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Changes with Growth in Bony Cranial Projections and Color Patterns in the Japanese Boarfish, *Pentaceros japonicus*

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Abstract Bony cranial projections and color patterns in *Pentaceros japonicus* Döderlein of various stages of growth were studied. In the jevenile, bony cranial projections were well developed and cloud-shaped markings were found on the side of body. Both the projections and markings disappeared by the time the fish attains 94.0 mm in standard length, but the markings remained in the specimen of Shiriya collected in a floating seaweed.

This species seems to shift the habitat from surface layers to deeper water at the stage when the projections and markings disappear.

Introduction

Pentaceros japonicus Döderlein in Steindachner and Döderlein (1883) occurs in the temperate and subtropical seas southward from Honshu. Recently one young specimen, 136.5 mm in standard length, was collected in a floating seaweed off Cape Shiriya (41°30′N, 142°00′E), Aomori Pref., Japan.

The adults have usually been caught in the depth between 300 and 400 m. The bony cranial projections and cloud-shaped, mottled color patterns on the side of body peculiar to the juvenile of this species have been noticed by many authors, i.e., Abe (1957), Hiyama and Yasuda (1961), Tomiyama and Abe (1963), Kuroda (1969), and Tabeta et al. (1976). However, the process and stage of disappearance of these juvenile characters have remained unknown.

The present authors examined 20 specimens of *P. japonicus* of various stages of growth from the Pacific off Japan. These specimens enabled us to elucidate the process of disappearance of the projections and markings.

The generic classification of this species, for which Jordan (1907) established the genus *Quinquarius*, followed Follett and Dempster (1963) who united the genera *Pseudopentaceros* and *Quinquarius* with *Pentaceros*.

Material and methods

Sampling data for the specimens dealt with in the present study are given in Table 1. These specimens are deposited in the Museum of Tokyo University of Fisheries (MTUF and TUFO), the Section of Zoology, University Museum, University of Tokyo (ZUMT), Ehime Prefectural Fisheries Experiment Station (EPFES), Iwate Prefectural Fisheries Experiment Station (IFES) and Shimonoseki University of Fisheries (SUF).

Counts and measurements were generally made according to the methods of Matsubara (1955); those to be especially mentioned are as follows: head length was measured from the tip of snout to the posteriormost margin of opercular flap; the interorbital width is the greatest distance between the tips of supraorbital processes, when the processes are present. Vertebral counts were taken from radiographs, counting the urostylar vertebra as one. The length of a fish is expressed as the standard length, unless otherwise indicated. The terminology of bony cranial projections followed that of Okiyama (1964) (Fig. 1). Coloration was observed on formalin specimens.

Results

Five different stages as given below are recognized in juvenile to adult specimens according to the feature of bony cranial projections, color patterns and size:

1) First stage represented by a specimen, 9.0 mm. This specimen has a bony cranial

Table 1. Sampling data of the specimens studied of *Pentaceros japonicus*. Specimens with the abbreviations EPFES, IFES and SUF are those loaned from Ehime Prefectural Fisheries Experiment Station, Iwate Prefectural Fisheries Experiment Station and Shimonoseki University of Fisheries, respectively. Bars indicate that the capture data are unknown.

Catalog number	Standard length (mm)	Date	Locality (Lat. N, Long. E)	Depth (m)	Method
MTUF 21779	9.0	Feb. 21, 1971	Izu Is. (31°06′, 140°09′)	Surface	Larval net
TUFO 1278	13.0	Feb. 21, 1968	Ogasawara Is. (26°47′, 145°07′)	Surface	Larval net
MTUF 21780	14.2	Jan. 23, 1971	South off Honshu (31°40′, 137°20′)	Surface	Larval net
SUF	35.0	Mar· 6, 1974	Ryukyu Is. (28°00′, 130°30′)	Surface	Larval net
TUFO 1279	37.2	Mar. 2, 1971	Ogasawara Is. (26°00′, 142°00′)	Surface	Larval net
MTUF 21778	46.8	Feb. 28, 1974	Hachijo I. (33°07′, 139°52′)	Surface	Gill net
ZUMT 12104	62.0	1922 or 1923	Tokyo Central Wholesale Market	—	—
MTUF 21772	62.5	Apr. 17, 1976	Hachijo I. (33°07′, 139°52′)	Surface	Gill net
MTUF 21773	76.6	Apr. 17, 1976	Hachijo I. (33°07′, 139°52′)	Surface	Gill net
MTUF 21733	94.0	Nov. 20, 1974	Sea of Hyuga (ca. 32°00′, ca. 131°35′)	100	Trawl
MTUF 21734	98.5	Nov. 20, 1974	Sea of Hyuga (ca. 32°00′, ca. 131°35′)	100	Trawl
ZUMT 32842	104.5	—	Sea of Ensyu (ca. 34°30′, ca. 137°45′)	—	—
ZUMT 47115	108.2	—	Tosa Bay (ca. 33°15′, ca. 133°45′)	—	—
ZUMT 25599	113.0	Apr. 3, 1933	Onahama (ca. 37°00′, ca. 141°00′)	300～400	Trawl
MTUF 21212	121.0	Dec. 6～9, 1935	Sea of Kumano (ca. 34°00′, ca. 136°30′)	—	—
EPFES	122.2	1972	Bungo Channel (ca. 33°00′, ca. 132°15′)	—	Trawl
IFES 554	136.5	Aug. 28, 1973	Off Shiriya (41°30′, 142°00′)	Surface	Dip net
ZUMT 47214	147.5	—	Tosa Bay (ca. 33°15′, ca. 133°45′)	—	—
ZUMT 21686	156.0	Jun. 8, 1937	Tosa Bay (ca. 33°15′, ca. 133°45′)	—	—
MTUF 21774	225.0	Jul. 1976	Hachijo I. (33°18′, 142°11′)	240～300	Hook and line

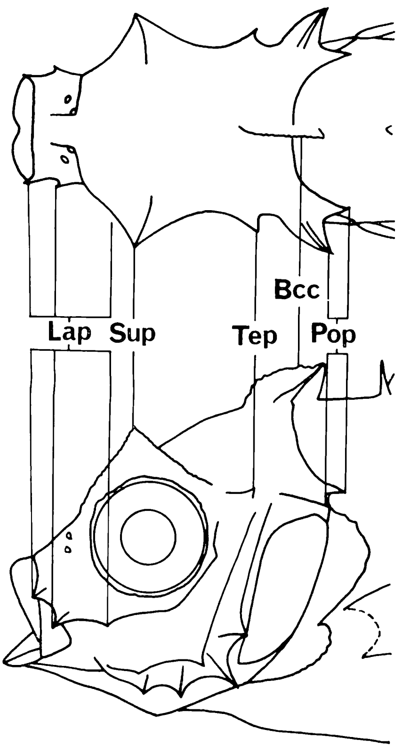

Fig. 1. Dorsal (top) and lateral (bottom) view of head of *Pentaceros japonicus*, MTUF 21780, 14.2 mm in standard length (6.9 mm HL) showing bony cranial projections. Bcc, bony cranial crest; Lap, lacrymal process; Pop, post-temporal process; Sup, supraorbital process; Tep, temporal process.

crest on the top of the head and on each side of the head a supraorbital process, a temporal process, a post-temporal process, and lacrymal processes. The bony cranial crest is large, serrated along its upper margin and pointed posteriorly. The supraorbital process takes the form of triangular, visor-like projection extending dorso-laterally. The temporal and post-temporal processes are plate-like, extending horizontally; the latter are larger and furcated posteriorly. The lacrymal processes are made up of two spines formed on the lower margin of the lacrymal. The preopercular margin has four strong spines, and the preopercular ridge is pointed at its angle.

The body is almost uniformly light brown, slightly darker posteriorly, with no cloud-shaped markings (Fig. 2, A).

2) Second stage represented by 2 specimens, 13.0 and 14.2 mm. The bony cranial projections are almost similar in structure to those of the foregoing specimen. Differences are seen in the lacrymal processes which are composed of three spines in this stage, and in the preopecular ridge, which forms a spine at its angle. The bony cranial crest assumes parallelogrammic shape. The margin of the supraorbital process is serrated.

The ground color of the body is brownish, with broad, dark brown, cloud-shaped markings (Fig. 2, B). There are pale blotches in front of the dorsal origin and at the base of the dorsal between the soft and spinous portions. The spinous dorsal, spinous anal, and pelvic fins are dark brown.

3) Third stage represented by 6 specimens, 35.0～76.6 mm. The bony cranial crest and supraorbital and post-temporal processes are reduced in size but still clearly appreciable. In front of the supraorbital process are two or three small processes. The temporal process is reduced into minute spine in the specimens of 46.8 mm or smaller, but is not recognizable in larger ones. The lacrymal processes and spines on the preopercular margin are transformed into serratures. The radial striae on the lacrymal and preopercle end as serratures along their margins. The serration is finer in larger individuals. The preopercular ridge is not noticeable.

Dark brown cloud-shaped patterns are well developed on the side of the body (Fig. 2, C). The markings are narrower and more complicated in larger samples (Fig. 2, D). The spinous portions of the dorsal and anal fins, the membranes of the pelvic fin and the base of the pectoral fin are dark brown.

4) Fourth stage represented by 5 specimens, 94.0～113.0 mm. The bony cranial crest, supraorbital and post-temporal processes are rudimentary, taking the form of small ridges. The lower margin of the lacrymal and the whole edge of the preopercle are finely serrated.

Vague trace of cloud-shaped body markings is seen in 2 specimens of 94.0 and 98.5 mm (Fig. 2, D), and the markings are absent in other specimens, in which the body is uniformly light brown.

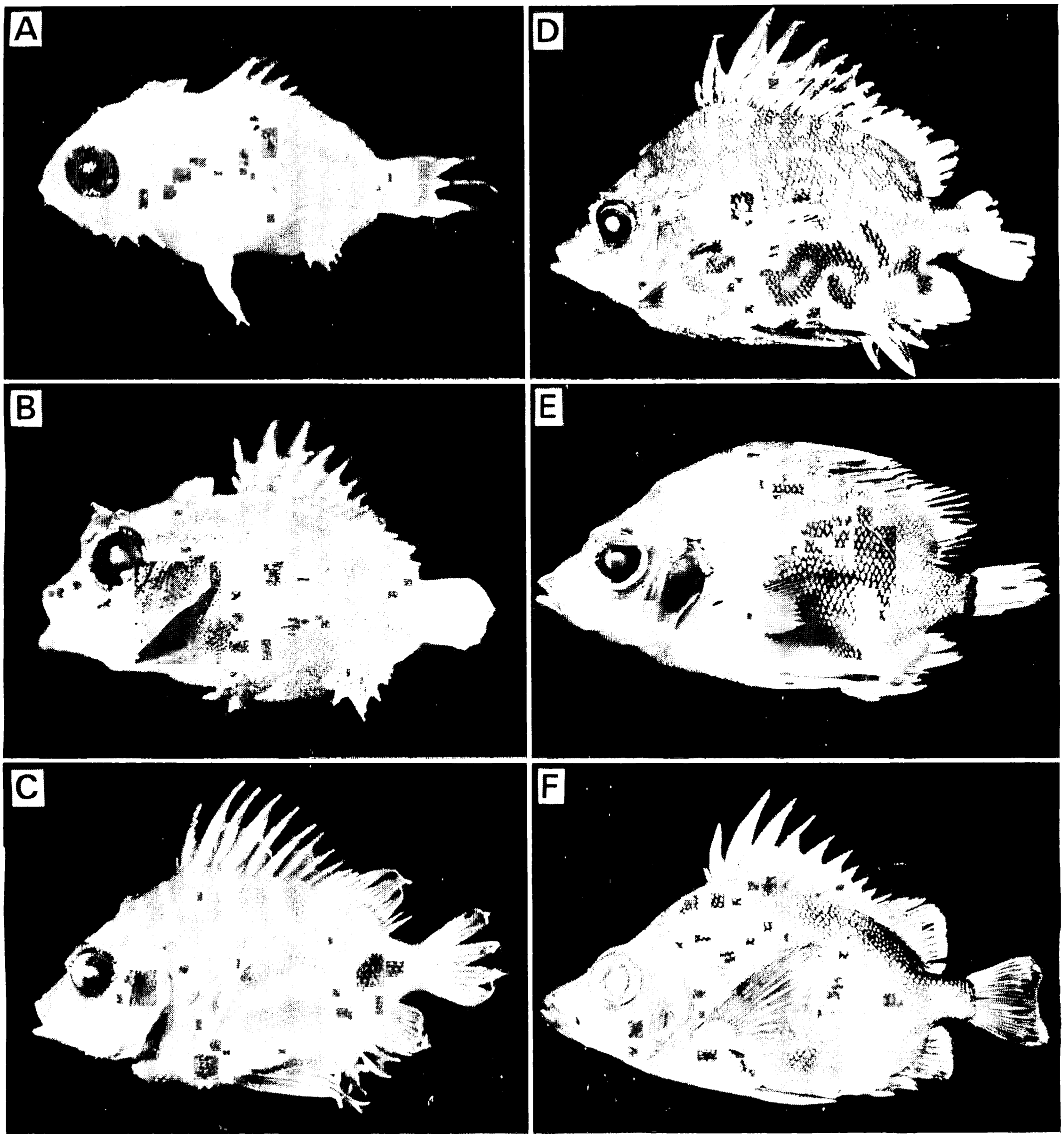

Fig. 2. Change with growth in color patterns in *Pentaceros japonicus*. A, MTUF 21779, 9.0 mm SL; B, MTUF 21780, 14.2 mm SL; C, MTUF 21778, 46.8 mm SL; D, MTUF 21773, 76.6 mm SL; E, MTUF 21733, 94.0 mm SL; F, MSUF 21774, 225.0 mm SL.

5) Fifth stage represented by 6 specimens, 121.0～225.0 mm. These specimens show no bony cranial projections except the specimen from Shiriya, 136.5 mm, which retains the rudimentary bony cranial crest and supra-orbital process. The lower margin of the lacrymal and the whole margin of the pre-opercle are very finely serrated.

The body is light brown, marked with no cloud-shaped patterns (Fig. 2, F). However, the specimen captured from Shiriya was remained markable cloud-shaped patterns on the side of body. The membranes of the spinous dorsal, spinous anal, and pelvic fins are dark brown.

To sum up, the bony cranial projections are already well-developed in the smallest specimen at hand, 9.0 mm, therefrom they

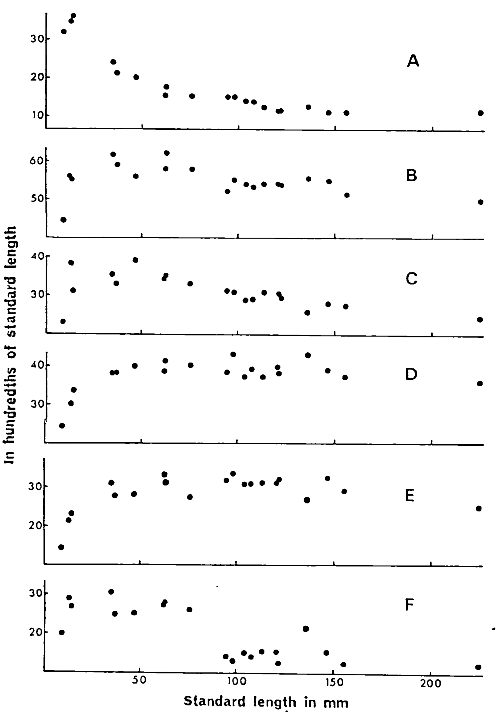

Fig. 3. Proportional measurements of body parts of *P. japonicus*. A, interorbital width; B, body depth; C, pelvic length; D, dorsal spinous base length; E, longest (3rd~4th) dorsal spine length; F, width between pelvic origins.

become reduced with growth. Whereas the cloud-shaped patterns appear in the individual of 13.0 mm and become most distinct in the medium-sized juvenile specimens between 35.0 and 76.6 mm. Both the bony projections and cloud-shaped patterns disappear in the same stage of growth, viz. 76.6 to 94.0 mm, except the specimen from Shiriya.

Table 2 compares meristic counts and proportional measurements for the specimens presently dealt with. While the interorbital width becomes narrower with growth (Fig. 3, A), there is a trend toward increase in the lengths of the body depth (Fig. 3, B), the pelvic fin (Fig. 3, C), dorsal spinous base (Fig. 3, D) and longest (3rd~4th) dorsal spine (Fig. 3, E) until the fish reaches a little more than 50.0 mm. There is a distinct turning point in the width between the pelvic origins at a standard length between 76.6 and 94.0 mm (Fig. 3, F). In specimens of 76.6 mm and smaller, the interpelvic space is broad, more than 20% of standard length, and flat, whereas it abruptly reduces in size, less than 16%, in specimens of 94.0 mm and larger except a Shiriya specimen. This turning point coinsides with the stage when the bony cranial projections and cloud-shaped markings disappear.

Discussion

Abe (1957) refers to the presence of supraorbital process in a 45.5 mm juvenile of *P. japonicus*, but makes no mention of other bony projections and of the juvenile color patterns. Tomiyama and Abe (1963) state that juveniles of the species have dark, irregular patterns. Kuroda (1969) reports that bony cranial projections and cloud-shaped patterns are seen in a sample of 87.0 mm in total length, but both of characters are not found in 2 specimens of 130.0 and 157.0 mm in total length, respectively. Tabeta et al. (1976) show well-developed bony cranial projections in specimens from 11.7 to 37.8 mm, well-marked, cloud-shaped patterns in a 37.8 mm specimen, and the absence of the projections and markings in a larger individual of 100.0 mm. However, the specimen of Shiriya, 136.5 mm in standard length, shows well-developed cloud-shaped patterns on the side of the body. Each of these descriptions except the specimen of Shiriya agrees well in the feature of the bony cranial projections and body markings with one of the above-noted five stages of similar size.

Though there are no studies so far made on the early life history of the species, the well-developed bony cranial projections and the flat and broad interpelvic space in our smaller specimens (9.0~76.6 mm) seem to represent morphological adaptation to pelagic life as is mentioned in many other fishes by Uchida (1937). With regard to the specimen of Shiriya, the cloud-shaped mottled patterns on the side of the body may also suggest its life associated with floating seaweed, considering that in *Oplegnathus fasciatus* (Temminck and Schlegel) the stage when juveniles begin to gather around floating seaweed corresponds to that of the formation of cross bands on the side (Uchida, 1926; Fukusho, 1975).

Incorporating all these observations and the sampling data for the specimens presently

Table 2. Proportional measurements in hundredths of standard length and counts of *Pentaceros japonicus*. Mean of each measurement is indicated in bracket. Bars indicate that countings were impossible.

Stage	1	2			3		4		5	
No. of specimens	1	2			6		5		6	
Standard length (mm)	9.0	13.0,	14.2		35.0~76.6		94.0~113.0		121.0~225.0	
Body depth	44.4	56.2,	55.6	(55.9)	56.2~62.4	(59.2)	52.1~55.2	(53.6)	49.6~55.7	(53.5)
Head length	44.4	46.2,	48.6	(47.4)	36.3~42.9	(38.5)	38.5~40.3	(39.5)	35.5~40.2	(38.9)
Snout length	11.1	13.8,	13.4	(13.6)	10.8~13.1	(12.1)	13.7~15.7	(14.5)	13.2~15.6	(14.9)
Eye diameter	13.3	16.2,	17.6	(16.9)	9.5~14.0	(11.5)	12.0~12.4	(12.1)	9.5~12.0	(11.3)
Upper jaw length	13.3	15.4,	15.5	(15.45)	11.2~12.9	(11.7)	11.5~12.8	(12.1)	10.3~12.9	(11.7)
Interorbital width	32.2	35.4,	36.6	(36.0)	15.6~23.4	(19.0)	12.9~14.9	(14.1)	11.1~14.7	(12.6)
Caudal peduncle depth	12.2	15.4,	15.5	(15.45)	12.8~14.6	(13.8)	12.0~12.4	(12.2)	11.1~11.7	(11.4)
Pectoral length	22.2	31.5,	31.7	(31.6)	30.4~34.3	(31.7)	34.2~36.7	(35.7)	28.6~38.3	(35.2)
Pelvic length	23.3	36.2,	31.0	(33.6)	33.3~38.9	(35.2)	28.9~31.5	(30.2)	24.3~30.6	(27.6)
Width between pelvic origins	20.0	29.2,	26.8	(28.0)	25.0~30.6	(27.2)	13.2~15.7	(14.4)	12.3~21.4	(15.0)
Dorsal spinous base length	24.4	30.1,	33.8	(32.0)	38.0~41.6	(39.5)	37.2~43.2	(39.1)	36.0~42.9	(38.7)
Dorsal soft base length	20.0	18.5,	16.2	(17.4)	16.1~22.2	(19.3)	18.8~22.4	(20.5)	19.0~21.8	(20.3)
Anal base length	21.1	23.1,	19.7	(21.4)	22.4~24.6	(23.7)	22.3~26.4	(24.1)	21.3~27.0	(23.7)
Longest (3rd~4th) D. spine length	14.4	21.5,	23.2	(22.4)	27.4~33.1	(29.8)	30.7~33.7	(31.6)	24.7~32.7	(29.4)
Longest (1st~2nd) A. spine length	10.1	9.2,	12.0	(10.6)	11.3~17.4	(14.3)	15.1~17.4	(16.3)	12.9~18.7	(16.2)
Dorsal fin rays	X, 15	XI, 14	XI, 13		XI~XII, 12~14		XI~XII, 13~14		XI~XII, 12~14	
Anal fin rays	IV, 11	V, 9	V, 8		IV~V, 9~10		IV~V, 8~9		IV~V, 8~9	
Pectoral fin rays	17	17	17		17		15~17		16~18	
Pored scales in lateral line	—	—	—		48, 50		47~55		47~54	
Scales above lateral line	—	—	10		10		9~10		9~10	
Scales below lateral line	—	—	29		28~30		27~30		28~31	
Gill rakers	—	—	—		6~8+16~18=23~25		7~8+17~18=24, 26		7~8+17~18=24~26	
Vertebrae	—	—	—		12+13 (MTUF 21772 11+14)		12+13		12+13	

Table 3. Comparison of measurements (% of SL) and counts among four species of *Pentaceros*. Data of *P. japonicus* were quoted from the present specimens, Steindachner and Döderlein (1883), Abe (1957), Follett and Dempster (1963) and Kuroda (1969); *P. capensis* from Cuvier and Valenciennes (1829), Barnard (1937), Smith (1951,1964) and Follett and Dempster (1963); *P. decacanthus* from Günther (1859) and Smith (1964); *P. hendecacanthus* from McCulloch (1915) and Smith (1964).

Species	*japonicus*	*capensis*	*decacanthus*	*hendecacanthus*
Distribution	Japan	South Africa	Atlantic and Pacific Oceans	South Australia
Body depth	44.4～62.4	43.5～58.8	ca. 58.8	55.6
Head length	35.5～48.6	33.3～37.0	33.3	35.7
Dorsal fin rays	X～XII, 12～15	XII～XIII, 12	XI, 13～14	XI, 13～15
Anal fin rays	IV～V, 8～11	IV～VI, 7～8	IV, 8～9	IV,10～11
Pectoral fin rays	15～77	16～17	—	17
Pored scales in L. l.	46～55	46～50	50～52	45～47
Scales above L. l.	9～11	7	—	10
Scales below L. l.	28～32	27～28	—	32
Predorsal scales	10～13	10	—	9
Gill rakers	6～8+16～18	5～6+15～17	5～6+13	6～7+15～18
Vertebrae	12+13 or 11+14	12+13		

examined (Table 1), it may be concluded that juveniles of *P. japonicus* possessing the bony cranial projections live in surface layers, and begin to take shelter among floating seaweed when they attain a standard length of about 13.0 mm, the stage when the cloud-shaped patterns appear. With the exception of the Shiriya specimen, the occurrence of the specimens of 94.0 mm and larger, which have no bony projections nor cloud-shaped markings, in the depth from 100 to 400 m (Table 1) indicates that juveniles generally shift from pelagic to bottom life when they reach a standard length between 76.6 and 94.0 mm. The Shiriya specimen retains juvenile feature in having bony cranial projections, cloud-shaped patterns and broad interpelvic space. The retention of juvenile feature seems to be resulted from the life of the specimen associated with a floating seaweed for an unusually long period.

Bony cranial projections have been recorded in juveniles of the South African *P. capensis* Cuvier in Cuvier and Valenciennes (1829) ranging from 63.0 to 75.0 mm in total length (Barnard, 1927, 1937; Smith, 1951, 1964) and in a 103.0 mm juvenile specimen of *P. hendecacanthus* McCulloch (McCulloch, 1915). Also, the presence of both bony cranial projections and cloud-shaped patterns has been reported in two juvenile specimens of *P. decacanthus* Günther of 34.0 and 54.0 mm, the only two known specimens of the species, one taken from the Pacific and the other from the southwestern Atlantic (Günther, 1859; Smith, 1964).

Comparison of known meristic and morphometric characters for these three species and *P. japonicus* (Table 3) shows overlaps to a great extent in all respects. The morphological similarity of these four species, as well as the absense of the record of adult *P. decacanthus* and the scales which are more or less irregularly arranged on the side of body in these species and therefore may be subject to miscounting, may indicate that they all belong to one and the same species, as Follett and Dempster (1963) have already suggested. *Pentaceros decacanthus* may represent a mere age variation (Smith, 1964).

The juvenile of *P. richardsoni* Smith has bony cranial projections and cloud-shaped markings similar to those in the juveniles of *P. japonicus* (Steindachner, 1866, under the name *P. knerii*; Graham, 1953, Honma and Mizusawa, 1969). This fact should probably indicate ecological similarity as well as phylogenetical affinity between the two species of juveniles.

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(Zama and Yasuda: Ichthyological Laboratory, Tokyo University of Fisheries, 4-5-7 Konan, Minato-ku, Tokyo 108, Japan; Asai: Tokyo Metropolitan Fisheries Experiment Station, Mitsune, Hachijo Town, Tokyo 100-15, Japan).

ツボダイの成長に伴う頭部骨質突起と斑紋の変化

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ツボダイ稚魚期にみられる成長に伴う頭部骨質突起と雲形斑紋の変化を明らかにした．頭部骨質突起は標準体長 9.0 mm の個体ですでによく発達していて，雲形斑紋は体長 13.0 mm から出現し始めるが，青森県尻屋崎沖の表層で採集された体長 136.5 mm の個体を除くと，頭部骨質突起および雲形斑紋は体長 94.0 mm に達するまでに消失する．採集された水深との関係から判断すると，頭部骨質突起と雲形斑紋の発達した個体は表層で遊泳生活を送っていると考えられ，表層から底層への移行に伴ってこれらが消失すると推察される．

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