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ADDITIONAL INFORMATION ON THE MORPHOLOGY OF AN EMBRYO WHALE SHARK

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An embryo whale shark, *Rhincodon typus* Smith, kindly loaned by the Marine Laboratory, Texas Game and Fish Commission, Rockport, shows several notable differences in proportional dimensions and other features as compared with accounts of adult specimens. To describe these differences is the purpose of this paper.

The embryo, 350 mm. in total length, is one that has been removed from an egg-case trawled from 31 fathoms in the Gulf of Mexico about 130 miles south of Port Isabel, Texas, on June 29, 1953. This specimen, believed to be the only embryo whale shark available, has been reported previously by Breuer (1954), Baughman (1955), and Reid (1957), who published dimensions of it and discussed its trunk ridges and oronasal groove. Reid also presented a figure of the underside of the head, while Breuer's and Baughman's accounts each included a photograph of the specimen and its egg-case. To supplement these already published figures, I submit here five additional illustrations of the embryo whale shark and its dermal denticles. For these drawings I am greatly indebted to the skill of Mrs. Fanny Phillips.

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Proportional differences.—In the following account the features of the embryo whale shark are compared for the most part with those of the adult (total length 17′ 3″) from Acapulco, Mexico, figured in Bigelow and Schroeder (1948). As dimensions of both these specimens are already available in their respective accounts, there is no need to reproduce such measurements here. Instead, I shall give, in general terms, the major differences between the embryo and adult, followed in each case by a figure in parentheses which is the proportional difference expressed as a percentage of total length.

The differences are: the adult is slightly broader headed (0.5), longer headed (1.4), and noticeably shorter tailed (6.3); the adult eye is strikingly smaller (0.9), but the gill-openings are longer (0.3 to 2.2); the first dorsal (2.6), second dorsal (8.4), anal (7.8), and pelvic fins (3.2) are further rearward in the adult; the first dorsal fin is proportionately higher (1.2), but its base is shorter (0.9) in the adult (however, the reverse is the case for both height and base length—about 2.0 and 0.3 respectively—in the second dorsal and anal fins); the distance between the first and second dorsal fins and between the anal fin and subcaudal origin are longer in the adult (4.8 and 3.4 respectively); the pectoral fin of the adult has a much longer distal margin (5.5) than that of the embryo, though the anterior margins are comparable; the lengths of the upper and lower lobes of the caudal fin are considerably shorter (7.3 and 4.2 respectively) in the adult than in the embryo.

The above differences are indicative of the growth change which the whale shark undergoes. Understanding such growth change is important in studying sharks because of the frequent need to rely on proportional dimensions to distinguish species. The pattern of growth change is by no means identical in all sharks, but there do appear to be common features (Beebe and Tee-Van, 1941, p. 107; Maschlanka, 1955, p. 12; S. Springer, 1960, p. 9; Garrick, 1960, p. 546), such as accelerated growth in the trunk region, as compared to the head and tail, which thus proportionately decrease with increasing total length; a tendency for the pectoral fin to increase its relative length or at least remain stable (though *Carcharhinus longimanus* (Poey) shows a relative shortening of pectoral fin from juvenile to adult, as noted by S. Springer, 1960, p. 9); a broadening of the head region; and a noticeable decrease in eye diameter. Dorsal fin heights tend to increase relatively in the galeoid sharks (but *C. longimanus* is again an exception), while in the squaloid sharks the reverse generally holds true (Garrick, 1960, p. 548).

The indicated growth change of the embryo whale shark fits the above pattern reasonably well except that the head length in the embryo is relatively shorter than that of the adult. This may be only an apparent difference for the following reason. The dorsal lobe of the caudal fin of the embryo is raised only slightly from the horizontal axis of the body; hence, the posterior margin between the dorsal and ventral lobes is deeply notched, the angle being less than 90°. In the adult the caudal fin is lunate, the dorsal lobe being raised steeply from the horizontal axis, with the result that the posterior margin is only slightly concave. It follows that the change leading from the slightly raised dorsal lobe in the embryo to the steeply raised lobe in the adult would yield relative total lengths which are not strictly comparable, and thus this difference would provide bias in proportional lengths of structures, such as head length, if calculated in terms of the total length. Accordingly, one would expect the head length of the embryo to have a lower relative value in terms of total length than is the case for the adult. Better comparison is afforded by examining the head length in terms of the length to the upper caudal origin—this shows the relative head length in embryo and adult to be the same, which is nearer to the actual situation in most other sharks.

The need for caution in extrapolating proportional dimensions of small specimens is demonstrated by the different growth rates operating on the first dorsal fin of the embryo as compared with the second dorsal and anal. Dimensions of the first dorsal fin in the embryo and in the adult indicate that the rate of vertical growth is proportionately faster than that of horizontal, whereas in the second dorsal and anal fins the horizontal growth is faster. A similar situation has been described for *Etmopterus baxteri* Garrick (Garrick, 1960, p. 548) and it may be relatively common. The lengths of the free rear tips of the dorsal and anal fins compared with their bases also show considerable change with growth. In the embryo, these free tips are relatively short (about 4.0 in base in the first dorsal fin) but in the adult they are much longer (about 1.4 in base in the first dorsal). Another change affecting the comparison of all fins is the usual tendency for fin tips to become relatively pointed in the adult, whereas in the embryo they are more rounded or blunt tipped (V. G. Springer, 1961, p. 480, gives an example of this in *Mustelus norrisi* Springer). The tip of the dorsal lobe of the caudal fin in the embryo is distinctly notched, presumably representing the subterminal notch, which is not evident in the adult.

Dermal ridges.—As noted by Reid (1957, p. 158), the embryo whale shark has a longitudinal dermal ridge originating on each side of the head and dividing, above the end of the pectoral fin, into two ridges which continue posteriorly. Reid identified this ridge as one corresponding to an upper divided ridge in the adult. The adult has, in addition, a lower ridge which extends the whole length of its body and forms a keel on the peduncle and anterior part of the caudal fin. I interpret the lower half of the divided ridge in the embryo to be the same as the lowermost ridge in the adult, since posteriorly the lower ridge forms the keel on the peduncle and caudal fin. This means that, at a later date, a third ridge must appear above the lower one in the embryo. Similar longitudinal ridges occur in some members of the family Orectolobidae. The embryo also has a middorsal ridge which extends from the level of the first gill-opening to the origin of the first dorsal fin and possibly is present between the first and second dorsal fins. Adults have been described with and without a middorsal ridge.

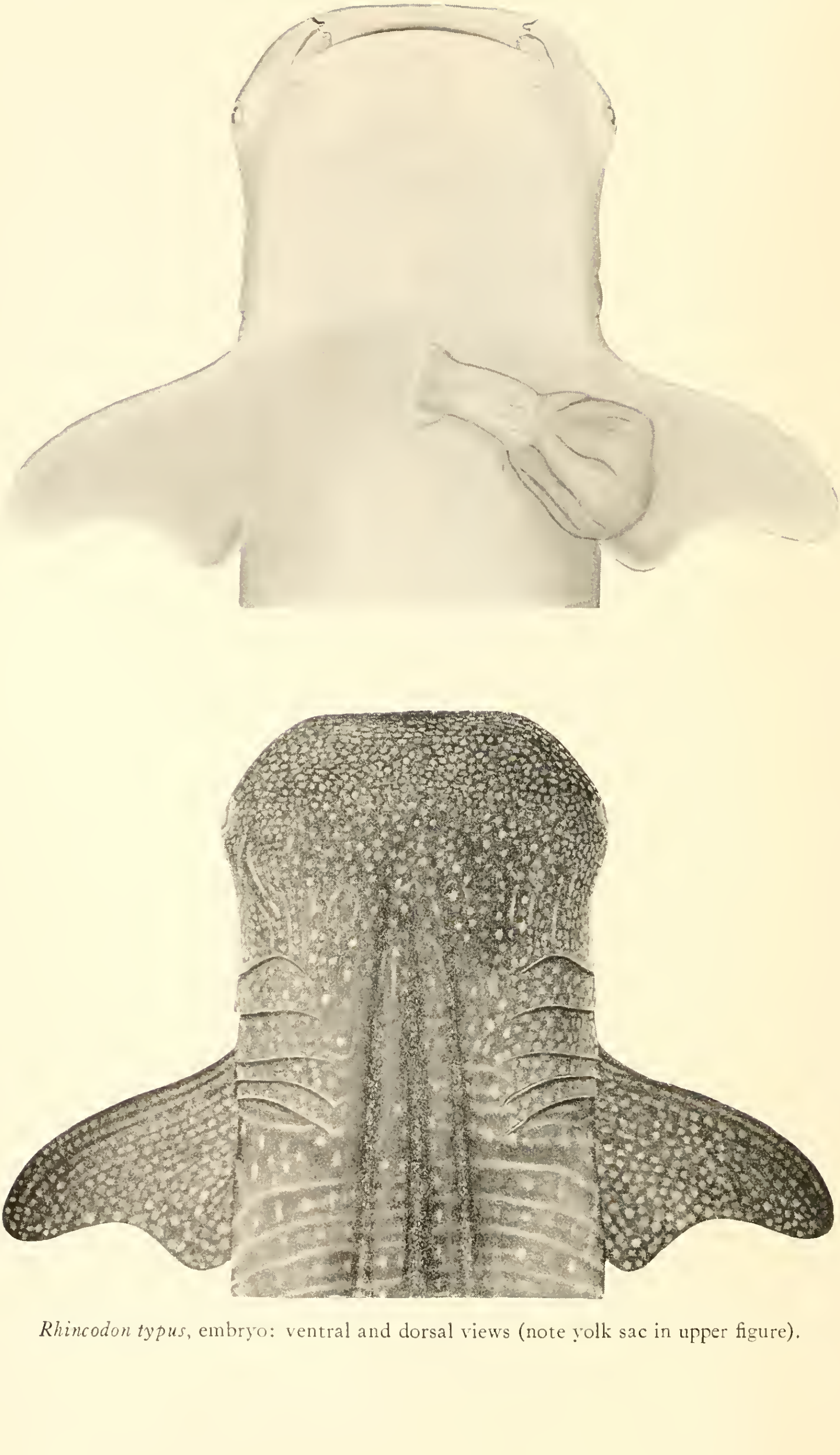
Precaudal pits.—The embryo has a prominent upper precaudal pit, with a notably wide, transverse front margin. There is also a small but distinct lower precaudal pit. Adults are described as having the upper pit but lacking the lower.

Nostrils.—Reid (1957, p. 158) reported that each nostril in the embryo is connected to the mouth by a distinct furrow—a character frequently used to support the view that the whale shark is closely related to, or belongs in, the family Orectolobidae.

On the basis of an adult specimen, Barnard (1935, p. 649) disputed this view. Without wishing to enter the controversy, I confirm Reid's description that, in the embryo, there is no doubt that the nostril is joined to the mouth by a naked or nearly naked furrow (pl. 4). However, in view of the close proximity of the nostril to the mouth, I wonder if any significance can be placed upon this connection. Also, in passing, I would mention that, in the embryo, the distance (in percentage of total length) from snout tip to outer nostril (0.6) is about half that of snout tip to mouth (1.0). Bigelow and Schroeder (1948, p. 189) give the reverse of these figures for the adult they describe.

Dermal denticles.—The dermal denticles of the embryo (pl. 3) closely resemble those of the adult in having ovoid blades, each with three posterior marginal teeth and a strong median longitudinal keel. Some denticles from the lower longitudinal dermal trunk ridge, however, are distinctly larger and are arranged in longitudinal pairs, with the anterior denticle overlapping the one posterior to it. These pairs are clearly visible not only because of their larger size, but also because of their darker pigmentation. The posterior denticle of each pair is similar in shape to the surrounding body denticles, but usually it has a broader topped longitudinal ridge. The anterior denticle is of the same size, but it is more nearly oval in shape, with only a median posterior tooth; its longitudinal ridge is broadly expanded and round topped, and usually it bears several minor ridges which converge posteriorly to form a single ridge.

Rhincodon typus, embryo whale shark, 350 mm. total length, from Gulf of Mexico.



Rhincodon typus, embryo: ventral and dorsal views (note yolk sac in upper figure).

Rhincodon typus, embryo: dermal denticles from in front of, and a little below, first dorsal fin. The two pairs of enlarged denticles, overlapping lengthwise (left center and upper right), are on the lower dermal ridge.

Rhincodon typus, embryo: left nostril with nasal flap reflected to show naked furrow leading from nostril to mouth.

I do not know if similar pairs of enlarged denticles occur on the longitudinal dermal ridges of adults. However, Ford (1921, p. 493) described the first denticles to erupt in *Scyliorhinus canicula*, *S. stellaris*, and *Galeus melanostomus* as being conspicuously larger than the normal body denticles and "symmetrically arranged in a sequence of transverse pairs forming two longitudinal rows, one on either side of the midline in a dorsolateral position." At a later stage, these larger denticles "lose their individuality eventually owing to the presence of equally large and similar scales which have grown up around them" (p. 494).

Teeth.—In the embryo, the teeth are for the most part still covered by membrane, but those that are visible show little difference from the teeth of adults.

Gill-rakers.—The plankton-sieving apparatus of the adult whale shark consists of transverse cartilaginous bars (representing gill-rakers) which join one gill-arch to the next; these transverse bars are further connected, one to the other, by a secondary grid of slenderer cross members. The entire structure is covered on its internal (pharyngeal) surface by a fine, spongelike lattice or veil derived from dermal denticles. This structure forms the sieving apparatus, with interstices 1 to 3 mm. in diameter.

In the embryo the sieve is still in a very early stage of development, comprising only the gill-raker elements. These project forward from each arch to the next, but their tips are still free. On the first arch there are about 26 rakers on the upper limb and 34 on the lower. The rakers are comparatively stout rods, closely arranged, with virtually no space between them. Each raker shows faint indications of being bipinnate, having very short processes developing along the sides. These processes are presumably the rudiments of the secondary grid members. There is as yet no obvious sign of the spongy tissue which will later line their inner surface.

Reid (1957, p. 157) suggests that the relatively advanced stage of development of the embryo whale shark and the extent to which its external yolk sac has been absorbed are indications that it is approaching the size at which it would hatch. This is probably correct. On the other hand, the abdomen is filled almost completely with yolk, forming an oval mass about 80 mm. long, 50 mm. wide, and 40 mm. deep. This yolk supply seemingly would allow sufficient reserve to complete development of the pharyngeal sieve either before or after hatching. Only further specimens will establish whether the juvenile whale shark feeds from the beginning in the same manner as the adults.

Color and pattern.—The color of the embryo when first removed from the egg-case was "bluish grey with white spots, the undersurface white" (Breuer, 1954, p. 29). After preservation, the embryo is brownish rather than bluish grey, but with the dermal ridges dusky. Adults have been described as being variously dark grey to reddish or greenish brown above and white or yellow below. The color pattern of small spots and narrow transverse bars on the embryo (pls. 1–2) is remarkably similar to that of adults.

Vertebrae.—Radiographs of the embryo whale shark show vertebral centra very clearly in the body region and the anterior four-fifths of the tail. The centra are widely spaced, presumably from incomplete calcification. In the body region anterior to the level of the origin of the upper caudal lobe, there are 81 vertebrae, while posteriorly on the caudal axis there are 72 countable vertebrae. The total number of caudal vertebrae is probably much higher, but those in the terminal fifth of the caudal axis are calcified or developed insufficiently to show on the radiographs.

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