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ON THE SCALE METHOD OF ESTIMATING THE AGE OF THE HERRING
(Clupea harengus)

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On the Scale Method of Estimating the Age
of the Herring (Clupea harengus).

by

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A method whereby the age of a fish may be estimated is highly desirable and within recent years two methods have been devised whereby it is claimed this end is secured.

Petersen in 1895 showed that if the lengths of a group of fishes which there was good reason to believe were of the same age, be plotted in a frequency-curve, a curve of the type of the probability-curve will be produced. He then concluded that in a sample including fishes of two or more generations, the curve of frequencies should show peaks corresponding to the number of generations. This method, it was recognized, could not find out the age of the individual fish. By the second,-- the scale method, it is claimed that the age of each fish can be estimated in a definite and exact number of years.

The writer has employed the Petersen method for the study of the growth of the herring and he has also, over a number of years, applied the scale method to this purpose. He has come to the conclusion that the claims made for the scale method have not been substantiated. The question of whether a method may yet be devised for the exact estimation of the age of a herring, from an examination of its scales is an open one. It is proposed then to point out some disabilities of this scale method and to show the want of stability in the claims made for it.

Hjort's statement in 1907 may be cited as the claim made for this theory.

"Later on, it was clearly demonstrated that not merely the otoliths but many of the bones, and what is more, the scales, showed age-rings--a fact which now enables us, with certainty and precision, to tell the age of every cod, haddock,

saithe, herring or sprat, as well as of many other species of fish." If this is a correct estimate, the method would be a very valuable instrument.

The herring scale is generally circular or oval in form; it is usually symmetrical, but sometimes asymmetrical. The upper surface of the scale is divided into two regions. The anterior is covered with fine ridges, usually transverse, but in some cases roughly concentric; the posterior region is devoid of ridges but it exhibits wavy lines more or less distinct, which run roughly parallel to the circumference. The under surface of the scale is devoid of ridges. The anterior striated region of the scale is overlapped by other scales; the posterior portion projects free of overlapping.

According to Dahl (2):- "In the anterior, striated part of the scale, we will clearly distinguish a certain number of narrow, concentric rings, starting like irregular semicircles from the base line. The narrow rings will, if strong light is permitted to pass through the scale, appear more transparent than the other parts. In subdued, or slightly reflected light, they appear darker than the striated parts of the scale". "An examination of individuals at different seasons further shows that the broad semi-transparent summer belts are formed during the physiological summer, and the narrow transparent rings during the physiological winter. Each succeeding summer belt with its winter ring thus represents an annual ring, and, by counting the number of such annual rings contained within the area of the scale, the age of the fish can, with some limitations, be determined."

Dahl makes, in support of his theory, the following statements:- "The regular striation characterising the summer stops nearly abruptly and leaves the rim of the scale almost quite blank during winter." "An examination of scales taken during summer shows that the striation generally extends to the very rim of the scales." He exhibits these differences by two diagrams.

Such a difference, if constant, would be readily recognised, but the writer has seen both conditions on the one scale: at one part of the perimeter there was a plain rim, and at another part the striations extended to the very edge. Dahl further states that a very narrow, blank rim may appear on the scale in summer.

This, it is inferred, is supposed to give rise to the summer or accessory ring which is observed as a faint ring in the so-called summer belt.

The writer has observed the blank rim on scales of herrings caught in June and July. There is a risk that the plain rim is damaged or rolled up. The rim varies in breadth in different parts of the scale. Anteriorly it is usually narrower than at the sides.

Dahl says that the winter ring first becomes recognisable at the beginning of the summer. "The greater transparency of the fully formed winter rings is, to some extent, to be attributed to the irregularity and faintness of the striation which passes over as the summer growth of the scale begins" (Dahl 2). It is to be inferred that such faint and irregular striations can be formed at any time during the summer.

The winter ring then is composed of a blank rim which is not a characteristic winter formation and a faint and irregular striation which is formed in summer.

Attention may be here directed to the contrast between the winter ring of the scale and that of the otolith. In the latter, the winter ring is of a different constitution to that part of the otolith formed in summer, that is, according to Reibisch's theory. So that when an analogy is drawn between the winter ring of the scale and that of the otolith, the comparison is not legitimate.

Nevertheless, Broch (1) writes as follows:- "Parallel investigations carried out on the scales and otoliths of the herring brought me to the result that, on the scale, the small rings, which by transmitted light are almost clear, represent the winter rings of the otolith, while the broad, less translucent parts are formed in the course of the summer period."

Schneider, however, found in some examples that the number of rings in the otoliths and vertebrae were alike, but sometimes smaller than the number of rings in the scales. Reibisch had doubted the applicability of the otolith method to the estimation of the age of the herring. "If, as was assumed, the deposit of lime in the formation of the otolith of Pleuronectes platessa is conditioned through the change in temperature, no such influence can be recognised in fishes, the otoliths of which show no layering. "Such fishes are," as Dr. Apstein states, "Among others, Herring, Mackerel, Bel." "An absence of stratification occurs exceptionally also in the Plaice."

Jenkins arrived at the following conclusion:- "In the Clupeoids we can estimate the age of the fish from the otolith, and this is indeed the only method known up till now by which the age of the fish can be estimated with certainty beyond the second year."

Uncertainty exists as to the time when the winter ring is formed. "The winter ring is formed in the physiological winter" (Dahl). What is the physiological winter? According to that author,- "The winter of the almanack and the physiological winter are evidently, to some extent, parallel." He, however, says:- "It is impossible at present to exactly fix the time for the commencement and cessation of winter and summer growth: on the one hand, individual variation may here exert considerable influence." The scales of certain herrings in the "middle of April showed the formation of a new summer belt." Certain

herrings, however, found up to the middle of May, had not yet commenced to form a new summer belt. That is, the former lot were in their physiological summer in April, and the latter herrings were in their physiological winter in May. The two seasons overlap. Lea (2) says: "We do not venture, as Schneider has done, to determine from the observation of a scale, whether the formation of a transparent winter ring is beginning, half-ended, or just completed." Lea further asserts that, "but few observations exist regarding the time for the formation of the growth zones of the herring scale, the broad striated summer belts, and the narrow, clear winter rings, "and" if we observe the longitudinal growth of the fish (on its scale) throughout all seasons of the year, we can arrive at some conclusion as to the time represented by the summer belt and the winter ring."

The plain rim of the scale is formed both in summer and winter. Is there any reason for assuming that the summer belt cannot be formed in winter? Such a problem involves the definition of the physiological summer and physiological winter, in terms of the seasons. The physiological winter appears to be a period during which the herring does not grow. If a herring stopped growing in summer could it be in its physiological winter? The physiological winter cannot be accepted as an accurate unit for age estimation. The scale method professes to give the age of the fish in years. Then it is necessary to correlate the physiological winter with a season. If the physiological winter occurs both in winter and summer in one fish, or in the winter with one fish, and in the summer with another, or if it occurs one year and not the next, one must be at fault in one's age estimation.

Dahl cites various factors which may influence the occurrence of the physiological summer and winter,- "and, on the other hand, climatic conditions

and geographical situation will probably be found to affect the beginning of summer and winter growth to some degree", and certain "facts seem to indicate that the commencement of growth is dependent upon age, as well as on the state of the sexual organs, and that the spawning process possesses the power of lengthening or assisting the conditions that give rise to the peculiar winter rings of the scale."

We have thus the following factors as possibly influencing the formation of the age criteria:

- (1) Individual variation of the fish.
- (2) Climatic conditions and geographical situation.
- (3) Age.
- (4) Spawning.

These factors are unknown quantities.

(1) If individual variations step in to affect the time of formation of the winter ring, the latter can be no better an age criterion than is the length of the fish.

(2) What are the climatic conditions which affect the formation of the winter ring? As Schneider (6) points out, it is not the low temperature of the winter. "The scales of Clupea (Alausa) dorsalis C. Val., captured in the Gulf of Guinea, showed the rings more faintly imprinted than in Clupea harengus, but, after all, not more indistinctly than in many examples of herring." "Accordingly, the so-called winter rings are also present in fishes which live in regions where, as in the Gulf of Guinea, perpetual summer prevails, and we must allow the term winter ring to lapse."

Fulton (26) and Lea, moreover, testify that growth of a fish may vary in summer independently of the temperature. What, then, are the climatic condition in question?

(3) The writer has not found any data regarding the influence of age, but Lea (42) suggests size as a factor. He says, "It looks as if it were the largest fish which first make their appearance in the new period of life which is indicated by the formation of a new summer belt on the scales."

(4) The great effect which spawning has on the physiological conditions of the fish is apparent. It is not, however, clear why this process should be expected to lengthen or assist the unknown, or at least undefined conditions which give rise to the winter ring. Dahl (15) says, "That the spawning process is itself the main cause of the winter ring, is clearly disproved by the fact that individuals which have never been sexually mature also possess the winter rings even from the first winter of the scales' existence." Lea says that "Helleveara has found that herring caught off the coasts of Finland often show faint rings which, in his opinion, are caused by the rapid development of the sexual products accompanied by fasting or by lack of nutriment. In spite of this, it seems as if these faint rings are easily distinguished from the real winter rings in this case, for the author concludes his interesting treatise in the following way:- Determination of the age of the fish by the scales did not present appreciable difficulty after I had practised it somewhat. In such localities, where the herring spawn during the whole summer, the scale examinations may possibly be more intricate."

A scale reader may, after some study of the scales, arrive at a rule whereby he recognises the winter rings. But how can he tell that in so doing he is reading aright? He has no check on his age estimates. A ring which depends in its formation on so many variables can not be very uniform in its

appearance.

"It will be both interesting and instructive", says Dahl (15) to study the precise nature of the growth of the scale and the structural differences between summer and winter growth from a histological point of view. It will also be necessary to study the precise moment when summer growth begins and ends in different localities, and for the different age groups, as well as to investigate the deeper physiological causes of the stagnation and revival of growth. To these important questions I hope to be able to return as I get the necessary material." "At the present time, however, I consider that by employing the scale test, a sufficiently correct idea of the age and growth of herrings in different portions of the sea can be obtained."

Lea (42) states that he has "arrived at a subjective certainty with regard to the correctness of Dahl's interpretation", and further that "the main considerations which form the basis of the scale studies are, (1) that the different growth zones which can be observed on the scales correspond to regular epochs in the life of the herring, or, more definitely, that a period of one year lies between the formation of two so-called winter rings: (2) that the so-called winter rings are at least annual rings seems to me to have been sufficiently proved in the papers which have been published. (Broch (9), Dahl (15), Lea (41))." I have been unable to find the proof in these papers.

Lea (42) says that the winter rings are at least annual rings. It is difficult to see how that can be unless the winter ring is formed in the same season each year. According to the advocates of the method there are winter rings which are annual rings and summer rings which are not annual rings. The latter may or may not appear in the scale. But it is to be inferred that there is no reason for assuming that if one faint ring appears in any summer another faint ring could not appear during the same summer. Further, can it be maintained

that the ring formed in summer is never a prominent one and that the winter ring may not sometimes be a faint ring? Schneider indeed says, "A priori, the assumption that an autumn herring in certain regions can possess twice as many age rings as a spring herring of the same age is not excluded. According to the investigations of Damas the scale of Gadus vireus may receive two rings in each year."

Some herrings had not commenced their summer growth by the middle of May. It follows then that they were in stagnation of growth at that time. There is no indication of how long a stagnation of growth is required to permit the formation of a winter ring.

The scale method of age estimation gains some credibility from the fact that its estimates are not a priori untenable." For example, if it be asserted that a particular herring 30 cm. long is eight years old there is nothing one knows of to make one deny the statement. But, if the rings were diagnosed as six-monthly rings, the age would be four years and that would also be quite a reasonable estimate, and so on. There is a long range of age, which could be accepted as possible for any wild herring. The assumption that the interval between different pairs of rings does not represent equal intervals of time is also quite within the limits of credibility. Before the method can be regarded as soundly established, it is necessary to prove (1) that the so-called winter ring is formed in a definite season of the year and only in that season, and (2) that one, and only one, winter ring is formed every year in every herring.

If the ring is a measure of time, it must be formed as the result of the influence of environmental factors which are constant. It is necessary to show that all herrings are subject to these influences at the same time every year.

Dahl (16) says, "A number of investigators have endeavoured to test and develop these methods--Reibisch's otolith method, and Hoffbauer's scale method, which both, on closer analysis, prove to rest on the fact that the growth of fishes is periodical according to the seasons of the year, and that this periodicity leaves certain traces which can be recognised in the whole of their osseous system and osseous formations."

The expression "periodical according to the seasons of the year" is vague. It may be granted that growth is periodical. The problem is to show in what way growth is periodical, how this periodicity is correlated with the season and further how it bears on the formation of the winter ring. The theory depends on the unproved assumption that a special ring is formed on every scale of every herring in each winter. There is nothing in the theory that justifies one scale of a herring showing a different number of rings from any other scale of the fish, unless it can be proved that some scales grow in area while others do not. If that happens, it must be due to individual variation, not to any external character such as the season, which cannot be supposed to act differentially on the scales of the one fish.

A fish cannot indicate its age by its structure, unless it grows both in summer and winter. There is no reason to believe that all herrings grow and stop growing in unison. That no herrings grow during winter is difficult to believe, because the roe and milt grow in winter as well as in summer. The skeleton and muscles grow in summer, why should they not grow in winter? The eggs of the herring hatch in summer and in winter so that one must assume, until it is proved otherwise, that in the range of temperature of the North sea during the year, of from 38° to 58° F. say, the physiological processes of the herring are in no way interrupted. One cannot therefore postulate a period of stagnation of growth for all herrings caused by the winter.

According to Dahl, "Up till the 10th or 11th year, the winter rings may, as a rule, be read off with absolute certainty. After that, it often becomes impossible to distinguish between the rings with the same degree of certainty and I have had in such cases to note the number of winters which I could plainly see without being sure that there was not really one more."

Lea says, "Adventitious rings will certainly be a source of errors both in age determination and in growth calculations." He states, however, "The only conclusion to be drawn from "certain" parallel observations is that the sources of error in determining age are small and of no significance for the biological problems to be elucidated."

The method is not practical. The recognition of the winter ring is not a simple matter. The test of prominence of the winter ring over the accessory ring does not lend itself to exact definition. The condition of the scale and the lighting have an important bearing on the appearance of the ring. When several rings are present on a scale, it is unlikely that every one will agree as to which is the winter ring.

In reading the winter rings, one is continually faced with problems like the following:-

(1) A ring is clear in a large part of its course, but dark in the remainder.

(2) A ring is clear in a small part of its course and is a prominent dark line in the rest of its course. The writer has seen a ring that was in one part of its course clearer than the summer fields on each side became, as it progressed, darker than the fields, and while in the former part the ridges on it were interrupted, the ridges were regular and continuous across where it was darker.

(3) The apparent ring may have clear ends on the basal line while the

crest of the bow, i.e., in the anterior part of the scale, is dark or not even traceable.

(4) The rings are in some cases not continuous. The apparently complete bow may consist of two curves starting as prominent clear lines from either side of the scale, and which do not meet and unite. They may approximate closely enough to appear to unite but really overlap. Some of the lines of a group may be invisible anteriorly.

(5) There are isolated bits of clear rings visible. One is not entitled to assume that the isolated part is a portion of a complete winter ring.

The reading of scales is very elusive. One can bring oneself to accept various rings as winter rings because the bright, prominent rings are connected by rings of intermediate brightness with the dull and obscurer rings. The reading of a particular herring scale will be affected by the general structure and appearance of a scale which has just been read. If one reads a scale in which the rings are shown indistinctly, one would in the next scale be inclined to include a larger number of rings than if the rings of the former had been prominent. Until some proof to the contrary is given, one must assume that every scale of the fish is acted on by the season in exactly the same manner and to the same extent. That is the only possible view to take if the ring is really a seasonal mark.

There is not a definite brightness marking all the "so-called winter rings." For example, on a small herring one might infer no winter ring was present if one were limited to accept only rings of a brightness and prominence such as one finds on a big scale. The standard of brightness is one personal to the individual and cannot be communicated to another observer. Does the question come to be simply a comparison between the rings on the one scale? Does one merely divide the rings on the scale into prominent and faint rings and regard

the former as winter rings, the latter as summer rings? If that were so, the result would be that a ring of a particular absolute prominence may pass in one scale for a winter ring and in another scale may be relegated to the summer period.

There are, moreover, not merely two classes of rings on the scale, e.g., prominent well-marked winter rings and faint summer rings. There are various degrees of prominence exhibited by the rings. Three or four different degrees of prominence may be seen in the rings of a scale. Experience shows that all the scales of the one fish do not exhibit the same number of rings.

It is usually assumed that one is justified in discarding scales which offer difficulties in reading. Is that legitimate, and if so, to what extent? No satisfactory explanation of the double rings seems to be available. Doubling occurs in the scale of the pilchard also (Page). So far no satisfactory reason has been advanced to induce one to believe that the prominent and faint rings are of different natures and that a particular absolute degree of prominence separates the winter from the summer rings.

The writer has at various times kept herrings in confinement and in one of these experiments the herrings lived for three years in the seawater pond of the Fishery Board Laboratory at Aberdeen, Scotland. A number of small herrings were captured in August, 1917, and transferred to the pond. These herrings, which range in size from 5.5 - 8.2 cm., occur in large numbers each year at Aberdeen. The herrings placed in captivity were not measured at the time. What is the age of these herrings? Some of them show a ring on the scale. Whether the ring is to be regarded as a winter ring the writer is not able to decide. It is not so prominent as the winter ring of a large herring, but one cannot expect so prominent a winter ring in so small a scale.

The herrings were fed regularly with chopped mussels, which were eaten readily. As far as could be judged by the eye, they grew at an approximately uniform rate.

Two years later, viz. (July, 1919), one of the herrings was examined. It measured 21 cm. in length, (measured to the middle of the fork of the tail). Three scales taken from this fish were kindly examined by an experienced scale authority to whom neither the length of the fish nor its history was communicated. He gave the age as at least 2 yrs. That means that he could not tell whether the herring was 2 or 3 years old.

A test was applied to three scales of this fish. The attempt was made to ascertain the length of the fish when the first ring was formed. The first scale gave 7.8 cm., the second 9.8 cm. and the third scale 5.5 cm. as the length of the herring when the first winter ring was formed. The question arises, is one right in the selection of the first winter ring? If one had only one scale of the fish to examine one could have no doubt on that point. It is only when he examines several scales that he begins to doubt his selection, that is to say, if he accepts the theory, because if the theory is valid, the first winter ring should be made on all the scales at the same time. If now one finds that the first winter rings were formed at different times on different scales he is forced to the conclusion that they are not winter rings. If it be maintained that the correct winter rings were not selected on these scales, then what are the criteria by which one can select? So far the writer has endeavoured to follow the method described by Dahl.

A year later another of the pond herrings was killed. It measured 23.4 cm. in length. Scales taken from it were sent to two other experienced scale readers. They read the scales independently and gave the age as 3. What is meant by 3 is not clear, but in any case an exact age is not given.

When one considers the difficulties which are involved in the scale method, one may ask what advantage it has over Petersen Length Method, whereby the range of size of successive year-classes is supposed to be obtainable. Lea (1) affords material for an answer, "As a final example, I shall show the results of age investigations in a sample of young herrings (spring-spawned) caught in the north of Norway during the autumn of 1909."

The criticism of the writer has been directed to the practicability of Dahl's method. It is not proved that the winter ring is an annual ring formed in a definite season. If annual rings exist one cannot recognise them by definite and unmistakable characters.

If it proves possible to tell the age of the herring in an exact number of years the results will be of much value, but if the estimates have to be taken with a number of reservations and if different observers cannot be certain that they are discriminating the winter rings aright, it will lead to confusion. Certain authors among whom may be cited Schneider, Belsman and W.F. Thompson (with reference to the Pacific herring) offer cogent criticisms and describe difficulties and disabilities of the method. Lea, who has to some extent become the chief sponsor for Dahl's method, and who is to be congratulated on the elaborate and laborious tests which he has carried out, himself admits the difficulties which he has met with and which he has endeavoured to surmount. The real defect is the want of experimental proof. Such can be obtained from herring kept in confinement and would not be a very difficult accomplishment. It would mean a period of years before the results would be available.

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