Japan. J. Ichthyol.
40(2): 237–245, 1993

魚類学雑誌
40(2): 237–245, 1993

A Young Basking Shark, *Cetorhinus maximus*, from Japan

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(*Received March 1, 1993; in revised form June 2, 1993; accepted June 23, 1993*)

Abstract A young, female basking shark, *Cetorhinus maximus* (total length 2.6 m) captured off the Pacific coast of Honshu, Japan, in early May 1977 was examined and estimated to be less than 6 months old, judging by the number of calcified rings in the vertebral centra. The elongate, hook-like snout with a ventral groove continuous with the palate is considered a characteristic juvenile feature of *Cetorhinus*, found only in very young specimens. It is thought that the snout structure is related to juvenile feeding, probably both in the mother's womb, if oophagy in fact occurs, and during the early, free-living stage, when the snout shape may increase the efficiency of water flow into the mouth. The likely rapid change from the juvenile snout condition to the adult type is probably produced by allometric growth of the rostral cartilages. The size and estimated age of the specimen conform well to a growth curve derived from Atlantic and Mediterranean basking sharks, indicating that no significant differences exist in age/length relationships of *Cetorhinus* populations world-wide.

A young female basking shark, *Cetorhinus maximus* (Gunnerus, 1765) (total length 2.6 m) was captured off Wagu, Pacific coast of Honshu, Japan, on May 4th, 1977. Because of its unique, hook-like snout, the shark, which had already been gutted and divided at the origin of the first dorsal fin base, was taken to the Toba Aquarium for examination. The peculiar juvenile snout notwithstanding, the combination of lunate caudal fin, enormously large gill openings, long gill rakers and very minute teeth sets *Cetorhinus* apart from all other sharks. The monotypic status of *Cetorhinus*, as recognised by Bigelow and Schroeder (1948) and Springer and Gilbert (1976), is followed here.

Inshore shoals of basking sharks habitually appear in Japan in spring, especially about the equinoctial week (Yano, 1976). Some 1200 basking sharks were caught for liver oil in Shima Province during 12 years to 1976, chiefly by spear, but catches subsequently decreased considerably (Yano, 1978). Capture of young individuals less than 3 m long is very rare in any ocean and the biology of the species is still poorly known. Only four free-living specimens of less than 2.6 m length are recorded thus far, from the Atlantic and Mediterranean: 1.65 m (Bigelow and Schroeder, 1948); 1.8 m (Parker and Stott, 1965); 2.54 m (Pengelly, 1881); and 2.6 m (Bigelow and Schroeder, 1948). It is known that the young snout form differs from that of the adult, the proportional length of the former being larger, but details of the shape and structure are poorly known. Various descriptions from young specimens (see Pavesi, 1874, 1878) are likely to be inaccurate, owing to the condition of the latter, as pointed out by Matthews and Parker (1950). In addition, specimens are rare and growth changes after birth rapid. Since the capture of the specimen considered here, no further small juveniles have come to hand. In this paper a description of the 2.6 m, Japanese *C. maximus* is given, together with the anatomy of the neurocranium and an age-estimation from the calcified rings of vertebral centra. The age/length relationship, implications of the juvenile snout form and a mechanism for its change to the adult form are considered.

Material and Methods

The specimen was captured near the Kaminoshima islet, off Wagu, Shima Peninsula, Pacific coast of Honshu, Japan, 34°12′N–136°49′E, in a gill-net

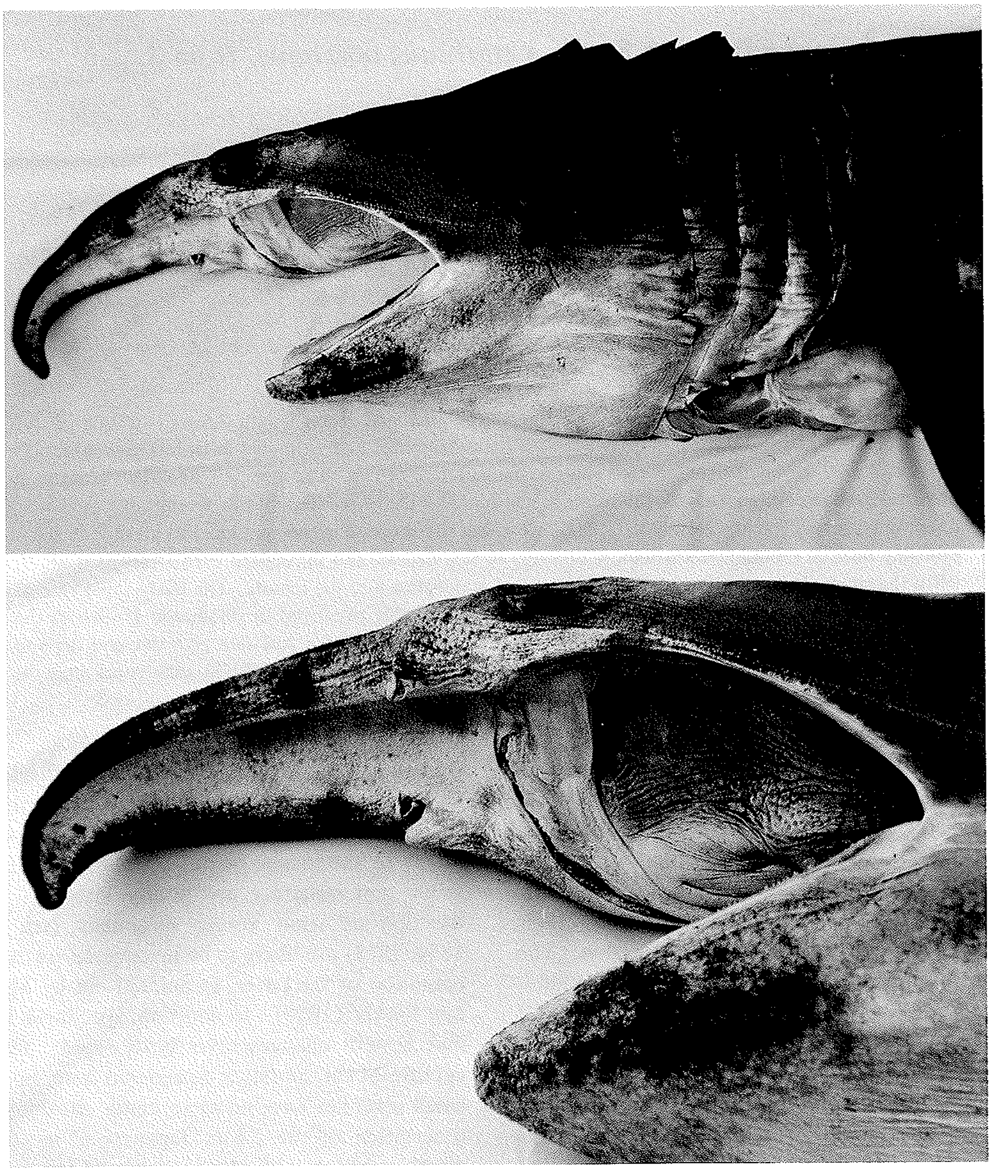

Fig. 1. *Cetorhinus maximus*, 2.6 m TL (female) obtained from the Pacific coast of Honshu, Japan on May 4th, 1977. *Top*—lateral view of anterior half of body. *Bottom*—ventrolateral view of snout and mouth.

set for spanish mackerel in 2.5 m water depth, on May 4th, 1977. Measurements along the body axis were taken on a horizontal line between perpendiculars at given points, the two pieces of the body being rejoined as accurately as possible. Because the snout was curved down and backwards, the anterior end of the subterminal portion of the snout was taken as the snout tip. Slices of vertebrae for age-estimation were taken from trunk vertebrae at the origin of the first dorsal fin base and a caudal vertebra slightly posterior to the cloaca, and preserved in weak formalin solution for observation. The ring radius (distance between the centrum center and inner margin of each calcified ring) and centrum radius were measured by micrometer along two axes (vertical, upper and lower radii; horizontal, left and right radii) in

Table 1. Measurements (mm) of a female *Cetorhinus maximus* obtained from Japan on May 4th, 1977. Proportional dimensions in per cent of total length are shown in parentheses

Total length	2600	
Fork length	2255	(86.7)
Tip of snout to:		
anterior margin of nostril	148	(5.7)
anterior margin of eye	197	(7.6)
anterior margin of upper lip	195	(7.5)
angle of jaws	367	(14.1)
spiracle	370	(14.2)
upper end of first gill opening	524	(20.0)
upper end of fifth gill opening	714	(27.5)
origin of pectoral fin	713	(27.4)
origin of first dorsal fin	1053	(40.4)
origin of second dorsal fin	1767	(68.0)
origin of pelvic fin	1478	(56.8)
origin of anal fin	1812	(69.7)
upper precaudal pit	2045	(78.7)
Distance from origin to origin of:		
first and second dorsal fins	714	(27.4)
second dorsal and caudal fins	278	(10.7)
pectoral and pelvic fins	765	(29.4)
pectoral and anal fins	1099	(42.2)
Depth and width at level of:		
just anterior to nostril	74×106	(2.8×4.1)
nostril	81×128	(3.1×4.9)
eye	96×146	(3.7×5.6)
first gill opening	291×—	(11.2×—)
first dorsal fin origin	307×181	(11.8×7.0)
second dorsal fin origin	161×150	(6.2×5.8)
pelvic fin origin	232×178	(8.9×6.8)
just anterior to precaudal pit	85×123	(3.3×4.7)
Minimum distance between nostrils	55	(2.1)
Width of nostril	29	(1.1)
Eye diameter (horizontal)	27	(1.0)
Length of gill opening in circumference:		
first	565	(21.7)
second	482	(18.5)
third	416	(16.0)
fourth	320	(12.3)
fifth	310	(11.9)
First dorsal fin:		
length of base	225	(8.7)
height	216	(8.3)
length of free base	72	(2.8)
Second dorsal fin:		
length of base	74	(2.8)
height	76	(2.9)
length of free base	68	(2.6)
Pectoral fin:		
length of base	132	(5.1)
length of anterior margin	397	(15.3)
length of posterior margin	338	(13.0)
Pelvic fin:		
length of base	140	(5.4)
height	100	(43.8)

Table 1. Continued

Anal fin:		
length of base	66	(2.5)
height	62	(2.4)
length of free base	52	(2.0)
Caudal fin:		
length of upper lobe (from upper precaudal pit to tip)	695	(26.7)
length of lower lobe (from lower precaudal pit to tip)	365	(14.0)
height	695	(26.7)
length (on horizontal line)	555	(21.3)
length from pit to fork on horizontal line	210	(8.1)
Lateral keel:		
length	252	(9.7)
maximum height	17	(0.6)

the transverse section, under a binocular microscope with transmitted light.

Results and Discussion

Morphometrics and general features

Measurements and proportions in total length (TL) are shown in Table 1. The snout length (snout tip to anterior margin of upper lip), 7.5% TL, is distinctly longer than in larger individuals, proportions of 6.5% TL in a 3.6 m female from St. Augustine, Florida, 4.7% TL in an 8.3 m female from Sarasota, Florida and 5.0% TL in an 8.5 m male from Drake's Bay, California, being listed by Springer and Gilbert (1976). Judging from the absence of claspers, the specimen was considered to be a female. Springer and Gilbert (1976) mentioned that the prepelvic length (snout tip to pelvic origin) is longer in females than in males, being 56.6% TL, 52.7% TL and 39.7% TL, respectively, in the three specimens listed above. The prepelvic length of 56.8% TL in the present specimen is keeping with former values.

The body is wider than deep at the head and postpelvic portion, and deeper than wide along the trunk. Well-developed lateral keels and precaudal pits are present. The skin is bluish dorso-laterally and pale ventrally, with rough dermal denticles. The eye is bluish black and the mouth large, being well extensible due to the loose articulation of the jaws. Three or four rows of small nodular teeth (about 2 mm long) are present throughout the entire length of both jaws, except for a narrow portion in the middle of the upper jaw (Fig. 1), being a somewhat fewer number of rows than in the 8.3 m adult female reported by Springer and Gilbert (1976). The tongue is voluminous and the gill rakers welldeveloped, about 45 mm (1.73% TL) in length on the central portion of the gill arch, a slightly smaller proportion than in a fully grown individual. The longest gill rakers known (150 mm, 1.81% TL) were reported for the 8.3 m specimen by Springer and Gilbert (1976).

No parasitic copepods were found, although four species belonging to the Siphonostomatoida have been reported from *Cetorhinus* (see Matthews and Parker, 1950; Kabata, 1979).

Age estimation

Calcified rings of the vertebral centra were used for age estimation. Such rings were distinct in the intermedialia, interposed by the radial cartilages (basineural and basihemal cartilages), in transverse sections (Fig. 2A, C). The calcified lamellae were narrow and whitish in reflected light, but dark in transmitted light, while the broad cartilaginous zones were dark in reflected light but bright in transmitted light. Images of two different, transverse and longitudinal vertical sections (Fig. 2) showed that the calcified lamellae were formed as closed concentric tubes intervening between the double cones. Seven complete and one peripheral, incomplete ring could be seen in both the precaudal and caudal vertebrae. The eighth calcified ring was distinct in the dorsal and ventral intermedialia, but was incomplete in the lateral intermedialia. As seen in Figure 2A and C, the calcified lamellae occasionally showed ramification and fusion. Ring and centra radii are shown in Table 2 as means of four measurements, but the eighth ring radius is a mean of the (two) vertical measurements only. The centrum radius of the

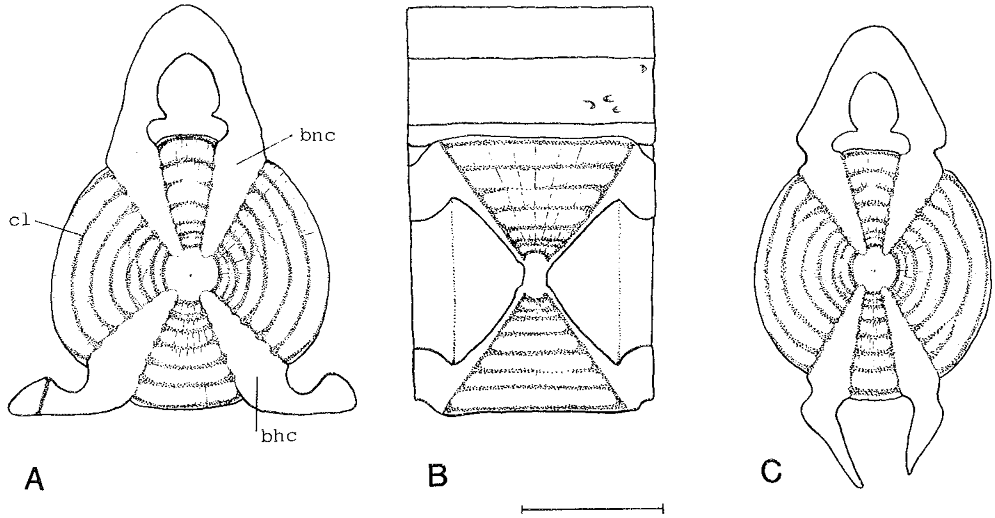

Fig. 2. Section of the vertebrae showing calcification. A) transverse section of a trunk vertebrae at the first dorsal origin; B) longitudinal vertical section of a trunk vertebra at the first dorsal origin; C) transverse section of a caudal vertebra slightly posterior to the cloaca. Abbreviation: *bnc*—basineural cartilage; *bhc*—basihemal cartilage; *cl*—calcified lamella. Scale indicates 20 mm.

caudal vertebra is about 10% smaller than that of the trunk vertebra, but no difference in the number of calcified rings was found.

A young trunk vertebra with seven calcified rings was illustrated by Ridewood (1921, fig. 13A), although the fish length was unknown. The illustration is very similar to that presented here, except for the incomplete eighth ring in the latter. Similar trunk vertebrae were illustrated by Gervais and Gervais (1876, pl. 15, figs. 1, 2) from a 3.65 m specimen from Concarneau, Finistere, in which eight complete calcified rings, accompanied peripherally by a cartilaginous marginal zone can be determined. Based on a comparison of their hypothetical asymptotic growth-curve from size/frequency analyses of available records with the observed relationship between length and the number of calcified rings in the vertebral centra, Parker and Stott (1965) suggested that at birth seven rings occur in the precaudal vertebrae, with two rings added annually thereafter. They further suggested a possible gestation period of three and a half years. If such suggestions are realistic, it follows that the present specimen, possessing an incomplete eighth ring, is almost 6 months old, having been born during the previous midwinter, probably about January. In Parker and Stott's (1965, fig. 3) relationship between the number of rings and fish length, derived from eight individuals ranging from 3.4 m to 8.77 m, lengths of about 1.9 m (for eight rings) and about 2.3 m (for nine rings) are given. Judging from the present specimen's length of 2.6 m (almost eight rings), their ring number's (age)/length relationship gives lengths too small for a given ring number. Following examination of the 8.3 m Sarasota specimen (16 complete calcified rings), Springer and Gilbert (1976) pointed out the same discrepancy for Parker and Stott's relationship, in which a length of about 5.2 m was estimated for 16 rings. Overcounting of rings seems to be a likely

Table 2. Mean ring radii (r) and centra radii (R) in a trunk vertebra at the first dorsal origin and a caudal vertebra slightly posterior to the cloaca of *Cetorhinus maximus*, 2.6 m TL (female), obtained from Japan on May 4th, 1977

	Trunk vertebra (mm)	Caudal vertebra (mm)
r–1	3.95	3.58
r–2	5.24	4.77
r–3	6.10	5.49
r–4	7.91	7.08
r–5	10.56	10.04
r–6	13.60	12.97
r–7	16.34	15.32
r–8	19.09	17.18
R	19.30	17.26

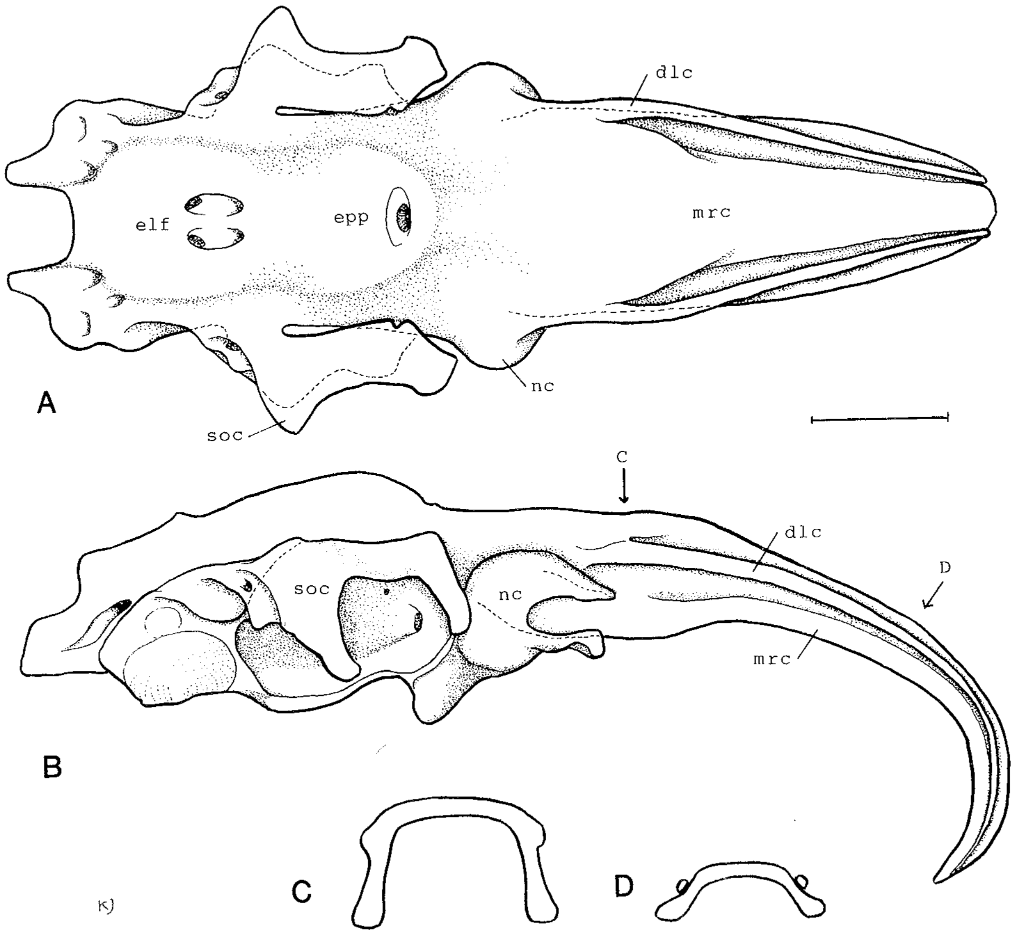

Fig. 3. The neurocranium of *Cetorhinus maximus*, 2.6 m TL. A) dorsal view; B) lateral view; C), D) transverse section by manipulation of the medial rostral cartilage at the points indicated by arrows in B). Abbreviation: *elf*—endolymphatic fossa; *epp*—epiphysial pit; *nc*—nasal capsule; *soc*—supraorbital crest; *mrc*—median rostral cartilage; *dlc*—dorsolateral rostral cartilage. Scale indicates 50 mm.

cause of the discrepancies in the ring number/length relationship of Parker and Stott (1965). On the other hand, Parker and Boeseman (1954) derived a growth curve from about 60 records of length and calendar month of capture in the Atlantic and Mediterranean. Age estimations (from the ring number) of the present specimen and Springer and Gilbert's (1976) Sarasota specimen as six months and four and a half years, respectively, show the lengths of the two specimens to conform well with Parker and Boeseman's (1954) growth curve. The latter estimated the length at birth to be about 1.8 m, with an average increase in length of 0.2 m per month during the six to eight months immediately thereafter, diminishing steadily to 0.06 m per month by the end of the fifth year. Although the present specimen is the only Pacific record with exact size/inferred age information, it suggests that significant differences in growth in *Cetorhinus* populations world-wide do not occur.

Snout and neurocranium

The snout anterior to the mouth is somewhat longer than the jaw, measured on a horizontal line. It is wider than high, gradually narrowing anteriorly and curving ventrally. The ventral surface of the snout is widely concaved, forming a remarkable lon-

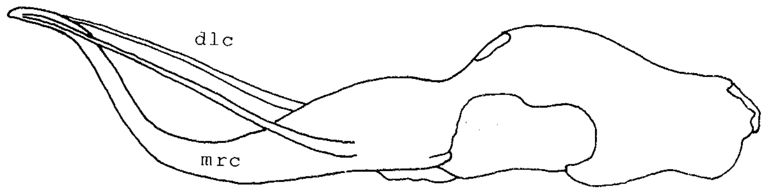

Fig. 4. The neurocranium of *Cetohinus maximus*, 2.95 m TL, lateral view exhibiting the likely transitional condition of the rostral cartilages, after Pavesi (1874).

gitudinal groove leading to the mouth (Fig. 1). This form of snout in a small juvenile is considered to be realistic, rathar than referable to distortion or shrinkage, as it showed no noticeable changes since capture of the specimen 16 years previously. The snout is supported throughout its length by rostral cartilages from the neurocranium and contains flabby ampullary tissue around the cartilages, especially in the proximal dorso-lateral portion. The neurocranium (Fig. 3) is slender and characteristic in having well developed rostral cartilages, which consist of a prominent median rostral cartilage (mrc) and paired rod-like dorsolateral cartilages (dlc). The median rostral cartilage is reversed U-shape in cross-section, forming a ventral groove, which is deeper proximally, becoming shallower distally (Fig. 3 C, D). The paired dorsolateral cartilages arise just in front of the nasal capsule (nc) and run alongside the median rostral cartilage to the tip. The supraorbital crest (soc) occurs as a narrowly-based, wing-like extension in the juvenile neurocranium. Cartilages connecting the dorsolateral rostral cartilages of both sides have been illustrated by Pavesi (1874, pl. 2, figs. 1, 2), termed "listerella interna" and "lista mediana," in his study of the neurocranial anatomy, but no such structures nor incorporation of the dorsolateral rostral cartilages about the middle of snout, as shown in his later study (1878, fig. 7), were observed here.

Pavesi (1874, pl. 2, figs. 1, 2) described the neurocranium of a 2.95 m specimen obtained from the Mediterranean, in which the median rostral cartilage was bent backward like a bow, probably resulting from the snout tip being drawn toward the base of the neurocranium by proportionally shortened dorsolateral cartilages, as illustrated in Figure 4. Such a condition of the rostral cartilages explains the snout shape found in 3–4 m specimens, in which the snout is stout and ends in a dorsally pointed prominence. Examples of this form of snout have been given by de Capello (1870, 3.82 m), Pavesi (1874, uncertain length, 2.95 m; 1878, 2.76 m, 3.25 m), Gervais and Gervais (1876, 3.65 m), Carazzi (1904, 3.37 m), de Buen (1925, 3.35 m?), Barnard (1925, 3.36 m), Bigelow and Schroeder (1948, 3.66 m), Matthews and Parker (1950, probably ca. 3 m), and Matthews (1962, uncertain length). These specimens were presumably fish of the year, considering that a length of 4.0 m is obtained in the first year after birth, according to Parker and Boeseman's growth curve. It seems certain that the snout shape alters with growth, as mentioned by Bigelow and Schroeder (1948). Although the last-mentioned authors stated that the snout of their 3.66 m specimen was the juvenile form, it can be strictly regarded as already transitional toward the adult type. It may be safely said that the snout changes its shape and relative length rapidly during the year after birth. The condition of the rostral cartilages described by Pavesi (1874) from a 2.95 m specimen hints at the mechanism producing a rapid change in snout shape with growth. Namely, the rapid morphological change is produced initially by allometric growth between the median rostral cartilage and the rod-like dorsolateral cartilages, followed by a gradual decrease in the relative length of the snout owing to allometric growth between the rostral cartilages as a whole and the rest of the body. A decrease in the proportional length of the snout with growth is referred to above.

There are no previously published references to the ventral groove under the snout. A photograph of a young basking shark caught in Portobello, English Channel, in June 1950, was included in Matthews and Parker (1950, pl. 8). Apparent traces of the ventral groove can be seen in the photograph, although the authors made no mention of it. The fish length was estimated from the photograph as 2.1–2.4 m, but is in fact believed to have been about 3 m, judging from the snout shape. The ventral groove had disappeared in individuals a little larger than the present specimen, according to the following figures; Pavesi (1874, pl. 1, fig. 3 [2.95 m]), Pavesi (1878, pl. 3, fig. 3 [3.25 m]), Carazzi (1904, fig. 1 [3.37 m]), Gervais and Gervais (1876, pl. 13, figs. 2, 3 [3,65 m]), Gudger (1935, fig. 3 [4.36 m]) and Matthews (1962, photograph of a basking shark of uncertain length). Furthermore, the ventral groove had disappeared completely from the median rostral cartilage in an 8.53 m specimen studied by Barnard (1937, fig. 1), in which the median rostral cartilage was very stout, being almost as wide as long, and had the ventral side almost flattened, although slightly depressed.

Considering the functional implications of the juvenile snout, it seems clear that newly-born basking sharks have a long snout with a ventral groove similar to the present 2.6 m specimen. Yano (1978) has speculated that its function is connected with oophagy (following observation of the same specimen dealt with here). In addition, a second function is possible. The flap-like juvenile snout with a ventral groove would assist feeding in the early, free-living young in respect to increasing the water current into the mouth and/or feeding efficiency, compensating for a presumably lesser ability to swim and feed. Photographs of a feeding basking shark in Hallacher (1977, fig. 1) show that when the fish swims with the mouth fully open, the snout receives water directly on to the ventral side, owing to the axis of the snout and head being somewhat upwardly directed. The ventral groove on the juvenile snout would clearly enhance such a feeding attitude.

Acknowledgments

We express our thanks to Messrs. H. Nakamura, and T. Kataoka and staff of the Toba Aquarium, and everybody concerned in the capture and transport of the fish. Thanks are also due to Dr. K. Nakaya, Faculty of Fisheries, Hokkaido University, for his critical reading of and comments on the manuscript.

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ウバザメの幼魚

伊澤邦彦・柴田輝和

三重県和具のサワラ刺網で 1977 年 5 月 4 日，特異な形状の吻を持つ全長 2.6 m の雌のウバザメ 1 頭が捕獲された．脊椎骨椎体に形成された石灰化輪紋の数から生後 6 カ月以内の，その年の 1 月頃に生まれた幼魚と推定され，腹面に溝を備えた長く湾曲した吻はウバザメの幼魚形態と考えられた．この吻の幼魚形態は急速に変化して生後 1 年（全長 4 m）でほぼ消失すると推定された．吻は神経頭蓋の 3 本の吻軟骨によって支持されており，生後 1 年以内に起こる吻の急激な形態変化は吻軟骨の相対成長によって引き起こされると考えられた．吻の幼魚形態は胎児期から誕生後の幼魚期にかけての摂食に関わり，母胎内では卵食性に関係して，誕生後の若い幼魚にとっては不十分であろうと考えられる遊泳摂餌能力を補償する口域の拡大あるいは流体力学的な意味で摂食に関与するものと考えられる．

（伊澤：〒514 三重県津市上浜町 1515　三重大学生物資源学部資源生物学教室；柴田：〒517 三重県鳥羽市鳥羽 3-3-6（株）鳥羽水族館．現住所：〒295 千葉県安房郡千倉町平磯 2492　千葉県水産試験場）