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Dorsal and Anal Fin Rays of the Japanese Anchovy, *Engraulis japonica*, and Their Pterygiophores

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Abstract

The first dorsal pterygiophore of the Japanese anchovy has a large median keel projecting forward. This pterygiophore is not formed by fusion of the two anterior proximal radials, but by its own developmental transfiguration.

Although each dorsal and anal pterygiophore from the second to the last was associated serially with one branched ray, the first dorsal pterygiophore supported three or four unbranched rays and the first anal pterygiophore two, three or four unbranched rays. These were called 2-, 3- and 4-type in accordance with the number of rays.

Among the rays supported by the first pterygiophore under both the dorsal and anal fins, the anteriormost ray in the 3-type and the two anterior rays in the 4-type were identified as vestigial rays. Therefore, it was concluded that the principal rays in the dorsal and anal fins of the Japanese anchovy consist of two unbranched rays succeeded by branched rays. The numbers of dorsal and anal fin rays are 15 and 18, respectively, in modes of the frequency distributions.

Introduction

In engraulid fishes, the numbers of dorsal and anal fin rays, along with the numbers of vertebrae and gill rakers, are important meristic characteristics not only for classifying fish into species, but also for distinguishing between subpopulations within a species (Blackburn, 1950; McHugh, 1951; Howard, 1954; Nakamura, 1970; etc.).

Hayashi (1961) counted the dorsal and anal fin rays of the Japanese anchovy, *Engraulis japonica*, based on the relationship between the fin rays and their pterygiophores, and recorded the counts as D. 15 and A. 17 in modes of the frequency distributions. Reexamining the relationship between the fin rays and the pterygiophores in fish of this species, however, it was found that his description of the morphology of the fins, including that in the text figures, was incorrect. For this reason, this report presents a redescription of the structures of the dorsal and anal fin rays and their pterygiophores, the corresponding relationships between the fin rays and the fin supports, and the number of fin rays.

Material and Methods

A total of 690 Japanese anchovies were examined in the present study. These fish were taken arbitrarily from thirty-one samples which were collected at twenty localities around Japan during the ten years from 1972 to 1981 (Fig. 1, Table 1).

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Table 1. Materials used in this study.

Station no.	Locality	Date	Number of specimens	Standard length in mm
1	Tokotan	Aug. 29, 1980	9	122 -138
2	Usujiri	Aug. 23, 1980	7	119 -137
3	Kamiiso (1)	July 15, 1972	5	139 -142
	(2)	Sept. 26, 1972	26	47 - 96
	(3)	July 27, 1973	8	64 - 72
	(4)	Oct. 31, 1973	23	51 - 81
	(5)	Oct. 23, 1975	8	57 - 66
4	Kaminokuni (1)	Oct. 23, 1975	45	33 - 71
	(2)	Nov. 12, 1975	15	70 -102
5	Toyama (1)	June 6, 1972	7	73 - 77
	(2)	Mar. 14, 1973	17	75 -134
6	Himi	Feb. 24, 1976	23	25.0- 40.0
7	Tsuruga	June 18, 1980	11	81 -103
8	Ōzuchi	Jan. 10, 1976	12	83 - 90
9	Kamaishi	Aug. 23, 1979	4	122 -143
10	Katagai (1)	Nov. 7, 1973	21	53 -100
	(2)	Apr. 4, 1977	9	91 -114
11	Maisaka	Nov. 20, 1980	65	15.5- 32.0
12	Shiroko	Nov. 21, 1980	9	84 - 95
13	Akaoka	June 3, 1981	43	11.3- 16.4
14	Susaki (1)	May 20, 1978	18	25.0- 35.0
	(2)	May 22, 1978	26	21.0- 30.0
	(3)	May 1, 1980	49	22.0- 34.0
	(4)	Sept. 26, 1980	83	21.0- 38.0
	(5)	Sept. 29, 1980	51	17.5- 33.0
15	Off Serizaki	Nov. 13, 1972	7	103 -110
16	Nishinoura	Jan. 5, 1973	18	62 - 83
17	Fukae	June 11, 1972	36	25.0- 43.0
18	Azuma	July 9, 1976	6	71 - 85
19	Higashiichiki	Oct. 6, 1972	23	21.0- 31.0
20	Kagoshima Bay	Nov. 10, 1977	6	99 -105

Almost all the samples had been preserved in 10 per cent formalin solution, and of those samples only the one taken from the coastal waters off Akaoka, St. 13, was buffered with borax until the fish were extracted. The fish were cleared and dyed according to Clothier's (1950) technique.

For each fish, standard length was measured first. The lengths were measured to the nearest 1, 0.5 or 0.1 mm in accordance with fish sizes. Observations on dorsal and anal fin rays and their pterygiophores were made under a Wild M8 Stereomicroscope. Although the fin rays and the pterygiophores in the specimens smaller than

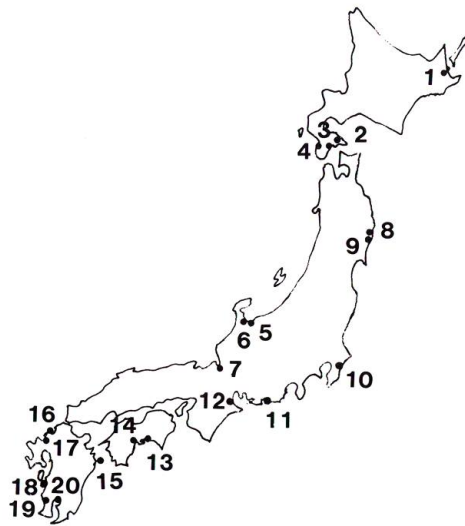


Fig. 1. Map showing sampling localities. Numerals represent the localities. Refer to Table 1.

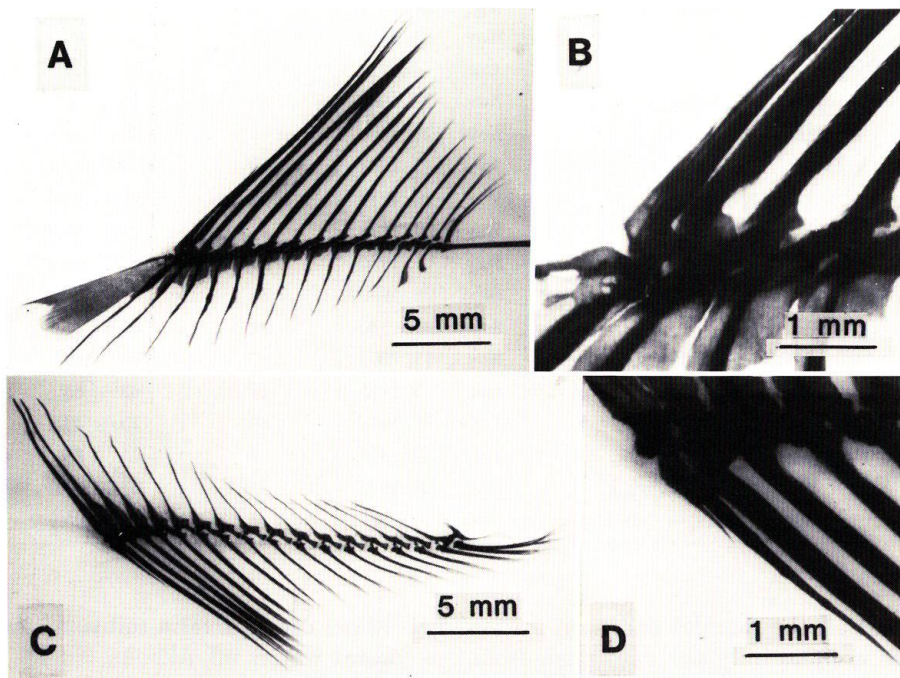


Fig. 2. Dorsal and anal fin rays of a 122 mm-fish, and their pterygiophores.
Dorsal fin rays and their pterygiophores (A) and enlargement of the anterior part (B). Anal
fin rays and their pterygiophores (C) and enlargement of the anterior part (D).

20 mm in size did not stain with alizarin red S, observations were possible. Except for four photographs of the anterior pterygiophores under the dorsal fin of the smallest specimens, all photographs were made with the stereomicroscope, which was furnished with an MPS 20 Microphoto System. The four photographs were made with a Nikon S Microscope equipped with an AFM Microphoto System, with the aid of Dr. H. Yabu. They are included in Fig. 5.

Pterygiophores of larval fish were photographed after they were dyed with aniline blue. The procedure was as follows. (1) The cleared fish stored in pure glycerine were placed in a 0.5 per cent water solution of aniline blue for 12 hours or more. (2) The fish were transferred into pure glycerine, which was changed 2 or 3 times, at 1 to 2 hours per change. In this step, surplus aniline blue was removed from the fish. When blue-stained flesh prevented the pterygiophores from being observed, it was carefully removed using a needle. (3) The fish were transferred to pure glycerine prior to photographing.

In order to find the length of the anterior arm of the first dorsal proximal radial, the distance between the tip of the arm and the distal end of the radial was measured using an Olympus STM-A Microscope equipped with X- and Y-microhandles and their digital indicators. The measurements were to the nearest μm .

Results

Associations of dorsal and anal fin rays with their pterygiophores

Counting all that could be seen externally, the number of dorsal fin rays ranged from 15 to 17 in almost all fish. Regardless of the fin ray counts, the rays in each fish usually consisted of the three anterior unbranched rays, which were succeeded by branched rays. Among the unbranched rays, the first was unsegmented and very short and the second segmented and about one-third the length of the third ray. The third was segmented and was one of the longest rays, together with the next two branched rays. The sizes decreased rapidly from the third branched ray to the last. The last ray branched from its basal part so as to appear to be two; but this ray should be counted as one, since it was associated serially with one pterygiophore. Every branched ray was segmented (Fig. 2A and B).

Thirteen to fifteen pterygiophores were found under the dorsal fins (Fig. 2A). Only the anteriormost pterygiophore was composed of distal, middle and proximal radials; the others consisted of two radials, lacking the middle one (Fig. 3). The proximal radial of the anteriormost pterygiophore had a large median keel projecting forward and was markedly different in shape from the other proximal radials. The proximal radials became smaller and shorter posteriorly (Fig. 2A). In the third and the succeeding pterygiophores, the distal portions of the respective proximal radials were bent backward. The amount of bend became greater posteriorly. In the second pterygiophore there was only a slight bend in the proximal radial, and in the first pterygiophore no bend could be seen in the proximal radial (Fig. 2A and B, Fig. 3, etc.). At the distal extremity of the last proximal radial, there was a stay in addition to a distal radial. The stay extended backward noticeably. The extended portion was thin and flexible, and dyed with alizarin red S in young and adult fish (Fig. 2A, Fig. 10A and B). The borderline between the proximal radial and the stay was vague in the larvae, but became detectable in metamorphosing or metamor-

phosed fish (Fig. 4A and B).

Each dorsal fin ray articulated serially with a pterygiophore by means of a distal radial at its bifurcated basal portion. Thus, a one-to-one correspondence between fin rays and pterygiophores was seen throughout the fin, except for the departure at the anterior end of the fin. The anteriormost pterygiophore supported three unbranched rays in the majority of fish. Among the three rays, the second, a short ray, and the third, the longest one, were joined to the pterygiophore by means of the middle and distal radials respectively, while the first, a very short ray, was supported only secondarily by a proximal radial. The fourth ray, i.e., the first branched ray, corresponded serially to the second pterygiophore and was supported

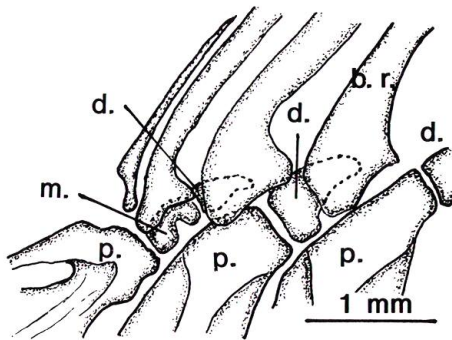


Fig. 3. Association between the anterior dorsal fin rays of a 142 mm-fish and their pterygiophores.

b. r.: The first branched ray. d: Distal radial. m: Middle radial. p: Proximal radial.

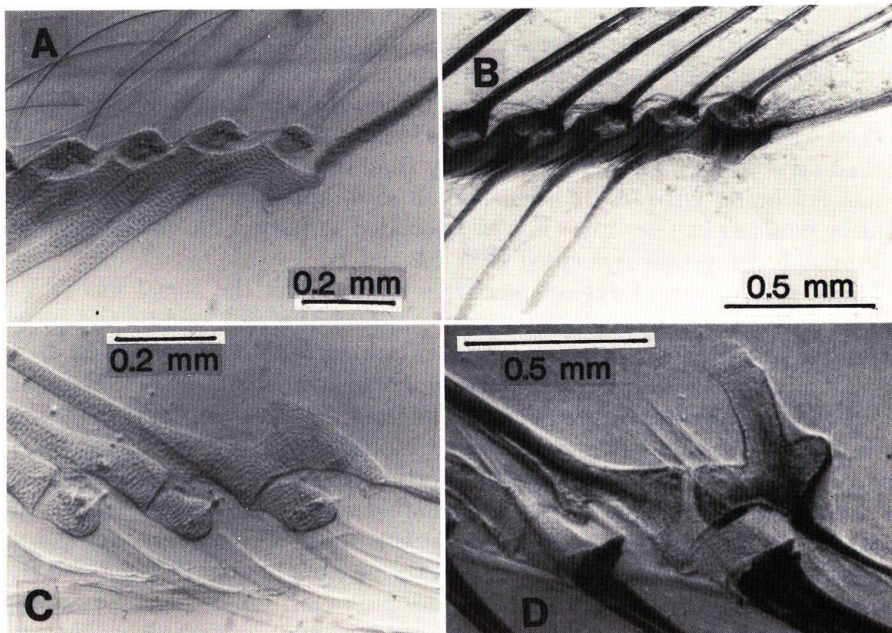


Fig. 4. Developmental changes in stay.

The posterior dorsal fin pterygiophores of a 19.0 mm-fish (A) and of a 35.5 mm-fish (B). The posterior anal fin pterygiophores of a 28.5 mm-fish (C) and of a 53 mm-fish (D).

secondarily by the third pterygiophore at the portion of its proximal radial that was bent backward. The succeeding rays corresponded structurally to the fourth ray. The last ray was held secondarily by the stay (Fig. 2A, Fig. 3, Fig. 4B).

In front of the dorsal pterygiophores, predorsal bones were arranged in a line. Among 263 young and adults, eleven or twelve bones were found in 247 fish, thirteen bones in 15 and ten bones in one fish. The first bone was the largest and was situated in the space between the skull and the first neural spine. The second and succeeding bones corresponded one-to-one to the first, and to the succeeding neural spines, by being located immediately posterior to the upper portions of the respective spines. The bones became progressively smaller posteriorly.

As for the anal fin, 18 to 20 rays were counted on it for most fish. These rays were similar in feature to the dorsal fin rays; that is, they were composed of three anterior unbranched and succeeding branched rays. Only the anteriormost, very short ray was unsegmented, and the third unbranched ray and the next two branched rays were longest. There was a rapid decrease in sizes, however, for several of the rays behind the longest rays. This decrease was less marked among posterior rays (Fig. 2C and D).

The anal fin rays were supported by sixteen to eighteen pterygiophores. Each pterygiophore consisted of distal and proximal radials. All the proximal radials were slender. The shortest proximal radial was one which was found in the central part of the arrangement. The distal portions of the third and succeeding proximal radials were bent backward. The bends, contrary to those in the dorsal fin, became gradually less marked in the direction of the penultimate radial (Fig. 2C and D, Fig. 8, Fig. 10C and D).

Serial and secondary associations between anal fin rays and their pterygiophores were the same as in the dorsal fin, despite the facts that the first pterygiophore lacked a middle radial and that its proximal radial had no projecting median keel (Fig. 2C and D).

There was a stay at the distal end of the last proximal radial. The shape of the stay was anchor-like in young and adult fish, whereas the shape was simple and the boundary line between the stay and the proximal radial not distinct in larval fish. The stay also extended backward, but the extended portion was, at most, about the same size as the last ray (Fig. 2C, Fig. 4C and D).

Development of the first pterygiophore under the dorsal fin

Observations on the development of the anterior dorsal pterygiophores were made for a series of larval fish of increasing sizes (Fig. 5). In a 12.8 mm-larva which had thirteen proximal radials, only the anteriormost radial was bar-like. The other radials had distal portions which were bent backward (A). In a 13.6 mm-larva which had fifteen radials, the bend occurred first at the third radial (B). Residue of the fin fold, which occupied an area on the anteriormost radial, was seen in both specimens. An expansion occurred on the central part of the front of the anteriormost proximal radial in a 14.1 mm-larva (C) and also in a 15.0 mm-larva (D). Counts of proximal radials were thirteen, and the bend began at the third radial in both of the specimens. The expansion spread upward and downward. In a 16.5 mm-larva, the anteriormost proximal radial developed into an obliquely inverted Y-shape. A pair of muscular tissues which adhered to the front of the anterior arm of

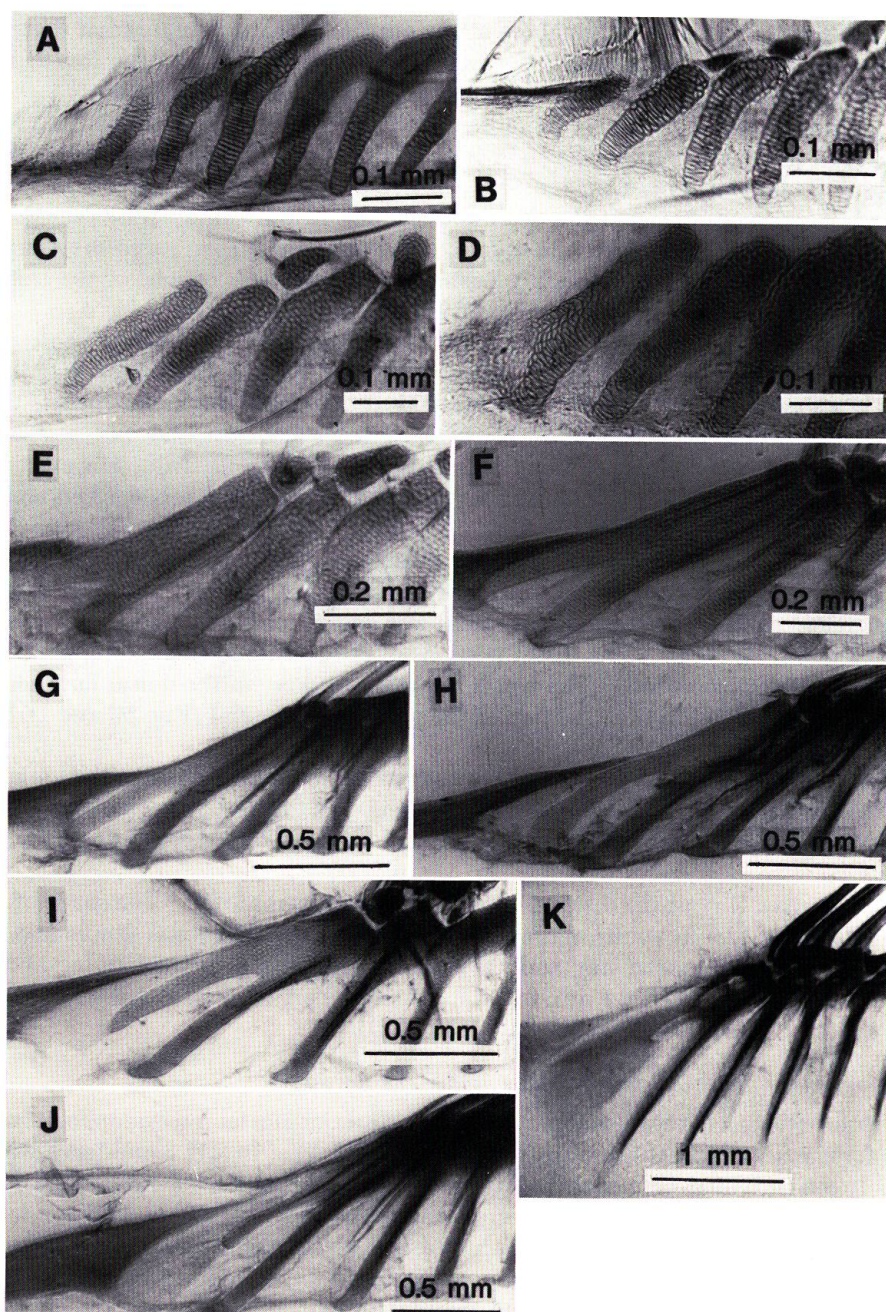


Fig. 5. Developmental changes in the first dorsal pterygiophore. The anterior pterygiophores of a 12.8 mm-fish (A), of a 13.6 mm-fish (B), of a 14.1 mm-fish (C), of a 15.0 mm-fish (D), of a 16.5 mm-fish (E), of a 21.5 mm-fish (F), of a 23.5 mm-fish (G), of a 25.5 mm-fish (H), of a 25.5 mm-fish (I), of a 30.0 mm-fish (J), and of a 35.5 mm-fish (K).

the Y-shaped radial was dyed with aniline blue and began to appear clearly. In this specimen, fourteen proximal radials were counted and the bent radials began at the third (E).

The first bent radial was the third in every specimen larger than 13.6 mm, even if the counts of proximal radials were different among the specimens. This indicates that the true anteriormost radial had not occurred yet in the 12.8 mm-larva, and first appeared in the 13.6 mm-larva.

The inverted Y-shaped radial developed proximally as the larva grew in size (F). When the larva attained a length of 23.5 mm, a bone-plate appeared on the front of the anterior arm of the radial, pushing up the muscular tissues (G). The bone-plate became larger following the growth of the arm (H) and then extended proximally beyond the arm (I and J). The first pterygiophore developed in a 35.5 mm-fish (K).

The distal radial of the anteriormost pterygiophore first appeared in a 16.5 mm-larva (E). In this larva, as well as in longer larvae, it was clear that the first pterygiophore was composed of distal, middle and proximal radials.

The anterior arm lengths (AAL) of the first proximal radial were measured. The values were distributed between 1.0 and 1.5 mm in the final period of the larval stage (Fig. 6). Four exceptional values which ranged from 1.659 to 1.759 mm were obtained only from the sample taken at Himi, St. 6. These values were excluded from Fig. 6. The arm was detectable in the first proximal radial of each adult fish as well as in young fish. The values measured in young and adult fish were between 1.0 and 1.5 mm (Fig. 2B, Fig. 7).

From the above facts, it can be concluded that the first proximal radial with a large median keel is not formed by fusion of the two anterior radials, but by transfiguration of the radial itself.

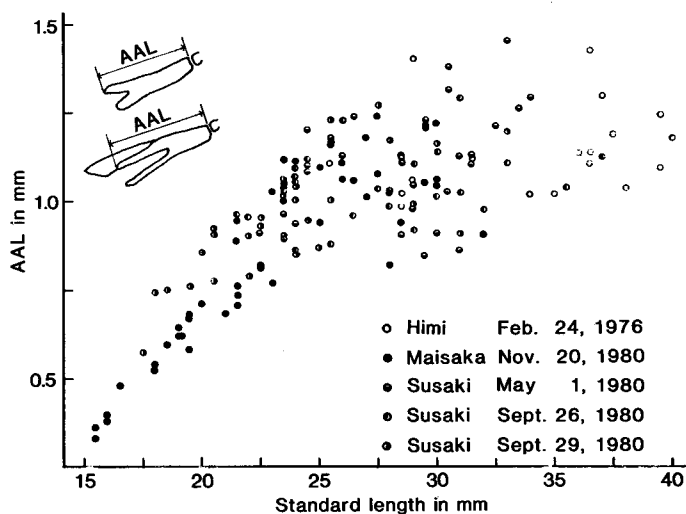


Fig. 6. Tendency of the anterior arm length (AAL) of the first dorsal pterygiophore to increase.

Number of fin rays associated with the first pterygiophore in each of the dorsal and anal fins

Dorsal and anal fins of 570 fish larger than 20 mm in size were examined in order to determine the association between the anterior rays and the first pterygiophore.

Three unbranched rays corresponded serially and secondarily to the first dorsal pterygiophore in 456 fish, and four unbranched rays in 114 fish. The former is called a 3-type and the latter a 4-type in the present study (Table 2). There was no significant frequency difference in type between larval fish and young and adult fish ($df=1$, $\chi^2=1.05$, $0.50 > P > 0.25$).

Regardless of fin ray type, the first branched ray articulated serially with the second pterygiophore in all young and adult fish except in two fish described later. This relationship was not ascertainable for almost all of the larval fish, since the

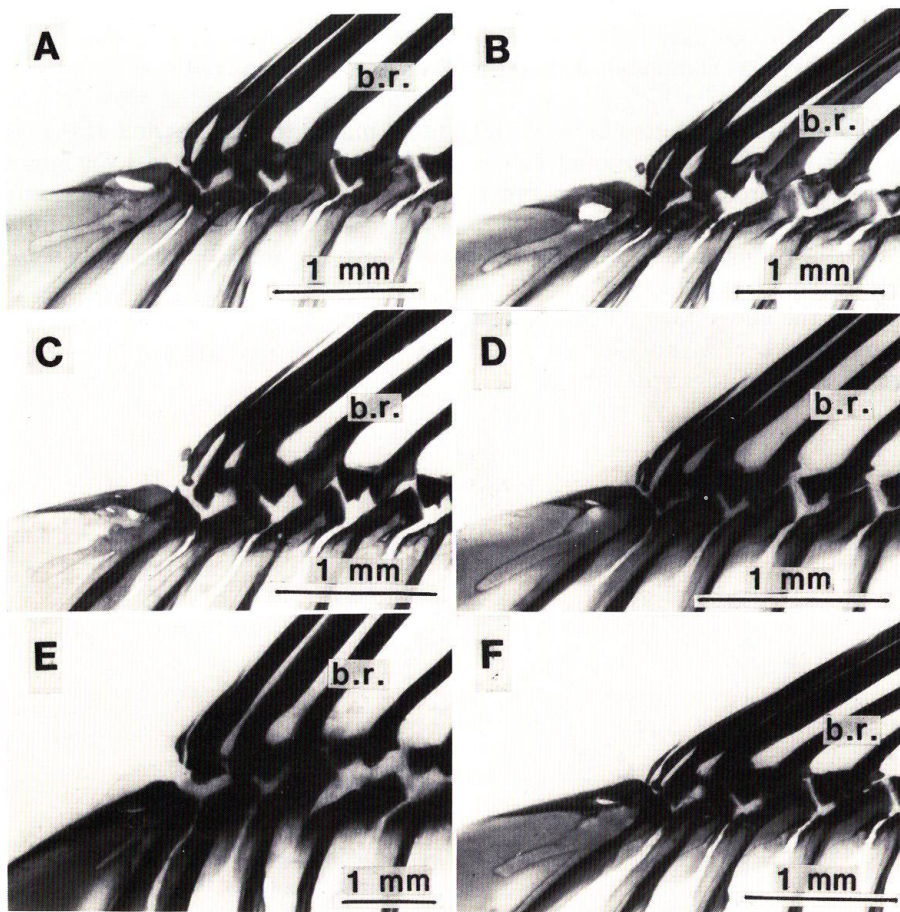


Fig. 7. Two types of anterior dorsal fin rays.

The 3-type fin seen in a 63 mm-fish (A). The 4-type fins seen in a 59 mm-, in a 68 mm-, in a 45 mm-, in a 102 mm- and in a 59 mm-fish (B~F). b.r.: The first branched ray.

Table 2. Frequency distribution of anterior dorsal fin ray types.

Stage	3-type	4-type	No.
Postlarvae	243	54	297
Juveniles and adults	213	60	273

Table 3. Frequency distribution of anterior anal fin ray types.

Stage	2-type	3-type	4-type	No.
Postlarvae	15	280	2	297
Juveniles and adults	3	266	4	273

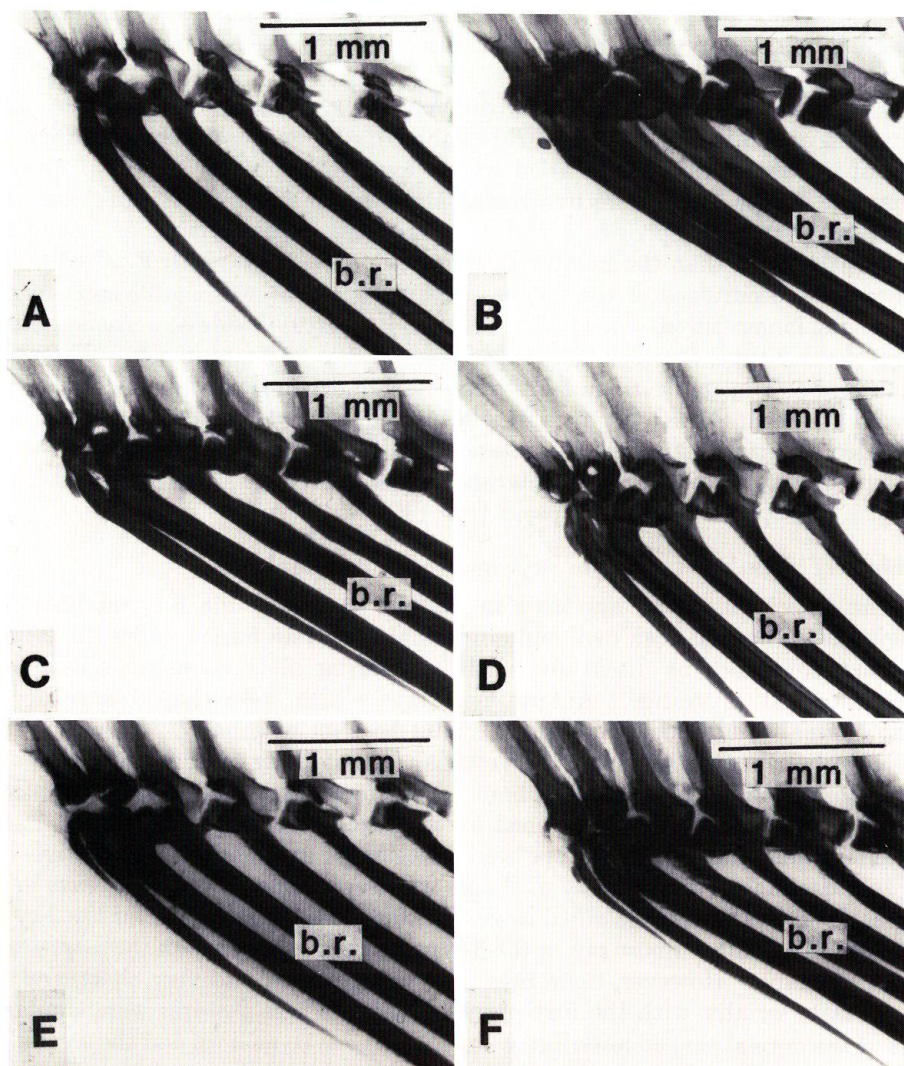


Fig. 8. Three types of anterior anal fin rays.

The 2-type fin seen in a 63 mm-fish (A). The 3-type fins seen in a 81 mm-, in a 76 mm-, in a 72 mm -and in a 66 mm-fish (B~E). The 4-type fin seen in a 68 mm-fish (F). b.r.: The first branched ray.

future first branched ray in them was not completed structurally. Many fish were classified as 4-type, and it was suggested that about 20 per cent of the fish of the species may belong to this type. In the 4-type fish, there was a minute ray situated in the anteriormost position, in addition to the three rays seen in the 3-type fish. The minute rays had a wide variety of shapes, i.e., they varied from spherical to normal (Fig. 7).

In anal fins, three types of relationships occurred between the anterior unbranched rays and the first pterygiophore, adding a 2-type, which had two rays associated with the pterygiophore. The 2-type fish lacked the anteriormost of the three unbranched rays seen in the 3-type fish. The second anal pterygiophore, like the second dorsal pterygiophore, articulated serially with the first branched ray in all fish except one (Fig. 8).

There was a significant frequency difference in types between larvae and larger fish ($df=2$, $\chi^2=6.15$, $0.050 > P > 0.025$) (Table 3). In the case of anal fin rays, the shape of the anteriormost ray varied widely even in the 3-type fish (Fig. 8B~E). Among the 3-type, there were five larvae and twenty larger fish with abnormally shaped rays—such as spherical, oval, or ellipsoidal. The number of larvae was significantly lower than the number of larger fish ($df=1$, $\chi^2=8.94$, $P < 0.005$). On the contrary, occurrence of the 2-type fish among larvae was significantly higher than among larger fish ($df=1$, $\chi^2=5.98$, $0.025 > P > 0.010$) (Table 3). Among fifteen larvae of the 2-type, fourteen fish ranged from 20.0 to 23.5 mm in size. They were reexamined at a magnification of fifty diameters under the stereomicroscope, but no fish could be regarded as a 3-type. It is suspected, however, that some of them were misjudged as 2-type fish, since the anteriormost sphere-like or oval-like ray was too small to project outward. The anteriormost ray in each of the 4-type fish was shaped like a sphere, oval or ellipsoid (Fig. 8F).

Numbers of dorsal and anal fin rays and their pterygiophores

The anteriormost ray appeared in various shapes in the 3-typed anal fins. Among these, the spherical, oval and ellipsoidal rays were buried under the skin, so that they could not be discovered without clearing the specimens. These were easily classified as vestige. Anteriormost rays which were shaped normally or nearly normally, although very small, could be seen externally. However, they seemed to be homogeneous with the vestigial rays, judging from the corresponding relationship with the first pterygiophore. Therefore, they should also be identified as vestigial rays. This was confirmed by the occurrences of the 2-type fish. The two anteriormost rays in the 4-type were categorized axiomatically as vestige.

In dorsal fins, a wide variety of shapes was seen among anteriormost rays in the 4-type. These rays were classified as vestige, for the same reason as for the 3-typed anal fins. The anteriormost ray in the 3-type and the second ray in the 4-type were normal in shape. However, these rays were unsegmented and very short, and did not associate serially with the first pterygiophore. These features were similar to those of the normal shaped anteriormost ray in the 3-type anal fin and the second ray in the 4-type. Therefore, the rays in the dorsal fin should be regarded as vestige as well.

It can thus be concluded that the principal rays in both the dorsal and anal fins of the Japanese anchovy consist of two unbranched rays succeeded by branched

Table 4. Frequency distributions of the principal fin ray counts in dorsal and anal fins, and of their pterygiophore counts.

Characteristic and stage	Dorsal fin			Anal fin					No.
Fin ray counts	14	15	16	16	17	18	19	20	
Pterygiophore counts	13	14	15	15	16	17	18	19	
Postlarvae	51 (3)	213 (1)	33	3	82	148 (2)	59	5	297
Juveniles and adults	46 (5)	202 1*	25 1*	3	44 (2)	147 (4) 1*	72 (1) 1*	7 (1)	273

() : Number of fish having the deformed pterygiophore.

* : Number of fish having the deformed fin ray.

Table 5. Differences in numbers of pterygiophores under dorsal and anal fins, for a series of larvae of increasing sizes.

Standard length (mm)	Number of fish having dorsal fin pterygiophore counts of :				Number of fish having anal fin pterygiophore counts of :				No.
	12	13	14	15	15	16	17	18	
11.1-11.5	1					1			1
11.6-12.0									0
12.1-12.5	2	3			1	1	3		5
12.6-13.0		3			1	1		1	3
13.1-13.5		2	4	1			7		7
13.6-14.0		1	1	2			3	1	4
14.1-14.5		2	4	3		1	7	1	9
14.6-15.0		2	2			1	2	1	4
15.1-15.5			6			1	2	3	6
15.6-16.0			1	1			1	1	2
16.1-16.5			2				1	1	2

rays. This means that all of the principal rays are segmented and that the counts are always one ray higher than the pterygiophore counts.

Principal rays in dorsal and anal fins of fish larger than 20 mm in size were counted by beginning from the short ray located adjacent to the longest unbranched ray. The values were distributed from 14 to 16 with a mode of 15 for dorsal fins, and from 16 to 20 with a mode of 18 for anal fins (Table 4).

Forty-three larvae which ranged in length from 11.3 to 16.4 mm were removed from the sample obtained at Akaoka, St. 13, and dorsal and anal fin pterygiophores were counted (Table 5). For those up to 13.0 mm, the counts increased in both fins as the larvae grew in size. For those over 13.0 mm, the counts ranged, regardless of larval size, from 13 to 15 for dorsal fins and from 16 to 18 for anal fins. The

distributions were comparable to those in Table 4. The results suggest that full numbers of dorsal and anal fin pterygiophores were present in larvae of about 13 mm long. The indication as to dorsal fin pterygiophores is in accordance with the observations on the development of the first dorsal pterygiophore.

Abnormalities seen in fin rays and pterygiophores

Deformations of fin rays were found in two dorsal and two anal fins, and deformations of pterygiophores were seen in nine dorsal and ten anal fins (Table 4).

The deformed fin rays occurred only in the fish sampled at Kamiiso, St. 3, on September 26, 1972 (Fig. 9). Abnormalities of fin rays of two dorsal fins showed a similar pattern. One unbranched ray, which had shrunk markedly, was supported serially by the first pterygiophore and had a scar from which a past break was inferable. The longest unbranched ray, rather than the first branched ray, articulated serially with the second pterygiophore (A). A similar unusual correspondence of an unbranched ray with the second pterygiophore was observed in the anal fin of one of the two fish with abnormal dorsal fin rays. In this case, shrinkage of the ray associated with the first pterygiophore was slight and no trace of a wound was detectable on the ray (B). Another deformation of anal fin rays observed was adhesion of the basal parts of two rays. The rays corresponded to the respective

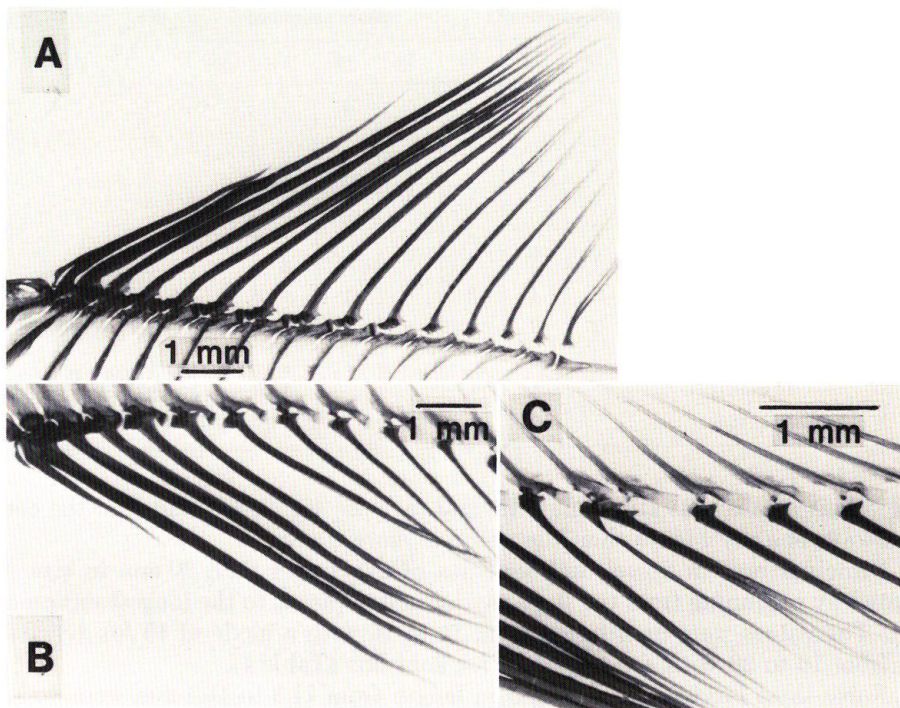


Fig. 9. Abnormalities in fin rays.

Deformed dorsal fin rays of a 77 mm-fish (A). Unusual serial association of an anal unbranched ray with the second pterygiophore seen in a 75 mm-fish (B). Adhesion of the basal parts of two anal fin rays in a 60 mm-fish (C).

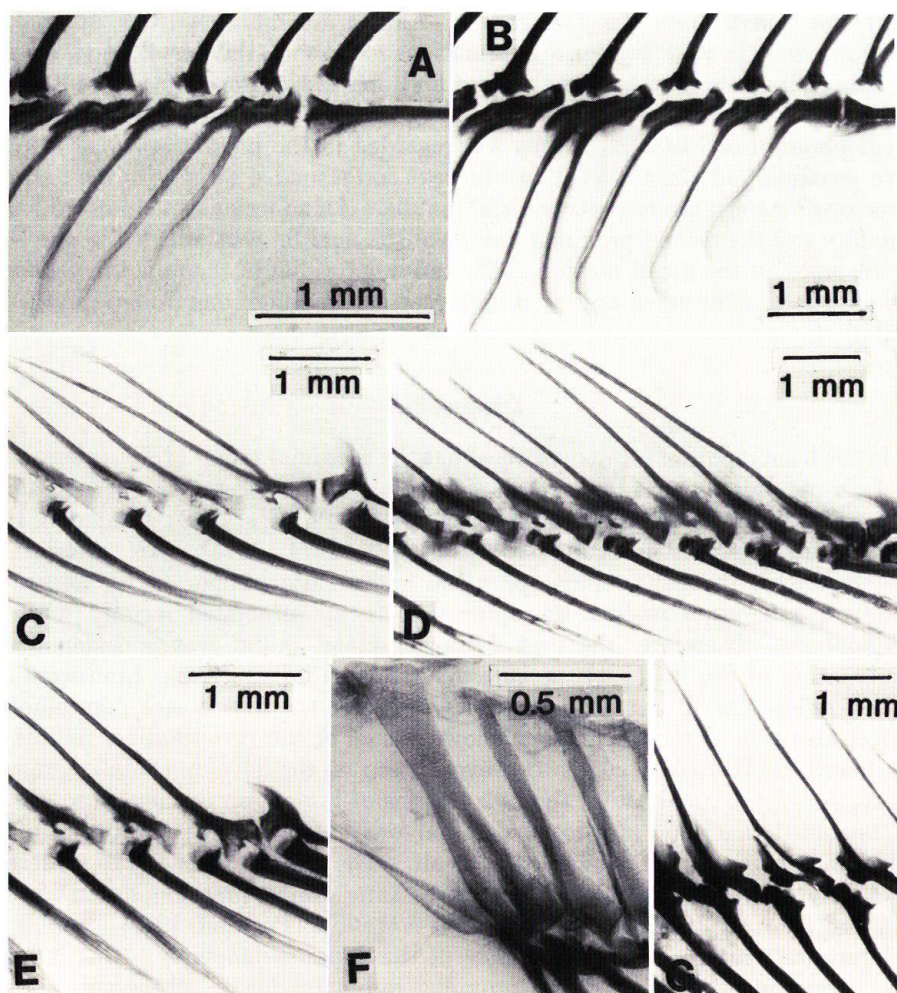


Fig. 10. Abnormalities of pterygiophores.

Inward bifurcation of a dorsal proximal radial appeared at the last pterygiophore in a 59 mm-fish (A) and at the fourth from the last pterygiophore in a 91 mm-fish (B). Inward bifurcation of an anal proximal radial appeared at the last pterygiophore in a 85 mm-fish (C) and at the fourth from the last pterygiophore in a 103 mm-fish (D). Bifurcation occurred at the distal end of the last anal proximal radial in a 68 mm-fish (E). Adhesion appeared on the inward halves of the two anteriormost anal proximal radials of a 29.0 mm-larvae (F). A crack occurred on the distal part of the anal proximal radial of a 141 mm-fish (G).

pterygiophores even though the anterior ray was feeble and the position of the posterior ray was shifted anteriorly (C).

Examples of deformed pterygiophores are shown in Fig. 10. All of the abnormalities in dorsal fin pterygiophores appeared as inward bifurcations of the proximal radial (A and B). Occurrence of the bifurcated radials was limited to the posterior portion of the fins. Among nine deformations, eight were seen at the last radial and

one at the fourth from the last radial. Among ten abnormalities in anal fin pterygiophores, six were similar malformations to those in the dorsal fin (C and D). Five occurred at the last proximal radial and one at the fourth from the last. A bifurcation of the distal end of the proximal radial was found in the last anal fin pterygiophore of one fish (E). This was regarded in the present study as a fusion of two proximal radials, since the two fin rays corresponded serially to the branches intervening between the respective distal radials. An adhesion of the inward halves of the first and the second proximal radials of the anal fin was detected in one larva (F). A crack in the distal portion of the proximal radial of the anal fin was found in two fish (G). The crack appeared in the seventh radial of one fish and in the last radial of the other.

Discussion

It has been reported for many fishes that the proximal radial of the anteriormost dorsal fin pterygiophore is larger than the radials of the succeeding pterygiophores and has a portion projecting forward (Bridge, 1896; Phillips, 1942; Chapman, 1944, 1948; Hikita, 1962; Weitzman, 1962; Potthoff, 1974, 1975). An anteriormost pterygiophore with such a large proximal radial also supported an additional spine(s) or soft-ray(s) besides the spine or soft-ray associated serially with the pterygiophore. Therefore, the first dorsal proximal radial was considered as a representation of the fusion of the anterior radials (Phillips, 1942; Lindsey, 1955; Kramer, 1960). As to the large proximal radial of the first dorsal pterygiophore which is also seen in the Japanese anchovy, fusion of the two proximal radials has been described (Hayashi, 1961). However, based on the developmental changes in the first dorsal proximal radial through a series of larval fish of increasing sizes, it was concluded that the first proximal radial was not formed by the fusion of the anterior radials but that it developed by itself. The same conclusion can be derived from a series of developmental changes in the anteriormost pterygiophore under the first dorsal fin of the blackfin tuna, *Thunnus atlanticus* (Potthoff, 1975), although its developmental features differ from those of the Japanese anchovy. On the other hand, formation of the first dorsal proximal radial by fusion of the two anterior radials was demonstrated for the white perch, *Morone americana* (Fritzsche and Johnson, 1980). Hence it follows that the enlarged first dorsal proximal radial, described for fish of many species, either developed by itself, or was formed by fusion of the anterior radials. For a determination of how the radial is formed, it is necessary to examine carefully the serial developmental changes in the anterior radials of the smaller larvae of the particular species. An exception was recorded by Bridge (1896); i.e., in a kind of catfish, *Platystoma tigrinum* [sic], the first dorsal proximal radial had three elements, which were more or less firmly united by suture throughout their entire length.

In the first anal proximal radial of the Japanese anchovy, fusion of the anterior radials was not seen, while this fusion was observed in the blackfin tuna (Potthoff, 1975) and the white perch (Fritzsche and Johnson, 1980).

The numbers of dorsal and anal fin rays of the Japanese anchovy have been recorded differently by different authors. Uchida (1958) described as D. II, 13~14 and A. II, 14~17; Hayashi (1961) as D. 13~17 with a mode of 15 and A. 15~20

with a mode of 17 ($N=9,080$); Hayashi and Tadokoro (1962) as D. 14~17 with a mode of 15 and A. 15~19 with a mode of 17 ($N=800$); Kinoshita (1962) as D. 14~17 with a mode of 15 ($N=4,790$) and A. 16~22 with a mode of 18 ($N=4,767$); taxonomists as D. 14 and A. 18. Uchida's description should be read as D. 15~16 and A. 16~19, which clearly indicates that he counted the rays using the same criteria as those in the present study. Kinoshita's method of counting was the same as that used in this report. Hayashi counted the fin rays based on the one-to-one relationship between the fin rays and their pterygiophores, but he mistook the first dorsal pterygiophore for fusion of the two anterior bones and assigned two rays to the pterygiophore and one ray to the first anal pterygiophore. In his counts, which include that of Hayashi and Tadokoro, the longest unbranched ray in the dorsal fin was therefore counted as the second and the longest unbranched ray in the anal fin as the first. However, in the anal fin, as in the dorsal fin, a segmented short ray which is situated immediately anterior to the longest unbranched ray should be counted as the first, because the short ray is not vestigial and thus there is no reason to exclude it from the count. Based on the above, it can be concluded that the numbers of principal rays in the dorsal and anal fins of the Japanese anchovy are D. 13~17, with a mode of 15, and A. 16~22, with a mode of 18.

McHugh (1951) counted dorsal and anal fin rays of the northern anchovy, *Engraulis mordax*, including all rays, however small, which could be seen without dissection. In the anchoveta, *Cetengraulis mysticetus*, also a member of the family Engraulidae, this criterion was used by Howard (1954). On the other hand, Berdegué (1958) counted anal fin rays in fish of this species by removing the scale sheet from the fin. He discovered a first fin ray by this simple dissection and concluded that Howard's counts were all one less than his counts. No information is available for judging which of the methods is more accurate. But it should be emphasized that counts of dorsal and anal fin rays in fish, especially in engraulid fish, should be made using well-defined and reasonable criteria.

In order to photograph dorsal and anal fin pterygiophores of larvae, aniline blue technique was used in the present study. This was a temporary expedient. Dingerkus and Uhler (1977) dyed cartilage in deep blue and bone in dark red by applying Taylor's (1967) enzyme clearing process to alcian blue stained specimens. Fritzsche and Johnson (1980) stained pterygiophores found under the dorsal and anal fins of the larvae of the white perch and the striped bass, *Morone saxatilis*, using a modified Dingerkus and Uhler's technique, and obtained satisfactory results. Dingerkus and Uhler's technique, along with its modified form, can be expected to be effective for dyeing fish bones, especially for dyeing cartilaginous bones of larval fish.

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