ARE SCALES AN INDEX TO THE AGE AND GROWTH OF HILSA?[1]

By DEWAN BAHADUR DR. B. SUNDARA RAJ, *M.A., Ph.D., F.N.I., Lucknow.*

(*Received in 1948; revised in 1949; re-submitted April 21; read May 5, 1950.*)

INTRODUCTION.

Scale reading is a comparatively recent and highly specialized branch of Fishery Research. A reasonably precise knowledge of the stock of fish, i.e., a census of the fish population classified into 'year classes' is essential for fisheries research and administration. In this paper an attempt is made to assess the age of Hilsa by certain markings on its scales.

In confined waters, where the fish are under control, the direct counting of stock and the reckoning of age and rate of growth by actual observation are possible. For most sea and even river fish such direct evidence is unobtainable, except to a limited extent by 'tagging' and the estimation of age and numerical strength is possible only by indirect methods. One such is the well-known Peterson method first propounded in 1895 which employs growth frequencies of random samples covering the full range of sizes of a fish. Other methods include the examination of scales, opercular bones or sections of otoliths, vertebrae and fin rays for annual growth rings. The scale method of age determination is the most widely used method at present. In clupeids, such as Hilsa, scales afford the best indirect evidence of age.

That the scales of certain fish afford evidence of their age has been known since the time of Anthony Von Leeuwenboek (1696)—well over 250 years. He cut sections of carp scales and wrongly interpreted each layer or lamella as representing a year in the life of the fish. Reaumur (1716) was the first to suggest that the markings on the scale give an indication of the rate of growth of the fish. To Mandl (1839) and Williamson (1849) we owe the distinction that is now drawn between the striated upper layer and the fibrous lamellated lower layer in fish scales. Steenstrup (1861) was the first to observe that all scales except placoid grow throughout life proportionately to the size of the fish. This is the basis of age determination by means of scales. Modern fish scale reading is confined to the upper striated layer except when polarized light is used for the elimination of false rings. However, it was not till the nineties that Haffbauer (1899) revived interest in scale reading. He experimentally proved that favourable and unfavourable seasons affected scale growth in the carp and caused the formation of annual rings by which it was possible to determine the age of the fish. Hoffbauer thus laid the foundation of this important line of research in fishery science and the principle has since been applied to several other food fish, notably the Salmon, Cod and Herring.[2]

During the last half century, the subject has received considerable attention from fishery investigators all over the world, particularly in Norway. The theory as well as the technique of scale investigation have been gradually developed in spite of adverse criticism and even scepticism and is now an approved and well developed method of fishery research which yields results of considerable precision otherwise unobtainable. The main theory is (1) that annuli or yearly growth rings are formed on scales, except in the tropics, as a result of varying temperature, amount of food

[1] This paper was read at the 33rd session of the Indian Science Congress, Bangalore, 1946.

[2] Even in temperate water, if food is available, fish continue to grow is proved by the well-known manuring experiments of Gross and Raymont in Scotland.

or other still obscure physiological causes and so their number is a record of the age of the fish, (2) that the length of the scale bears a constant proportion to the length of the fish in all stages of growth, except the earliest before the scales are formed. The rate of growth of the fish can thus be ascertained by the relative position of the annual rings on its scales. Age determination and growth determination are thus the two main aims of scale reading in modern fishery research.

Hilsa Scales.

In shape and markings, scales differ in different groups of fish. Even in the same fish the scales are not of the same shape in the different parts of its body. It is customary to use only the shoulder scales which are the best developed for scale reading. In *Hilsa*, scales are discernible when the fry attain 40 mm. or 1·6″ in length. For scale reading, scales from fish of 4·5″ (115 mm.) onwards are suitable as those from younger fish show hardly any markings. A fully formed dorso-lateral (pectoral) scale of an adult *Hilsa* is subquadrate in shape (Plate I). In markings the *Hilsa* scale is typically clupeid in character. The small apical or posterior field is sharply separated from the basal or anterior region. The apex is pellucid and without circuli and has numerous horizontal radii, which tend to make the apical margin somewhat dentate. In the young the apical radii are few. In the very young only beginnings of the radii are noticeable on the nucleur border. The basal or anterior field of the scale is covered by exceedingly fine circuli (Plate I, fig. 1B) which do not seem to have any relation to the many indistinct rings of growth. The two striking features of *Hilsa* scales are:—(1) In the adult fish the circuli are not absolutely transverse but tend to follow the contour of the basal margin, and do not reach the lateral margins of the scale at right angles or even obliquely, as in most clupeids. (2) Everywhere, except in the apical and nuclear regions, the scale is traversed by undulating roughly parallel transverse grooved lines (Radii) at more or less regular intervals. Most of the outer 'grooves' reach the lateral margins of the scale obliquely. Those nearest the nucleus, however, pass into the apex on either side of the nucleus as horizontal apical radii. These transverse grooves, therefore, have been rightly identified as radii by Baudelot (1873) and later by Cockerell (1910). As a rule, the transverse radii in *Hilsa* scales are entire. Some are, however, incomplete or interrupted in the middle. Some in the centre of the scale anastomose and in rare cases form an irregular network.

Growth Rings in *Hilsa* Scales not Annual.

Even in the smallest scale examined from *Hilsa*, hardly a few weeks old, two or more delicate concentric 'lines of growth' occur (Plate II, fig. 2) which are indistinguishable in appearance from the recognized annual growth rings or annuli in Herring scales of Europe and America. In the young, as well as adult *Hilsa*, these rings are too numerous to be annuli and do not occur at regular intervals. Evidently there are frequent checks to the growth of *Hilsa* or its scales which cause the formation of these growth rings about which little is known. Another significant feature is the occurrence of double rings on some *Hilsa* scales which were examined by experienced scale readers both in Liverpool and Norway. The significance of this is also unknown. Prasad, Hora and Nair (1940) commenting on the growth rings of *Hilsa* scales in Bengal stated in 1940, 'We believe that they are formed not at regular intervals but whenever conditions of life become unfavourable'. These growth rings on *Hilsa* scales are too numerous to be considered annual growth rings or 'annuli'. Consequently they cannot in the present state of our knowledge provide any evidence of age or rate of growth and must be discarded. This seems to be true also of other tropical fish. Thus to the fishery investigator in India this important clue to the age and rate of growth of fish is denied.

Transverse Radii indicate Age of *Hilsa*.

On examining the other markings on *Hilsa* scales it was noticed that the transverse radii in the *Hilsa* scale occurred at regular intervals and increased in number more or less proportionately with the age and size of the fish notwithstanding its provenance. I suggest that these afford a clue to the age of *Hilsa* and possibly to their rate of growth. Scales from some 500 specimens of different sizes from all over India have been studied. As in other fish, the dorso-lateral scales of the pectoral region are the best developed and were found to give reliable numbers of radii while those of the caudal peduncle are as a rule poorly developed and usually had more transverse radii which however were not constant. For the statement below only the normal dorso-lateral scales of the pectoral region have been taken into account. Both complete and incomplete transverse radii were counted since incomplete radii, by their relative position in the regular series, deserved to be taken into account.

The statement below summarizes my studies extending over a number of years on *Hilsa* scales from Bengal, Madras, Bombay, Sind and U.P. waters and a specimen from Iraq.

Overall length of fish in inches.	No. of transverse radii counted.	No. of radii mostly seen.	Age actually counted or estimated.
4″– 5″	2–4A	2 or 3	*From the river or tank*—1st year.
5″– 6″	2–6B	3 or 4	(Actually ascertained from rivers and confined waters.)
6″– 7″	3–5	4 or 5	Mostly from Palta Water Works, Calcutta, the Sundarbans,
9″–11″	5–9A	6 or 7	lower reaches of the Cauvery and Godavari rivers and connected tanks after the monsoon floods.
12″–13″	8–12A	9 or 10	*From the river and tank*—2nd year.
13″–14″	8–13A	9 or 10	(Actually ascertained from rivers and confined waters‡.)
14″–15″	11–14A	9 or 12	From the lower reaches of the Cauvery, Krishna and
15″–16″	11–17A	12 to 17*	Godavari and connected tanks.
16″–17″	13–17B	14 to 17	
17″–18″	13–17A	12 to 17	
18″–19″	11–18A	13 or 14	*From the sea ascending rivers to spawn*—3rd year or older
19″–20″	11–20B	13 to 16	(estimated.)
20″–21″	15–27†	16 to 18	From the Cauvery, Krishna and Godavari rivers during the monsoon floods.

A & B.—The maximum number of radii in these groups is also the number of inches in the length of the fish.

* 17 radii on most scales of a *Hilsa* measuring only 15″-16″ is unusual and is due probably to some error in counting. As the scales have been lost this cannot be checked.

† When the number of radii is as large as 25 to 27 a greater age than 3 years is probably indicated.

‡ Specimens from Calcutta Water Works tanks and some tanks in Madras.

4″ – 5″. This means sizes from 4″ to just short of 5″.

The largest male and female fish examined measured 21 inches or 654 mm. in length (overall). Messrs. Chacko and Ganapathi (1949, p. 17) have recorded a female 23·5″ long but have not described its scales. The fish whose age is known, from the Calcutta Water Works and from some tanks in Madras, have been compared, size for size, with fish taken from open rivers and the sea and scales of both were found to possess the same average number of radii.

In the statement the fish have been arranged in groups differing from one another by one inch. The collection studied was not quite complete. For instance,

there are no fish of the size 7″ to 8″, 8″ to 9″, round about 10″ and 11″ to 12″. The number of fish in each group also varied enormously. Nevertheless, there is an intelligible correlation between the number of inches in col. 1 and the number of radii in col. 2 of the statement. In 7 out of 13 groups marked A, the maximum number of radii is the minimum number of inches; in three groups marked B the maximum number of radii is the maximum number of inches. Messrs. Chacko, Zobairi and Krishnamurthi (1948) have confirmed this observation after examining 1,100 specimens and have ventured to estimate the age in months.

Transverse Radii and Growth Rate of *Hilsa*.

The intervals between the radii, though slightly smaller towards the margin of the scale, seem to me to be too uniform to provide data for calculating the rate of growth, unless it is proved that *Hilsa* grows more or less uniformly till it attains maturity. Cultural experiments in tanks and many more counts than are recorded in this paper will be needed to settle this relationship satisfactorily.

Discussion.

I am aware that I am suggesting a significance to radii in fish scales which may be unacceptable to the conventional scale reader. Few authors have suggested the use of radii for estimating age. Baudelot in 1873 observed that the number of grooves (concentric or transverse radii) of an individual scale is capable of varying with age. Taylor (1916)[1] discusses in detail the use of radii in age determination of fish. At page 304 he states as follows:—

'The different means of determining age with more or less accuracy are:

(1) A count of the annuli aided by—

(*a*) Polarized light.
(*b*) The selective action of picrocarmine stains.
(*c*) The origins of the radii.

(2) Identification of year groups by measurements of length and weight.

These methods may be used in combination.'

At pages 309 to 310 he observes that the radii are only supplementary to the annuli as a means of age determination.

'The origins of the radii.—Like polarized light and picrocarmine stain, the radii are only supplementary to the annuli as a means of age determinations.

As in the majority of teleosts, radii appear on the scale of *Cynoscion regalis* only on the anterior side. They begin, usually four to six in number (on the sides of the fish), at about the seventh circulus, counting from the focus. These usually continue to the periphery. As the scale increases in size, more radii are added on either side of those first appearing beginning at various distances from the periphery. Proceeding laterally from the long axis, one finds that they extend diminishing distances from the periphery. They are usually symmetrically arranged —i.e. a radius beginning on one side of the axial radius will correspond with a similar radius beginning at the same distance from the periphery on the other side. The points at which radii begin in the main coincide with the annuli. It would, then, be a simple matter to count these points to determine age, but this rule is by no means infallible. Radii often begin between two annuli, and sometimes continue for a short distance only and then disappear. But radii beginnings, notwithstanding this variability are sufficiently constant to afford a valuable means of verifying and supplementing the other methods.'

At page 316 he concludes—

'Age may be determined in two ways: (1) by counting the annuli, the count being facilitated by (*c*) beginnings of radii; (2) by year groups in length and weight.'

As no regular annuli occur in *Hilsa* scales, radii are the only indication of age and an attempt is made in this paper to use them *exclusively* for the determination

[1] I owe this reference and the loan of Taylor's paper to Dr. S. L. Hora.

of age. Also no author to my knowledge has suggested the use of radii for determining rate of growth as is done in this paper.

As radii normally radiate from the centre to the periphery of a scale they usually give no indication of the rate of growth of a fish. In most clupeid scales the anterior radii are transverse but are not as numerous or as regularly spaced as in *Hilsa*. Describing transverse radii in clupeid scales, Cockerell mentions 7 or 8 transverse radii in all widely broken in the middle except the first, in the pilchard; 5 in *Opisthonema*; 2 or 3 in *Sardinella* and only 2 in *Baevoortia*. In the adult *Hilsa*, measuring 21 inches, I have counted as many as 27 radii.

It is true that growth rings or annuli actually show the outline of the scale at successive stages of growth, whereas transverse radii in the *Hilsa* scale have no such known significance. But in the absence of recognizable annuli, the transverse radii in *Hilsa*, the number of which are fairly constant for a given length of fish, will, I hope provide some evidence of age and even possibly of growth of *Hilsa* where at present such evidence is lacking. The correlation between the number of transverse radii, and the actual size and age of *Hilsa* can be worked out more or less accurately up to the adolescent stage from the young *Hilsa* entering tanks, and residing in the rivers before proceeding to the sea. From tanks connected with the Cauvery in Madras and with the Ganges in Bengal we have collections of young *Hilsa* whose exact age up to 2 years is definitely known, and from whose scales the number of transverse radii corresponding to the age and size of the fish was counted. This was checked by simultaneous collections from the rivers Cauvery and Godavery. On this data available up to 2 years the age of the adult *Hilsa* returning from the sea to breed and whose age is unknown, was deduced (*vide* statement above). Direct proof of age for confirmation will only be available after tagging experiments on sea-going *Hilsa*, suggested by me (1930-31, p. 32) are carried out. In 1935-36 investigations in Madras waters showed that *Hilsa* take 2 years to grow to the adult size and reside in the estuaries of rivers for this period. In Bengal fish of 12 cm., i.e. one year old fish, have been found in the open sea, due probably to the perennial influx of fresh water and the estuarine conditions prevailing in the sea not found along the Madras coast. I stated at that time 'the period they spend at sea and whether they breed more than once in rivers and the age limit of the fish remain yet to be discovered' (1935-36, p. 38). My scale studies on *Hilsa* seem to suggest that normally only the third year is spent at sea by most *Hilsa* before they return to the river to breed. The average of the maximum number of transverse radii (col. 3 of the statement) usually seen in the first year is 7, in the second year 14, and in breeders returning to the rivers apparently three years old, 18. Though some half grown males, apparently a year old, may be in milt and take part in spawning before going to sea. This has been recorded also for Salmon (Meek, 1946). A few full grown fish, however, seem to survive to a greater age as the radii in their scales reach a maximum of 27. This indicates a longer life than 3 years for the fish, and the breeding of the fish more than once, as they were taken in the Godavery river during monsoon floods.

There is some doubt as to the extent to which these transverse radii provide evidence of the rate of growth, as they are regularly spaced except a few peripheral ones. Evenly spaced radii must be presumed to indicate a uniform rate of growth of the scale and therefore of the fish. Of this there are other indications, for instance the maximum number of transverse radii generally corresponds with the number of inches in the length of the fish except in very large specimens (*vide* cols. 1 and 2 of the statement) and the transverse radii though evenly spaced are progressively closer to each other towards the periphery, indicating a gradually slower rate of growth as age advances. In a specimen from Iraq measuring 13·8 inches in the Indian Museum collection, 13 radii were found which conforms to the average number on scales of Indian fish of the same size and age. The growth, after the fish have attained adult size of about 20 inches, is very slow or imperceptible, as in most

adults. This is shown by the disproportionately large number of radii (27) compared with the length of the fish in inches (21 inches). A more intensive study of the scales correlated with age in addition to tagging experiments is required before the evidence regarding the rate of growth of *Hilsa* from its scales can be finally accepted.

An intensive study of all the available characteristics of scales of other tropical fish besides the accepted 'growth rings' may provide evidence of their age and growth as in *Hilsa*.

Summary.

A census of fish populations classified according to age is essential for fishery research and administration. A brief history is given of scale investigation which is now a recognized method of research in fishery science. Scales specially of clupeid fish provide, by annual growth rings, indirect but reliable evidence of age and rate of growth, otherwise unobtainable. In the tropics however growth rings even when present fail to furnish any intelligible evidence of age or rate of growth.

The *Hilsa* scale is described in detail. In *Hilsa* the growth rings are too numerous and ill defined for the estimation of age, but the transverse radii in the anterior region of the scale which are regular and well defined, was found to provide evidence of age. From *Hilsa* grown in tanks in Bengal, and Madras, whose age was known up to 2 years, the average number of transverse radii was found to correspond more or less with the size of the fish in inches. The scales of a large number of *Hilsa* from the river and sea from the east and west coast of India and Iraq, when examined were found to bear the same constant relation to the size of the fish, except in the full grown fish. It is, therefore, suggested that the radii in *Hilsa* scales should be used for age determination.

Evenly spaced radii seem to suggest uniform growth, but further study is required to establish this. The suggestion is also made that all available characters of scales besides the conventional growth rings, if studied, may throw light on the age and rate of growth of other tropical fish.

Literature Cited.

Baudelot (1873). Récherches sur la structure et le Développement des Ecailles des Poissons. *Osseu Archives de Zool. Experimentale at Generale.* Tome ii.

Cockerell, T. D. A. (1910). The scales of the *Clupeid fishes Biol. Soc. Washington*, **33**, 61–64.

Chacko, P. I., Zobairi, A. R. K. and Krishnamurthi (1948). The radii of scales of Hilsa ilisha (Hamilton) as an index of growth and age. *Curr. Sci.*, May, **17**, 58–159.

Chacko, P. I. and Ganapathi, S. V. (1949). On the Bionomics of *Hilsa ilisha* (Hamilton) in the Godavary river. *Journ. Mad. University*, **18**, 16–22.

Heffbauer (1899). Die Alterabestimmung des Karpfen an seiner *Schuppe*. *Jabres—Bericht des Schesischen Fischerei*—Vereins.

Hora, S. L. and Nair, K. K. (1940). Further observations on the bionomics and fishery of the Indian Shad *Hilsa ilisha* (Hamilton) in Bengal waters. *Rec. Ind. Mus.*, **42**, Part I, 35–50.

Hora, S. L. (1938). A preliminary note on the spawning grounds and bionomics of the so-called Indian Shad *Hilsa ilisha* (Hamilton) in the river Ganges. *Ind. Mus. Rec.*, **40**, Part II, 147–158.

Leuwenhoek, A. (1696). *Opera omnia, lugduni Batavorum iii* opistola, **107**, 191-2.

Mandl. (1839). Récherches sur la structure intime des écailles des poissons. *Annales des sciences* naturelles, 2 serie, t. ii.

Meek, A. (1946). Migrations of Fishes.

Prashad, B., Hora, S. L., and Krishna Nair, K. (1940). Observations on the Seaward migration of the so-called Indian Shad, *Hilsa ilisha* (Hamilton). *Rec. Ind. Mus.*, **42**, Part IV, 529–552.

Reamur (1761). Observations sur la matière qui color les perles fausses et sur quelques autres matières animales d'une autre couleur, a l' occasion de quoi on essaye d' éxpliquer la formation des écailles des poissons. *Histoire de l' academie royale des sciences.*

Raj, Sundara, B. (1932). Madras Fisheries Admn. Report for 1930-31, p. 32, paras 115, 116.

——— (1937). Madras Fisheries Admn. Report for 1935-36, p. 38, para. 157.

——— (1938). Madras Fisheries Admn. Report for 1936-37, p. 3, para. 5(iv), p. 35, para. 171.

Taylor, Harden, F. (1916). The structure and growth of the scales of the Squeteague and the Pig fish as indicative of life-history. Bull. U.S. Bureau, Fisheries, **34**, 1914, 289–330, PL-LIX.

Williamson, W. C. (1849). On the microscopic structure of the scales and dermal teeth of some ganoid and placoid fish. *Phil. Trans. Royal Society of London*, **139**, Pt. II, 435–476.

——— (1851). Investigations into the structure and development of the scales and bones of fishes, *ibid.*, 653–702.

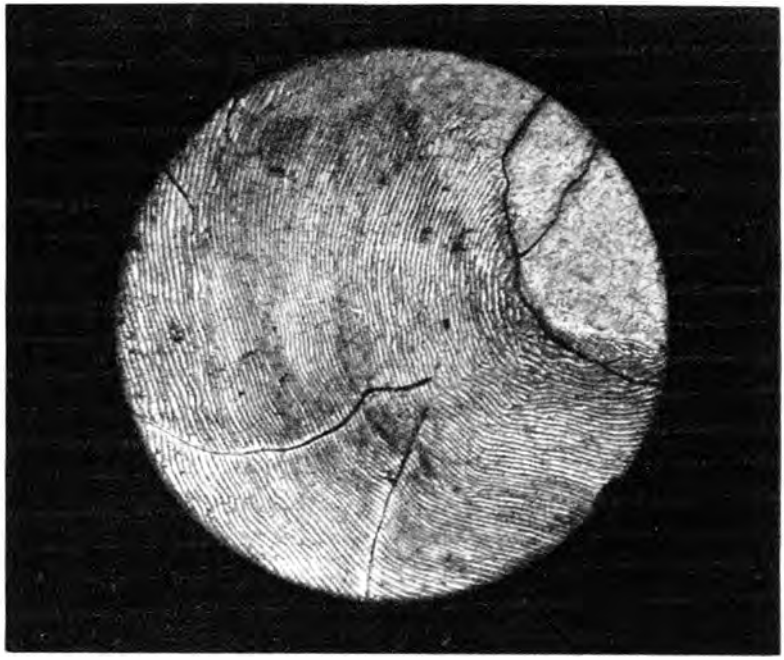

FIGURE 1B.
Part of the small scale enlarged to show the fine circuli.

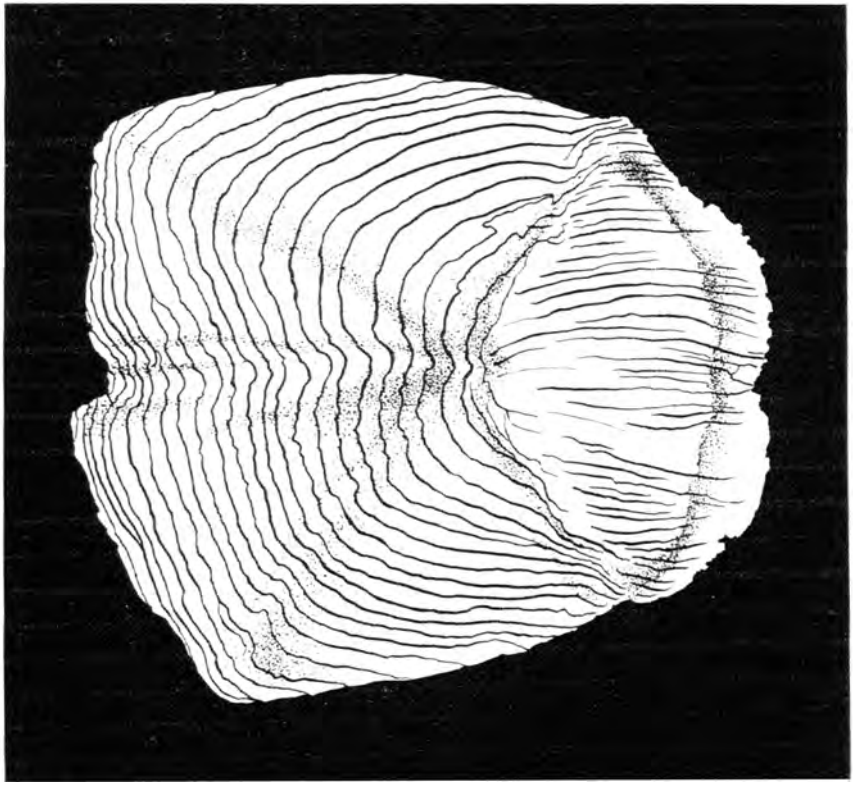

FIGURE 1A.
Scale of an adult male Hilsa 21 inches long showing 27 transverse radii.

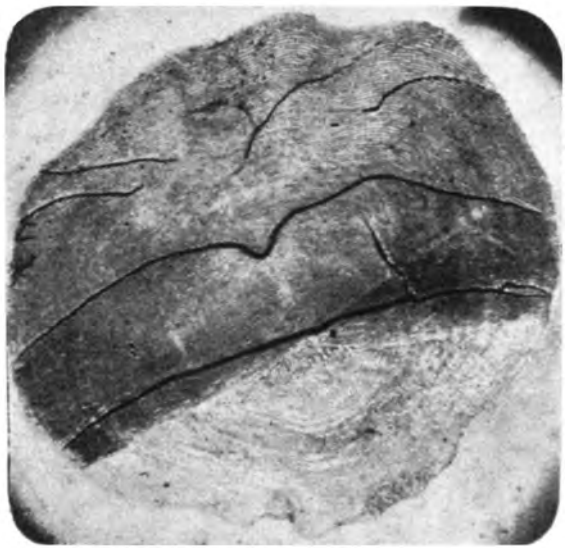

FIGURE 2.

Photo of small scale from a young Hilsa measuring 4·6 inches showing growth rings in addition to transverse radii and circuli.