shelbourne, 1964, 1965; Riley, 1966), but other abnormalities were not discussed. Although the exact nature of the influence of the rearing tank on the production of abnormal specimens of lined soles is unknown, it is possible that harmful effects are created by (1) frequent contact with sides of small rearing tanks, (2) unnatural lighting, and (3) high concentrations of metabolites. Seshappa and Bhimachar (1955) reported failure of eye migration in the tongue sole *Cynoglossus semifasciatus* (Cynoglossidae) when postlarvae were kept in the dark. Two of my previous rearing experiments with *A. lineatus* also produced abnormal individuals. Some juvenile specimens of other flatfishes, *Paralichthys albigutta* (Bothidae) and *Gymnachirus melas* (Soleidae), also developed abnormally when reared from eggs hatched in my laboratory. The high incidence of abnormalities in the reared lined soles suggests that these conditions in flatfishes are not

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necessarily genetically controlled. When present in significant numbers, abnormalities may have important implications for those considering flatfishes in aquaculture.

METHODS

Rearing techniques were briefly described and larval development through metamorphosis reported by Houde et al. (1970). Methods used to rear *A. lineatus* were similar to those described in detail by Houde and Palko (1970). The 31 juveniles of lined sole were maintained in two 75-liter aquariums and fed on frozen brine shrimp (*Artemia salina*). Before metamorphosis larvae were fed wild zooplankton which consisted mostly of copepods. Beginning 50 days after hatching and at approximately 1-month intervals, growth was determined by measuring fish to the nearest millimeter total length (TL) and then returning them to the aquariums. Individuals were recorded as normal or abnormal when they were measured, the distinction being based on whether the dorsal fin was hooked.

Beginning 137 days after hatching, some fish were sacrificed and preserved for detailed examination. Radiographs were made to study skeletal structures. Specimens were accessioned into the fish collection at the Tropical Atlantic Biological Laboratory.

NORMAL SPECIMENS

Only five specimens were normal in all respects (Figure 1). Meristics and morphometrics of normal individuals fell within the range of variation for the species (Jordan and Evermann, 1898).

GROWTH AND MORTALITY

Growth was compared between grossly deformed specimens with hooked dorsal fins and normal specimens or those whose only anomalies

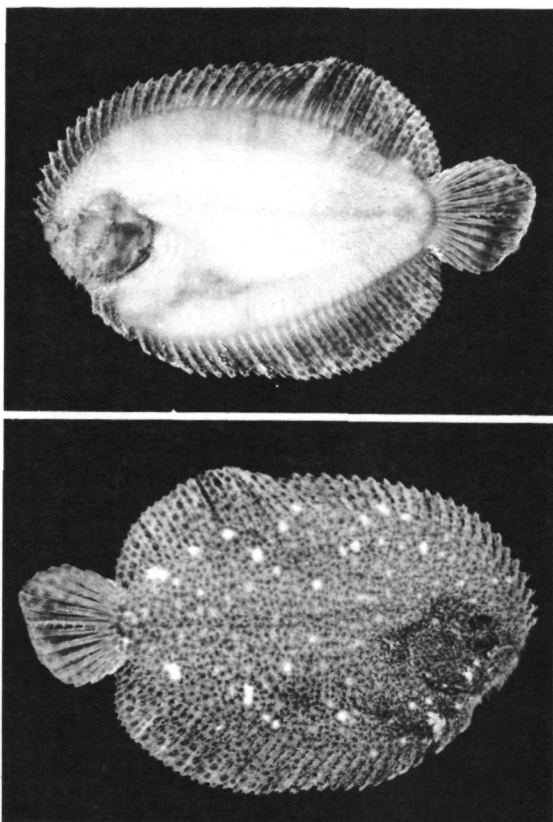


FIGURE 1.—Left side (upper photo) and right side (lower photo) of 45.8 mm TL normal *Achirus lineatus* reared in the laboratory. Dorsal fin was bent when specimen was preserved but it is normal.

consisted of unusual pigmentation and the presence of a left pectoral fin. Specimens with abnormal pigmentation or with left pectoral fins were classified as "normal" at the time they were measured because such conditions could not always be detected in small living juveniles. Although "normal" individuals initially were longer than abnormal ones, some compensation apparently occurred, and little difference in lengths was apparent between specimens still living from the two categories at 250 days after hatching. Both "normal" and abnormal specimens averaged about 52 mm TL at this time. No natural mortality occurred for either normal or abnormal lined soles between 50 and 275 days after hatching.

TABLE 1.—Abnormalities of *Achirus lineatus* reared in the laboratory. A plus symbol indicates the presence of the abnormality and a minus symbol indicates its absence.

Specimen number	Total length	Pigment on blind side		Left pectoral fin	Hooked dorsal fin	Left eye migration
		Body	Head			
64	32.6	100	100	+	+	incomplete
65	27.5	100	100	+	+	incomplete
68	29.5	100	100	+	+	incomplete
69	39.6	100	100	+	+	incomplete
72	45.8	100	100	+	+	incomplete
73	41.6	100	100	+	+	incomplete
84	42.7	100	100	+	+	incomplete
85	48.0	100	100	+	+	incomplete
88	60.0	100	100	+	+	incomplete
91	52.0	100	100	+	+	incomplete
92	50.0	100	100	+	+	incomplete
93	53.0	100	100	+	+	incomplete
67	34.8	100	100	+	+	nearly complete
83	43.8	100	100	+	+	nearly complete
87	61.0	100	100	+	+	nearly complete
90	77.0	100	100	+	+	nearly complete
75	58.4	100	100	+	—	complete
79	56.3	100	100	+	—	complete
89	69.0	100	100	+	—	complete
66	45.5	100	~70	+	—	complete
74	54.8	100	~70	+	—	complete
63	39.1	100	~10	+	—	complete
78	52.1	100	~10	+	—	complete
70	48.1	100	~10	—	—	complete
77	54.5	~90	0	—	—	complete
186	66.0	0	0	—	+	no eye migration
71	45.8	0	0	—	—	complete
76	63.6	0	0	—	—	complete
80	42.6	0	0	—	—	complete
81	40.3	0	0	—	—	complete
82	52.9	0	0	—	—	complete

¹ This specimen had a small albinistic area on the right side of its head.

ABNORMALITIES

PIGMENTATION

Among the many abnormally pigmented specimens (Table 1) four major categories could be distinguished. Three were types of ambicoloration and the fourth was partial albinism: (1) Nineteen specimens were completely pigmented on both sides (Figures 2 and 3). (2) Two specimens were completely pigmented except for the mouth region on the left (blind) side (Figure 5). (3) Four specimens were completely or almost completely pigmented on the body of the blind side but not on the head, which had little (10%) or no pigment (Figure 6). (4) One specimen was partially albinistic on the right side of the head, but other pigmentation was normal. The

eye completely failed to migrate in this specimen (Figure 7). Normal coloration (five specimens) consisted of a lack of pigment on the blind side, except for tiny melanophores scattered over the posterior third of the body (Figure 1). All except two ambicolored individuals had some other associated abnormality, but normally pigmented specimens were always normal in other respects.

LEFT PECTORAL FIN

The left pectoral fin disappeared from normal lined soles when metamorphosis was nearly complete (Houde et al., 1970). A fin with 1 to 6 rays remained on 23 of the 31 juveniles from the rearing experiment. All specimens with a left pectoral fin also were abnormally pigmented.

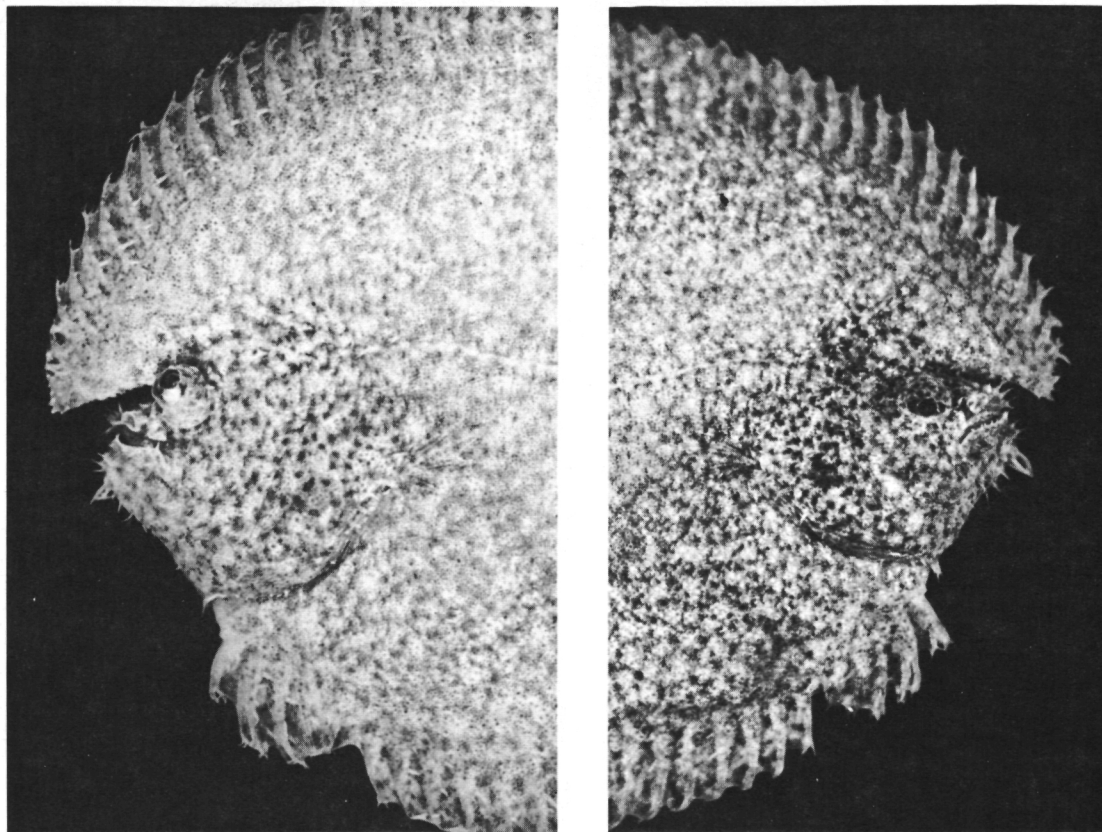


FIGURE 2.—Left side (left photo) and right side (right photo) of head of 39.6 mm TL abnormal *Achirus lineatus* reared in the laboratory. Ambicoloration, hooked dorsal fin, incomplete eye migration, and presence of a left pectoral fin.

Usually the fin was associated with a hooked dorsal fin and failure of eye migration (Figures 2 and 3), but a pectoral fin also was present on some individuals without those abnormalities (Figure 5).

HOOKED DORSAL FIN

Seventeen specimens had a hooked dorsal fin. In normal metamorphosis, the left eye of *A. lineatus* migrates across the dorsal midline under the projecting dorsal fin; the "hook" of the dorsal fin subsequently grows down toward the snout, eventually becoming adnate to the head. Development of the dorsal fin during metamor-

phosis was described for normal *A. lineatus* by Futch, Topp, and Houde.³ In normal lined soles the first five dorsal fin pterygiophores articulate with serrations in the supraoccipital bone. The three anteriormost pterygiophores are directed anteriorly, lying nearly parallel to the axis of the neurocranium. A fleshy connection is established between the dorsal fin and the prefrontal complex of the neurocranium. Radiographs of abnormal lined soles revealed that rotation of the frontal and prefrontal bones was incomplete during metamorphosis. The anteriormost pter-

³ Futch, C. R., R. W. Topp, and E. D. Houde. Developmental osteology of the lined sole, *Achirus lineatus* (Pisces: Soleidae). (Unpublished manuscript.)

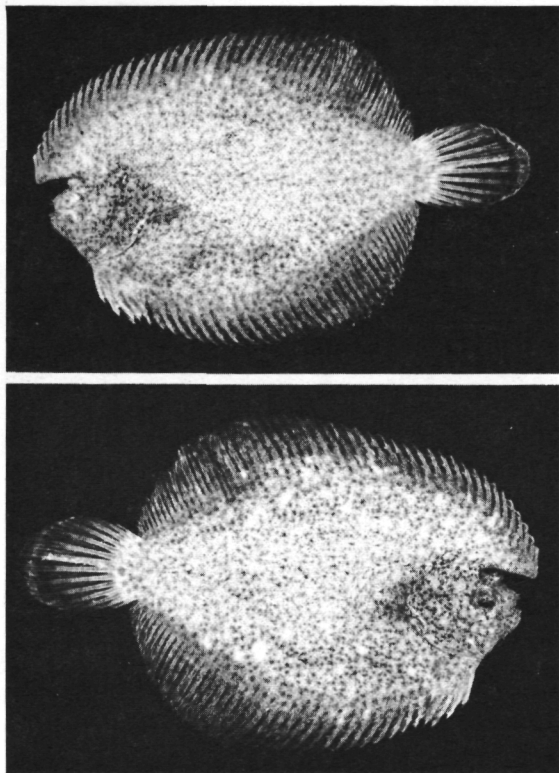


FIGURE 3.—Left side (upper photo) and right side (lower photo) of 32.6 mm TL abnormal *Achirus lineatus* reared in the laboratory. Abnormalities include ambicoloration, hooked dorsal fin, partial eye migration, and presence of a left pectoral fin.

gyiophores appeared normal and articulated with the supraoccipital serrations, but were directed away from the neurocranium at an angle of about 20° . No fleshy connection was established between the dorsal fin and the incompletely rotated prefrontal complex. Hooked dorsal fins and eye migration failure are associated (Figures 2 and 3), but the hooked condition can also be present when eye migration is nearly normal (Figure 4).

EYE MIGRATION

Migration (rotation) of the left eye was incomplete in 17 specimens. The abnormality

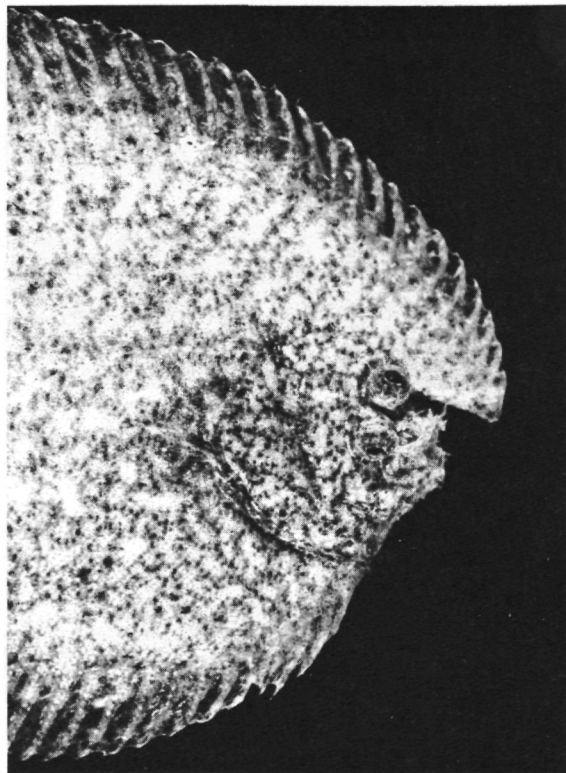


FIGURE 4.—Right side of head of 34.8 mm TL abnormal *Achirus lineatus* reared in the laboratory. Abnormalities include ambicoloration, hooked dorsal fin, and presence of a left pectoral fin. Eye migration nearly complete.

ranged from almost total failure of migration (Figures 2 and 7) to various stages of partial or nearly complete migration (Figures 3 and 4). All individuals with this abnormality also had hooked dorsal fins and were ambicolored or partially albinistic. In normal *A. lineatus* eye migration began at about 3.5 mm TL and was complete at 6.5 mm TL (Houde et al., 1970).

REVERSAL

A single reversed specimen was reared. This specimen was not included among the 31 treated in Table 1 because it was preserved before metamorphosis was completed. Reversals among the

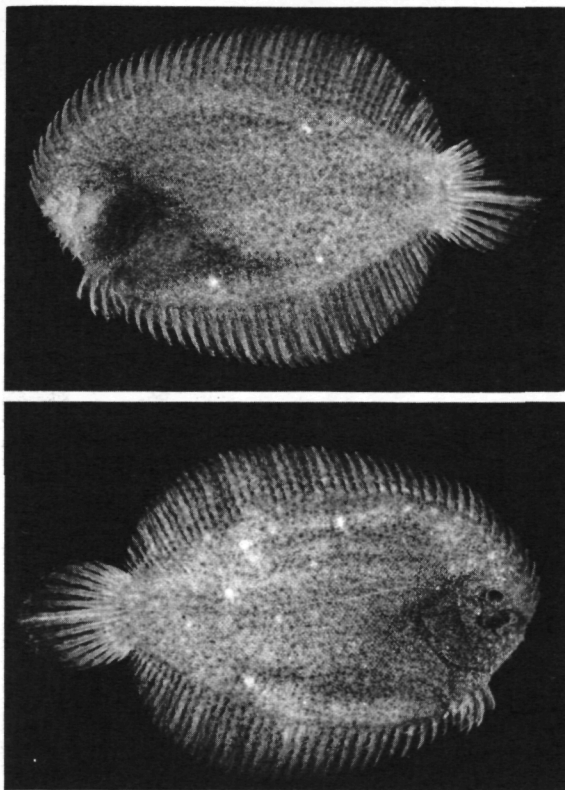


FIGURE 5.—Left side (upper photo) and right side (lower photo) of 45.5 mm TL abnormal *Achirus lineatus* reared in the laboratory. Abnormalities include ambicoloration and the presence of a left pectoral fin.

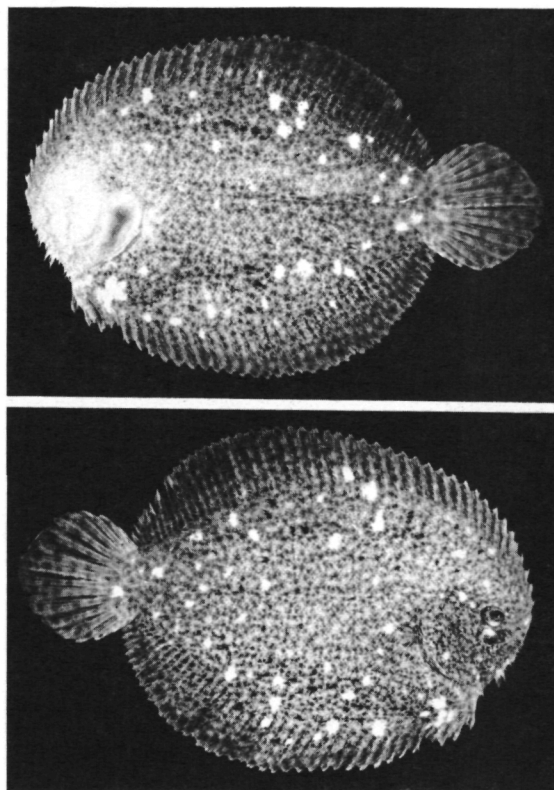


FIGURE 6.—Left side (upper photo) and right side (lower photo) of 48.1 mm TL abnormal *Achirus lineatus* reared in the laboratory. Specimen is ambicolored but otherwise normal.

Soleidae are extremely rare⁴ (Hubbs and Hubbs, 1945). The specimen was a nearly metamorphosed individual of 5.5 mm TL (Figure 8), that appeared normal in other respects when compared with other postlarvae of the same length. Internal organs were not examined to determine whether they were reversed. Normal *A. lineatus* of the same length have been illustrated and described by Houde et al. (1970).

⁴ The photograph in Herald (1961; fig. 139) should not be mistaken as a reversed *Gymnachirus williamsoni*, because in actuality this photograph was produced by an accidental reversal of a Kodachrome slide during preparation of the text.

SUMMARY

Most abnormalities of the laboratory-reared *A. lineatus* appeared related to each other. The presence of related anomalous conditions in individual specimens of flatfishes often has been reported, and the apparent association of ambicoloration, hooked dorsal fins, incomplete eye migration, and the tendency toward symmetry in paired fins has been discussed (Dawson, 1962; Gudger and Firth, 1936; Norman, 1934). The 26 aberrant juvenile specimens in my series of 31 were examined to determine the association of abnormal conditions in individual fish. Examination of Table 1 shows that the abnormalities are associated. Sixteen specimens had

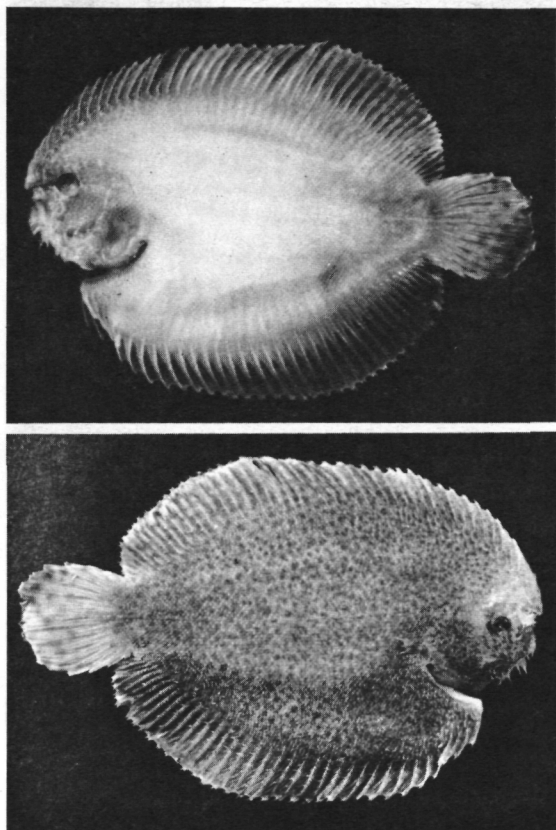


FIGURE 7.—Left side (upper photo) and right side (lower photo) of 66.0 mm TL abnormal *Achirus lineatus* reared in the laboratory. Partial albinism, hooked dorsal fin, no eye migration.

all four major anomalies and 16 to 23 specimens had two or three coexistent aberrancies. The "rule" of Gudger and Firth (1936), that was supported by extensive data on flatfishes (Dawson, 1962), stated that specimens with complete pigmentation of the body and pigmentation covering at least one-quarter to one-third of the head on the blind side will have a hooked dorsal fin and incomplete eye migration. Five of my lined soles fitted that category of ambicoloration but had neither a hooked dorsal fin nor incomplete eye migration (Table 1 and Figure 5). All but two ambicolored specimens also were abnormal in some other respect. Ambicolored individuals in which the body and more than 10% of the

head on the blind side were pigmented retained a pectoral fin on the blind side. Eye migration never was complete in those specimens with a hooked dorsal fin.

A single specimen (Figure 7; #86 in Table 1) was unique in that the left eye completely failed to migrate. A portion of the right side of its head was unpigmented making it the only partially albinistic specimen in the series. The left side, which was unpigmented and lacked a pectoral fin, was similar in these respects to the blind side of normal lined soles. A well-developed hooked dorsal fin was present. Similar abnormalities were present in a naked sole (*Gymnachirus melas* Nichols) that was reared at the laboratory.

The high percentage of abnormalities in laboratory-reared *A. lineatus* must have been influenced by rearing conditions, since abnormal lined soles apparently are extremely rare in nature. Further controlled experiments should make it possible to determine what factors cause abnormal metamorphosis of lined soles and perhaps other flatfishes. These experiments also might test the common assumption that survival of abnormal flatfishes is lower than that of normally metamorphosed individuals, since no advantages in either survival or growth of normal juveniles of *A. lineatus* were detected in the initial rearing experiment.

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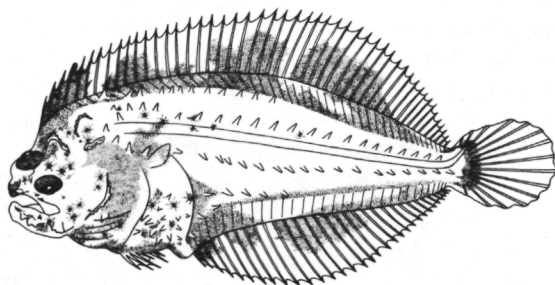


FIGURE 8.—Left side of a reversed, nearly metamorphosed, 5.5 mm TL specimen of *Achirus lineatus* reared in the laboratory.

Futch, William J. Richards, and C. R. Robins have reviewed and criticized the manuscript. The reversed specimen was illustrated by Grady Reinert. Photographs were taken by Andrew Ramsay and Anna Delor.

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