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THE SCALES OF THE HERRING

AS A MEANS OF DETERMINING

AGE, GROWTH AND MIGRATION

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Introduction.

The programme of the International study of the Sea has during the last years taken up the study of the natural history of the herring. These investigations are in charge of the International commission A.

The study of Herrings has presented considerable difficulties, especially in regard to methods. Notwithstanding the excellent preliminary works of Prof. HEINCKE it was therefore considered necessary to undertake some investigations in order to attain methods for a closer description of the different herring tribes and their habitat in the oceans.

These preliminary investigations have chiefly been entrusted to the case of the Norwegian Fisheries investigation.

During the cruises of the „Michael Sars" a considerable amount of material was collected from various parts of the North Sea, partly in order to describe the herring tribes of which Prof. HEINCKE had only had a limited material, partly to define the distribution of these tribes in the North Sea. This material has been treated by Mr. HJALMAR BROCH, who subsequently published a paper in the Bergen museum Aarbog. „Norvegische Heringsuntersuchungen während der Jahre 1904—1906. Unsere Heringsstämme und ihre Wanderungen".

While treating this material, Mr. BROCH observed, that the scales of the herring are excellent for the purpose of determining the age of the herring. I find however that F. A. SMITT was the first who noticed a connection between the scales of herrings and their age. In his „Skandinaviens Fiskar" published at Stockholm in 1895 he gives on page 957 a deliniation of a herring scale accompanied by a short description where he mentions the concentric rings which he regards as lines denoting

an interruption in the growth of the fish. The question arose, if the further study of the scales might lead to methods employable also for a description of the different herring tribes. As Mr. Broch, on account of other occupations, had to discontinue his investigations, which I have had the opportunity of continually following, the work was continued by me.

The following paper will shortly deal with the main results, which I have been able to attain, and which may be supposed to be of special importance to the methods for herring investigation.

A comprehensive, more special description of the different herring tribes and their natural history must be postponed for a later publication which probably will appear in the reports of The International Commission A.

Before closing this paper I wish to express my thanks to those gentlemen who have kindly rendered assistance to my work. Dr. Redeke of Helder, Dr. Garstang of Lowestoft and Dr. Holt of Dublin have, upon the request of Dr. Hjort, convener of the International Committee A, been kind enough to procure material from Dutch and British coasts. To all these gentlemen I wish to forward my best thanks.

Chapter I.

Some preliminary remarks on the structure of the scale.

The scale of the herring consists of an oblong irregularly elliptic and transparent plate.

The anterior part of the scale, which is concealed in a fold of the skin, has on the outer surface a structure, characterised by a number of fine transversal ribs or striae. These ribs start from an irregular median line and run with slight branchings and irregularities out towards the margin of the scale. (See Fig. 1).

This striated structure suddenly ceases along a transversal, somewhat curved line, which I will term the base-line, a little behind the centre of the scale. The posterior and exposed part of the scale is irregularly oval or sometimes triangularly shaped, with a frayed posterior edge.

In the anterior striated part of the scale we will, according to the size of the fish from which the scale is taken, clearly distinguish a certain number of narrow concentric rings, starting like irregular half-circles from the base line.

When examined with a weak lens (Zeiss loup 10) these 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.

These narrow half-circular rings, of somewhat irregular outline, divide the scale into a number of areas. Thus in the centre there is a half-circular plate limited by the base line and by a narrow half-circular ring. Then comes a broader horse-shoe shaped belt, followed by a narrow

transparent ring: then again a similar horse-shoe shaped belt, which is succeeded by another narrow transparent ring; and so forth according to the size of the individual fish from which the scale is taken.

These narrow transparent rings represent the physiological winter, and the broader less-transparent areas the physiological summer growth.[1])

The central plate with its winter-ring and the succeeding horse-shoe formed areas with their winter-rings thus represent annual rings;

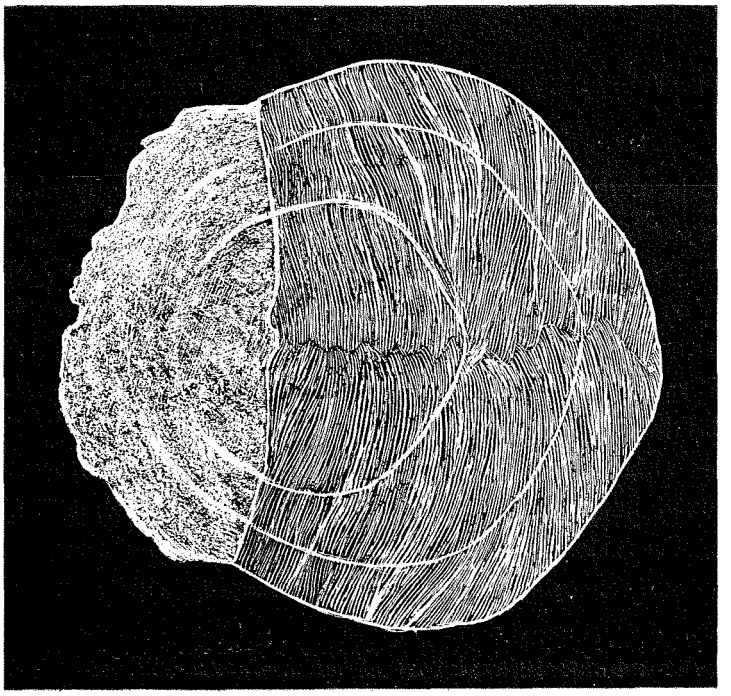

Fig. 1. Herring Scale.

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.

The analytical results detailed in the following chapters furnish in my opinion the most conclusive proof that this interpretation of the scale is correct. (See Figs. 4 and 6). For these plainly show that the

[1]) The terms winter and summer hence forth used in describing the structure of the scale thus denote physiological winter and summer.

annual rings are added to regularly, to a degree parallel to the size and therefore to the growth and age of the individuals from which the scales are taken.

An examination of individuals at different seasons further shows that the broad semi-transparent horse-shoe shaped belts or areas are formed during summer and the narrow transparent rings during winter. The following drawings will to some extent illustrate this.

In Fig. 2 we see the magnified margin of a scale from a herring taken on 3rd March 1907. The drawing represents a period including the winter of 1906—1907, summer 1906, winter 1905—1906 and part of the summer 1905. We here see that the winter is characterised by

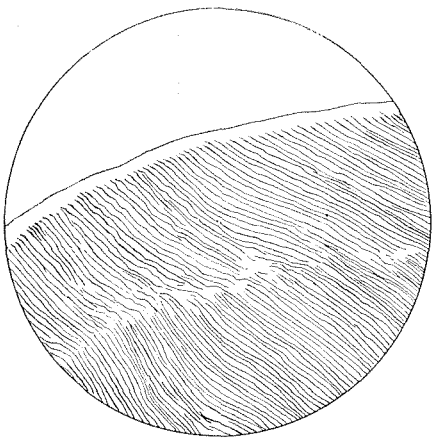

Fig. 2. Margin of scale in winter.

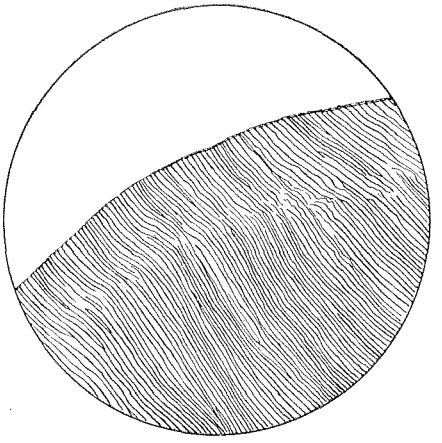

Fig. 3. Margin of scale in summer.

a cessation or minimum of growth. The regular striation characterising the summer stops nearly abruptly, and leaves the rim of the scale almost quite blank during winter. The structure of the previous winter shows that the striation is here broken besides being much thinner and more irregular. As the area of the scale expands in the beginning of summer, the striation passes, in thin and irregular lines, over the blank rim of the scale. Then as summer advances the regular growth of the striation follows the expansion of the scale: and an examination of scales taken during summer shows, that this striation generally extends to the very rim of the scale, as depicted in Fig. 3.

Sometimes however we find in summer also a very narrow blank rim on the scale: or parts of the rim may be thin and faintly striated and some-

what ressembling the strong blank ring of winter. Whether this phenomenon is caused by an intermittent or irregular growth producing a faint accessory ring during summer like those formed in the otoliths of plaice and cod, I cannot at present determine. Certainly such accessory rings have been observed in the summer-belts on some herring scales; and they are easily to be distinguished from genuine winter-rings, being exceedingly faint and imperfect.

The greater transparency of the fully formed winter-rings, which is so easily seen with a weak lens, is thus (as an examination with more powerful lenses will show) to some extent to be attributed to the irregularity and faitness of the striation which passes over, as the summer growth of the scale begins.

The part of the scale that is formed during winter is also evidently thinner than the areas formed during summer; and from certain angles of view a small groove may be observed in the scale coincident with the winter-ring.

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, 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. The material in my possession has not been collected with a view to elucidate this point and accordingly does not admit of any attempt to settle such a question finally. I will merely mention that the scales of young immature herring from Bergen in the middle of April showed the formation of a new summer-belt and that the progress of the formation of this belt has been followed until May. At the same time examination of large spawners which were found up to the middle of May showed that the scales of these fish had not yet commenced to form a new summer belt. These facts seem to indicate that the commencement of growth is dependent upon age as well as on the state of 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.

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 scale's existence.

It will be both interesting and instructive 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.

In herring which spawn in spring the scale is formed during the first summer of their existence, and the number of winter-rings will thus enable us to determine the number of winters during which they have lived and consequently to decide their age with more or less accuracy corresponding to our knowledge of the duration of the spawning season.

When herring spawn during autumn the question becomes a little more complicated. In the first place does the „physiological" winter of these herrings, which gives rise to the winter-ring, correspond to the winter of the almanack?

The question may be answered in this way, that the scales of autumn-spawning herrings from the northern portion of the North Sea during the summer months, when the sexual organs are developing, show a distinct summer growth: and that scales of spent herrings from the Skagerack in winter show stagnation.

The winter of the almanack and the physiological winter of the adults are thus evidently to some extent parallel.

The young of the autumn spawners pass the first winter of their existence as very small fish. The probability is that the great majority do not get their scales until the next summer. At least I found, during the cruises of the „Michael Sars" (in March 1904) on the Jutland Bank, young herrings 4 cm. long, which did not possess any scales whatever.

This shows clearly, that a considerable proportion at any rate of

the autumn spawning herrings will be about $1^1/_2$ years old, when the formation of the first winter ring is completed.

There is of course the remote possibility, that some of them in certain parts of the North-Sea may get the scale in the first winter, and until this point has been thoroughly investigated it will of course be a source of some uncertainty.

This uncertainty is however greatly diminished by circumstances which will later appear; and in most cases the age of the autumn spawners or at least the northern types, can be arrived at the same manner as the age of the spring spawners, if we only remember to consider the first winter ring as representing $1^1/_2$ or $1^1/_4$ years.

All these scales of the same individual are of the same age. I have repeatedly compared scales taken from different parts of the body of the same herring and always, excepting regenerated scales found them to possess the same number of annual rings. The sample af scales for examination may thus be taken anywhere along the body of the fish. The small scales of the tail ought to be awoided, especially in large fish, as their minuteness renders the examination more difficult. For examination I prefer the scales on the forepart of the side of the body, because they are the largest.[1])

They are in many cases easily examined with a pocket lens — at least this holds good up to 4—5 years old. Zeiss dissecting microscope with lens 10 or Zeiss microscope with Oc. II and lens a_1, are quite sufficient as a rule. Only in very few instances will a more powerful lens be of some service in distinguishing very fine rings in the scales of old fish.

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 numbers of winters which I could

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[1]) Occasionally we find scales which are unfit for examination as to age. These seem to be scales which once have been lost and regenerated. They are characterised by the possesion of a large central area of irregular and blurred structure, which seems to correspond of the area to the lost scale. From the first winter after regeneration the structure becomes quite regular, like that of the other scales of the same individual.

plainly see, without being quite sure, that there was not really one winter more.

The scales taken for examination have been placed in small envelopes and dried carefully, away from strong artificial heat.

It is easy to examine them, when they have been softened for a moment in water. They can be cleaned quite quickly either with a small brush or by means of a pair of tweezers and the fingers. For large scales I prefer the latter method. During examination under the lens the scales should be covered with a layer of water, or water and glycerine.

A mixture of gelatine glycerine sterilized with carbolic acid is excellent for imbedding samples for finer microscopical examinations.

Chapter II.

Analysis of age of Norwegian Spring Herring.

In March 1907 I visited the great Spring Herring Fishery, which annually takes place in the neighbourhood of Haugesund.

On the 11th and 12th of March I procured 3 different samples of herrings from localities, which are several miles distant from one another. They were all taken in seines of a mesh close enough to retain much smaller herrings. All were, with one exception (an individual of 22 cm.) sexually mature; being either ready to spawn, spawning or in few cases just spent fish.

The samples were:

Sample I.	From seine, Vespestad, Bømmelø	375	herrings
— II.	„ Purse, seine Gjeitung, Bømmelø	275	—
— III.	„ seine, Espevær	274	—
	Total	924	herrings

These samples have been separately subjected to an analysis of size and age, determined by the number of annual rings of the scale.

The aggregate results obtained by this analysis are detailed in the following table. The scales of the fish had all their last winter ring in the margin and as the individuals were spawning their age in years is determined by the number of winter rings.

It will be seen, that their age ranges from 3 years to at least 14. As I have previously remarked, the counting of the winter rings (for reasons before mentioned) becomes more difficult from the 10th and 11th year onwards, and therefore we cannot entirely trust the accurary of the figures for the years from 11 to 14. The figures only denote the number of winters, which could be seen with certainty.

Analysis of age in 924 Norw. Spring Herrings.

Born		1904			1903			1902			1901			1900			1899			1898			1897			1896			1895			1894			1893		
Length in cm.	Nr. of Ind. exam.	3 years			4 years			5 years			6 years			7 years			8 years			9 years			10 years			11 years			12 years			13 years			14 years		
		♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.
22	1	—	1	1																																	
23	—	—	—	—																																	
24	1	—	—	—	1	—	1																														
25	9	4	1	5	4	—	4																														
26	31	8	—	8	8	7	15	1	7	8																											
27	92	1	—	1	38	27	65	13	10	23	3	—	3																								
28	121	—	—	—	43	31	74	21	21	42	5	—	5																								
29	147	—	—	—	31	7	38	39	22	61	19	18	37	4	4	8	—	3	3																		
30	137	—	—	—	5	3	8	7	22	29	20	28	48	13	17	30	11	11	22																		
31	145	—	—	—	—	—	—	4	4	8	16	20	36	17	21	38	24	35	59	2	2	4															
32	116	—	—	—	—	—	—	—	—	—	4	3	7	14	20	34	28	37	65	5	4	9	—	1	1												
33	41	—	—	—	—	—	—	—	—	—	—	1	1	2	1	3	10	11	21	3	7	10	—	2	2	1	1	2	—	1	1	—	—	—	—	1	1
34	24	—	—	—	—	—	—	—	—	—	—	—	—	—	3	3	3	2	5	—	4	4	2	3	5	—	3	3	2	1	3	—	—	—	—	1	1
35	39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	2	2	4	7	3	10	4	3	7	6	5	11	—	5	5	—	1	1
36	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	1	2	3	1	—	1	3	1	4	—	2	2	1	—	1
37	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	2	—	—	—	—	—	—	1	2	3	1	—	1	1	—	1	1	—	1
Tot.	924	13	2	15	130	75	205	85	86	171	67	70	137	50	66	116	79	100	179	12	19	31	10	11	21	7	9	16	12	8	20	1	7	8	2	3	5
Average size: cm.	30.1	25.5			27.7			28.6			30			31			31.6			32.8			34.6			35			35.05			35.5			35		

By means of the figures in the above mentioned table the following diagrams have been constructed.

Fig. 4 shows the average length of the fish as a function of age. The smooth course of the curve indicates of accuracy of the method. The very small irregularities of the curve are probably chiefly due to inaccuracy in the measuring of the individuals (fractions of centimetres being noted as nearest whole number).

Fig. 5 shows the number of individuals as a function of age, males and females separately and taken together. The proportions of males to females in the agregate is nearly equal, the whole sample containing 468 males to 456 females. The diagram however shows, that among the

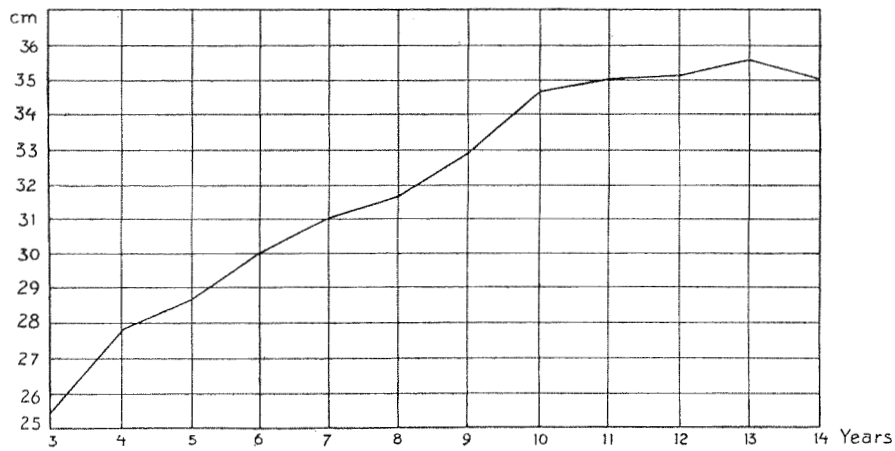


Fig. 4.

young spring herrings the males outnumber the females and that among the older fish the females become more numerous in proportion. This may denote that death occurs earlier among the males, or it may also denote that the females do not partake in the spawning so early as the males.

The male and female curves, as well as the aggregate curve plainly show, that the number of individuals of different ages varies greatly.

Thus the individuals 5, 6 and 7 years old are less numerous than the 4 year olds, while those of 8 years are nearly as numerous as those of the 4th year. This circumstance alone seems to exclude all possibility of using the present material as a means for calculating deathrate or even the relative duration of life of the Spring herring.

Evidently variations of very great moment are bound to occur from

year to year in the number of individuals of any given age and the nature and scope of these variations will form an important subject for future investigations.

Fig. 6 represents a diagram showing the size, age and numbers of the individuals contained in the whole sample, denoted by curves calculated by means of the figures in table I.

Besides the variation in size compared with age, we also here note the same facts, which were shown by the diagram in fig. 5.

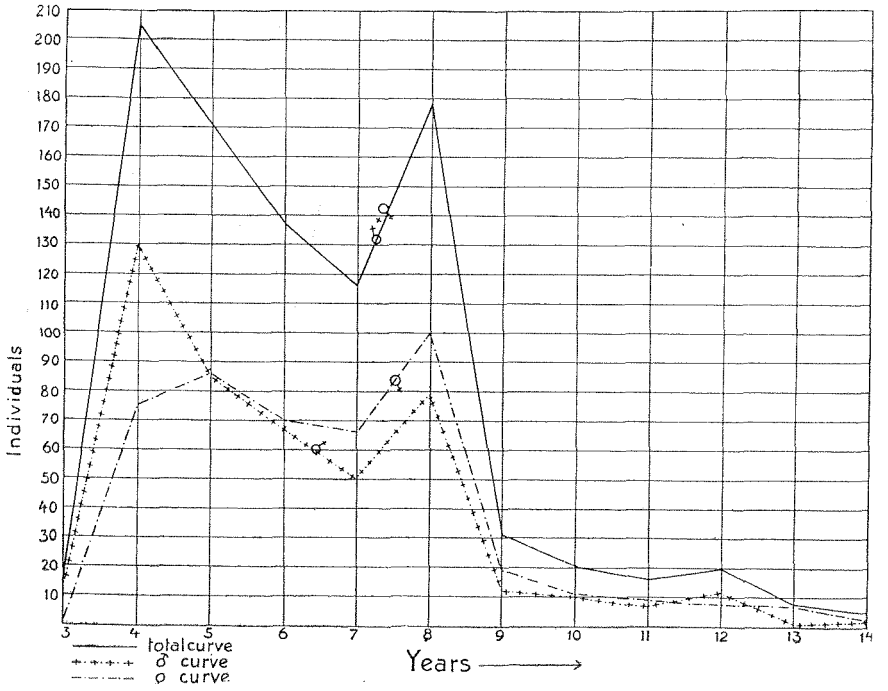


Fig. 5.

We see the irregularity of the numeric relations of the different ages and also note that there is an irregularity relating to size parallel to the numeric irregularity. See for example the curves for the 7 and 8 year olds, and also those for the 8 and 9 year olds.

The facts shown by these curves seem on the whole to indicate, that the life history, the surroundings and the growth of the different year-groups and even of the individuals of these groups must have been very varying.

When individuals for instance of 28 cm. length may be 3, 4, 5, 6,

7 or 8 years old, when a herring of 32 cm. may be from 5 to 11 years old, it seems safe to conclude, that such individuals have lived under highly varying circumstances and conditions.

The general value of the facts shown by the analysis mentioned naturally depends on the sufficiency of the material. Is this material sufficient and to what extent may it be considered as representative?

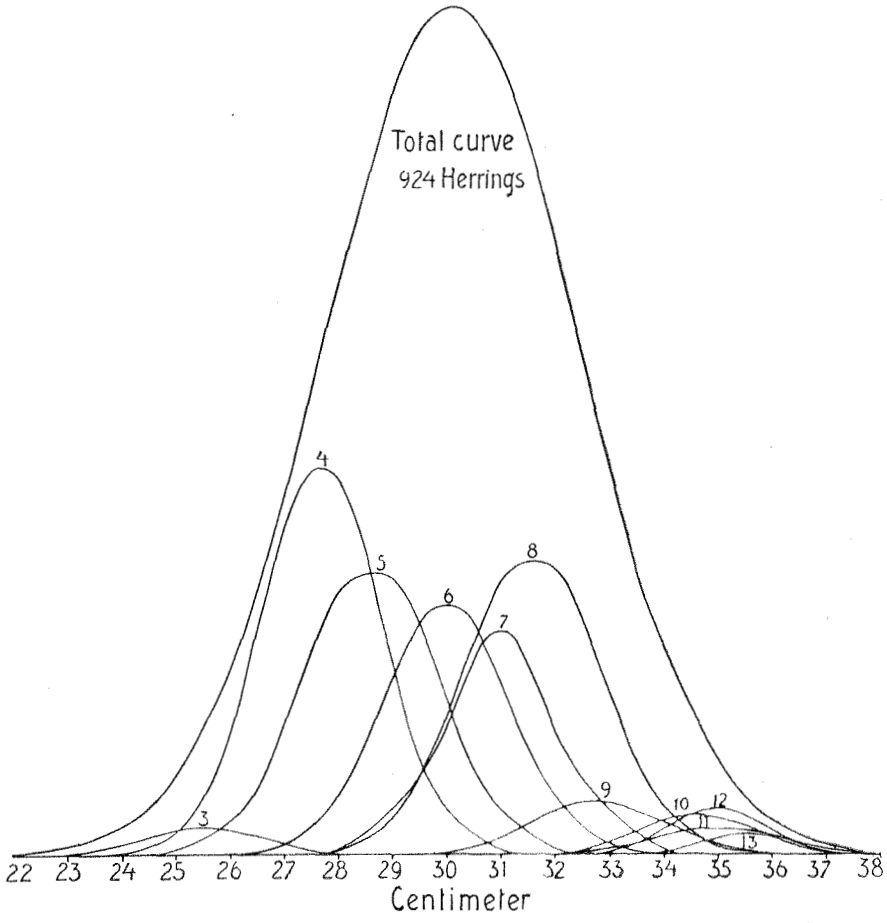


Fig. 6.

The spring herring fisheries last about 2 or 3 months and take place on a stretch of coast more than 100 miles long. It is therefore self evident, that it is impossible at the present moment to consider my samples as entirely representative of the whole Spring Herring tribe. Many more investigations have to be carried out, before we shall be in a position to

determine how much material we need to obtain a representative picture of the herring as a whole.

As illustrating our method however it is of interest to examine how far the sufficiency of my present material goes. If we consider the 3 different samples, of which the total results are compounded, we shall see, that the above-mentioned characteristics are to be recognised also in each of these.

Thus the predominance of young males and old females found in the aggregate analysis is plainly seen by an examination of pencentage of males of different age in the 3 samples.

	Years											
	3	4	5	6	7	8	9	10	11	12	13	14
	% ♂	% ♂	% ♂	% ♂	% ♂	% ♂	% ♂	% ♂	% ♂	% ♂	% ♂	% ♂
Sample I...	87.5	68	63.5	67.3	50	50	46	50	37.5	50	0	33.3
— II...	100	53.8	45.2	48.7	40	42.5	28.5	54.5	50	55.5	25	100
— III...	75	62.7	37.7	28.3	35.7	37.1	50	25	50	100	0	0

Also the peculiar numeric preponderance of the 8 year old fish shown by the aggregate analysis is easily traced in the separate samples. The following table giving the numbers of individuals of different age contained in the 3 samples shows this quite plainly.

Number of individuals of different age contained in the 3 samples.

Age in years	3	4	5	6	7	8	9	10	11	12	13	14	Total
Sample I.....	8	91	71	52	48	66	13	6	8	8	1	3	375
— II.....	3	39	31	39	40	78	14	11	6	9	4	1	275
— III.....	4	75	69	46	28	35	4	4	2	3	3	1	274
Total	15	205	171	137	116	179	31	21	16	20	8	5	924

The main features of the 3 samples thus have a remarkable resemblance considering that these samples were taken at places many miles distant and from shoals of herrings, which judging by the size of the individuals were entirely different.

Thus the average sizes were:

In sample	I.....	30.20 cm.
- —	II.....	31.03 „
- —	III.....	29.37 „

As an illustration of the great difference in size (or bulk), that these averages really denote, I give the results of some weighments of herrings which I undertook.

Length i cm.	Nr. of ind. weighed.	Average weight.
25	6	109 gram.
26	10	120 —
27	15	140 —
28	12	173 —
29	11	193 —
30	12	210 —
31	12	228 —
32	7	243 —
33	7	267 —
34	0	Interp. 287 —
35	7	309 —
36	1	365 —

This table clearly shows, that a difference of one or two centimetres in length really implies a much more important difference in bulk and weight.

Notwithstanding such great variation in special respects, the general correspondance in others is, as the tables above show, quite common to all the samples.

The present material thus permits the following conclusions.

1) The spring herring does not as generally supposed consist of one or two age groups. It consists of many groups of individuals ranging from 3 to at least 14 years of age.
2) The number of individuals may continue to be high even in the older age groups and many fish exist which probably have spawned up to 10—11 times.
3) The true relation between the numbers of individuals of different ages cannot be determined by this material.

In order to form some idea of the age and size of the younger stages of our Spring Herrings I have examined some samples of smaller herrings caught in seines in the skjærgaard outside Bergen.

I here give an analysis of 2 samples of young herrings from the vicinity of Bergen.

Length in cm.	Nr. of Ind. examined	Year of berth								
		1906			1905			1904		
		1—1¼ Years			2—2¼ Years			3—3¼ Years		
		♂	♀	Total	♂	♀	Total	♂	♀	Total
10										
11	5	—	—	5						
12	18	—	—	18						
13	15	—	—	15						
14	17	—	—	16	—	—	1			
15	1	—	—	1						
16										
17										
18										
19	4	—	—	—	2	1	3	1	—	1
20	6	—	—	—	1	2	3	1	2	3
21	14	—	—	—	3	4	7	6	1	7
22	15	—	—	—	1	2	3	6	6	12
23	9	—	—	—	—	—	—	3	6	9
24	2	—	—	—	—	—	—	2	—	2
Total	106	—	—	55	7	9	17	19	15	34

The samples consisted of 56 small herrings 11—15 cm. long from the Manger, caught 19/4 1907, and 50 larger herrings socalled „notsild" from the Herløfjord, caught 12/4 1907.

All these herrings were, with the exception of 3 individuals 22, 22 and 23 cm. long, sexually immature (HEINCKES Stage I). The 3 mature individuals were 2 males with swollen testes and 1 female spent. These 3 individuals were all a little over 3 years old.

All the individuals had commenced to grow after the winter and the scales were all characterised by the presence of a commencing summer-belt at the margin.

An examination of the number of vertebra (Vert. S.) in the individuals of the two samples showed that the individuals 11—15 cm. long averaged 57.23 and those 19—24 cm. long 57.43, values which resemble the values of the spawning spring herrings.

It may be superfluous to remark, that the above mentioned analytical

table of young herrings from Bergen, may only be considered as an example illustrating the size and age of young immature herrings in a certain locality at a certain time. Only extensive investigations will enable us to form an idea of the size, age and growth of the young immature herrings along the entire coast of Norway.

In Plate I. I have represented a series of scales from Norwegian Spring herrings and young immature herrings from the coast illustrating the average size and age of the individuals. The scales are drawn in true proportion, the length of the baselines of the scales always corresponding to the length of the individuals.

An examination of this plate will clearly illustrate the fact already shown by means of the diagram Fig. 4 that the individuals do not cease to grow until they become very old. Even till the age of 10 years they grew very well, as will plainly be seen from the curve. If we examine the scale we shall also find this fact illustrated in the scale itself. The summer belts are broad and well developed up to the seventh year (in many cases even longer) and even in later years the area of the scale still greatly expands. The record of the growth contained in the scales thus on the whole shows a growth of great uniformity and regularity even up to old age. On the other hand however when comparing the figures on Pl. I we observe, that the different individuals evidently have encountered very varying conditions. Evidently the annual as well as the individual variations of growth are of great importance.

Chapter III.

Analysis of age in other Herring types.

In order to compare the Norwegian Spring Herring with other herring-types I have excamined samples of herrings from the Skagerrack, the Viking Bank, the West coast of Ireland, the Zuider sea, the coast by Lowestoft and finally the Trondhjem fiord.

a. Skagerrack and North Sea Herrings.

A sample of 212 herrings caught in the Skagerrack on March 4 1907 with driftnets not far off the coast was examined. The sample contained herrings in nearly all stages of sexual development.

The analysis showed the sample to consist mainly of spent herrings (HEINCKES stage VII) evidently spent autumn spawners, which during the whole winter occur in the catches along the norwegian coast of the Skagerrack. Besides these there were a considerable number of full herrings (HEINCKES stage III—V), which were going the spawn during the spring months. A few were immature fat herrings, which had never spawned.

The sexual organs of 29 herrings were in the 2nd stage (HEINCKES nomenclature). In this stage I was owing to insufficient experience unable to determine, whether they were immature fish just beginning to ripen or recovering spents, and therefore I omit them altogether.

The analysis of the remaining 183 herrings works out as follows. For the sake of brevity only the totals for both sexes are recorded in the table as the analysis shows the distinction of sexes to be immaterial.

Number of winter-rings.

	Length in cm.	Nr. of Ind. exam.	3	4	5	6	7	8	9	10	11	12	13
Fat and Full Herrings Heincke's St. I, III—V.	24	2	2										
	25	11	5	5	1								
	26	16	3	11	2								
	27	11	—	10	1								
	28	4	—	2	1	1							
	29	3	—	1	2								
	30												
	Total	47	10	29	7	1							
Spent Herrings Heincke's St. VII.	25	4	—	—	2	1	1						
	26	15	—	—	4	2	6	3					
	27	48	—	—	4	9	9	11	8	6	1		
	28	48	—	—	3	7	10	11	6	4	5	1	1
	29	19	—	—	—	2	2	7	4	4			
	30	2	—	—	—	—	—	—	—	—	2		
	Total	136	—	—	13	21	28	32	18	14	8	1	1

The examination of the scales of these herrings showed them all to be in the middle of winter or period of stagnation of growth.

Most of these herrings have also been subjected to an analysis as to total number of vertebrae (Vert. S.) and number of the vertebra in the spinal column carrying the first closed hæmal arch (Vert. H.). This analysis gives the following results.

	Average for Vert. S.	Average for Vert. H.
42 Fat and Full-herrings	57.57	25.57
110 Spent-herrings	56.55	24.89

The sample evidently contains two kinds of herrings, which differ in size and age, state of sexual organs and also in number of elements of vertebral column.

The fat and full-herrings are young Norwegian spring herrings, and their age is consequently determined by the number of winter rings.

The spents are undoubtedly the autumn spawners of the North Sea kinds, which during autumn and winter frequent the Skagerrack.

As these herrings do not form a scale at all during their first winter of existence their age must consequently be determined by adding $^1/_2$—$^1/_4$ year to the number of years derived by counting the winter rings of the scale. This circumstance considerably emphasizes the disproportion between

size and age, which the table of analysis shows to exist between the spent autumn spawners and the spring herrings, a difference which will appear still more conspicuous if we compare it with the great analysis of spring herrings on page 12.

The difference between the autumn spawners and the spring herrings also is clearly recorded in the growth of the scale. The scales of all the spring herrings contained in the Skagerrack sample showed the same uniform growth we described in the case of the spring herrings from Haugesund.

The scales of the spent autumn spawners however showed quite another picture. If we compare the scale of autumn spawners from the Skagerrack on Pl. II (see figs. 7, 8, 9) with those of Spring Herrings of the same age (figs. 4, 5, 6), we shall clearly observe the great difference.

The scales of the autumn spawners present unlike the spring herrings a record of rapidly diminishing growth even from the 2nd and 3rd winterring of the scale. This quite corresponds to the facts shown by the analytical table on page 21.

Another striking feature of the scale of the autumn spawner is the enormous central area of the scale contained within the first winter ring. The magnitude of this area compared with the area of scale is quite striking and will easily be seen, when contrasting scales from fish of the same age.

The explanation of this feature must in my opinion be sought in the fact that the young of the autumn spawners pass their first winter without any scales whatever. In winter or early spring, when the other herrings spawn, these young from the autumn are of a considerable size. As before mentioned I have found such naked young herring ca. 4 cm. long on the Jutland Bank in March.

These young get a much longer summer growth in their first year than the young of the spring herrings and as a consequence form a much larger scale in the first year.

So characteristic is the picture presented by the scale of an autumn spawning herring that in most cases the study of one scale is quite sufficient to determine the properties of the individual, from which it is taken.

The very same picture is also presented by the scales of the autumn spawners from the Northern portion of the North Sea, of which I have examined a small sample[1]) and of which I have represented 3 scales fig. 10, 11, 12 on Pl. II.

In order to try if this great difference between the scale of the autumn spawner and the scale of the spring herring can be expressed by figures, I have endeavoured to use the following method.

I made a series of drawings of the scales of spring herrings and a similar one of autumn spawners all 5 or more than 5 years old. All were taken at random. With a planimeter I then measured the area of the scale limited by the 5th winter ring and the area limited by the first winter ring in all the drawings. I then divided the value of the area limited by the 5th winter with the value of area limited by the first winter. In this way I obtained a coefficient (coefficient 5 : 1), which denotes how many times larger the individual scale was when the 5th winter-ring was formed than when the first winterring was formed.

The aggregate results were:

Norw. Spring Herrings. Coefficient 5 : 1.		Skagerrack and North Sea autumn spawners. Coefficient 5 : 1.	
No. 1 =	37.90	No. 1 =	4.03
„ 2 =	11.62	„ 2 =	3.80
„ 3 =	16.50	„ 3 =	3.50
„ 4 =	8.75	„ 4 =	5.40
„ 5 =	6.38	„ 5 =	6.99
„ 6 =	8.00	„ 6 =	3.45
„ 7 =	9.16	„ 7 =	6.65
„ 8 =	15.00	„ 8 =	4.91
„ 9 =	13.34	„ 9 =	8.60
„ 10 =	9.20	„ 10 =	6.22
„ 11 =	9.00	„ 11 =	5.26

[1]) This sample consisted of 21 herrings caught in the Northern part of the North Sea 48 miles west off Feje Light, $^{11}/_{7}$ 1905. Among these 21 herrings 15 could be recognized as autumn spawners by means of the scale alone and examination of their sexual organs showed this to be the case. 5 individuals had characteristic spring herring scales and examination of their sexual organs proved them to be recovering spring herrings. 1 Individual had a scale resembling the spring herrings but proved to have sexual organs developed.

Norw. Spring Herrings. Coefficient 5 : 1.		Skagerrack and North Sea autumn spawners. Coefficient 5 : 1.	
No. 12 =	13.10	No. 12 =	5.49
„ 13 =	12.62	„ 13 =	18.33
„ 14 =	12.67	„ 14 =	6.09
„ 15 =	11.58	„ 15 =	3.61
„ 16 =	13.77	„ 16 =	3.95
„ 17 =	14.17	„ 17 =	3.90
„ 18 =	9.00	„ 18 =	2.55
„ 19 =	8.40	„ 19 =	3.95
„ 20 =	10.52	„ 20 =	3.50
„ 21 =	9.66	„ 21 =	3.92
„ 22 =	9.00		
„ 23 =	8.30		
„ 24 =	7.24		
„ 25 =	16.63		
Total 25 Ind.	301.51	Total 21 Ind.	113.10
Average =	12.06	Average =	5.39

The picture of the scale, which we obtain through the eye, tells us of course in most instances just as much about the difference as these coefficients. A representation of the characters by means of figures however can more accurately describe the range and standard of the variation.

I have not had the opportunity of extending the above mentioned method to a large number of individuals of both types and consequently I cannot consider the range of variation and the average values of the coefficient above mentioned as final or wholly descriptive of the two types. My only object in attempting to represent this variation by means of figures is to show, that this difference in the scales of various types evidently may be far greater than the difference to be observed in the ordinary numeric characters, which are at present employed for the distinction of herring types.

b. Atlantic herrings from Ireland.

From Roundstone on the Irish West coast I have through the courtesy of Dr. HOLT received a sample of herrings caught in the first days of June.

The analysis gave the following results:

Number of winter-rings.

Length in cm.	Nr. of Ind. exam.	3	4	5	6	7	8	9	10	11	12	13
28	1	1										
29	3	1	—	—	—	1	—	1				
30	22	1	5	2	5	1	3	2	1	—	1	1
31	17	—	—	1	2	7	1	1	3	2	—	
32	4	—	—	—	—	1	—	—	1	1	1	
Total	47	3	5	3	7	10	4	4	5	3	2	1

For the sake of brevity I only give the totals for both sexes. There were 16 males and 31 females in the whole sample.

The sexual organs were all in the recovering stage (HEINCKES stage II) excepting those of one female 32 cm. long which were beginning to ripen (HEINCKES stage III). The Herrings were all in excellent condition. The abdominal cavity was full of fat and oil, and the fish possessed a plumpness reminding of mackerel in good condition. Judgeing by these features they were all fish, which had spawned in autumn and which had now nearly recowered condition and were beginning to develope their sexual organs. The scales prowed to be in the course of forming a new summer belt outside the last winter ring.

The scales were nearly all of the same type as the scales of the autumn spawners from the North Sea.

As will be seen from the figure below (Fig. 7) they exhibit the same kind of growth as that described in the Skagerrack and North Sea autumn spawners.

The fish evidently obtain a large size before the first winterring is formed and grow wery well untill the 3rd winterring is formed. Then growth becomes very slow. The above annalysis will clearly show this. While the Skagerrack autumn spawners analysed by me (see page 21)

do not exceed 30 cm. in length, these Atlantic herring attain a larger size and, as the analysis shows, seem to attain this size quicker than any of the herrings we have as yet analysed. If we compare the size of the Roundstone Herrings of 3 years (or 3 winters) with that of the 3 year old Norwegian Spring Herrings on page 12 we shal clearly observe this.

As to the real age of these Roundstone herrings the bulk of them should, assuming that they are autumn spawners, be a little more than $^1/_2$ year over the number of years denoted by the winter rings. As I have mentioned, the majority of the scales proved to be of the same type as the scales of the autumn spawners from the Skagerrack and the North

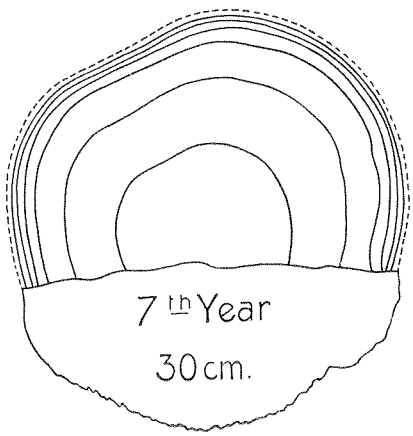


Fig. 7. Scale of Roundstone herring.

Sea. In fact 35 of the specimens prowed to have such typical scales with an enormous central area.

In 4 individuals however the central plate was smaller and somewhat corresponding to that of the Norse Spring Herring. In 8 individuals the central plate contained within the first winter ring was exceedingly small followed by an enormous summer belt in the second summer.

The first annual rings of these scales in fact very much resemble the scales of spring herrings from Lowestoft which later on will be described.

As long as we do not know the life history of the young of the Roundstone herrings, we shall be unable to judge if the abovementioned irregularities in the size of the central area of their seales are due to

some of them getting a scale before going through their first winter. Possibly they may be due to the individuals being spawned in another season of the year, than the majority. As a consequence we cannot be sure that in a certain number of cases (when the central plate is exceedingly small) we have not overestimated their age by one year.

c. Zuider Sea Spring Herrings.

Dr. REDEKE has kindly forwarded to me a sample of herrings caught in a herringseine (heeringssegen) at Helder $^{6}/_{4}$ 1907.

The analysis gave the following results:

Born		1904			1903			1902			1901			1900		
Length in cm.	Nr. of Ind. exam.	3 Years			4 Years			5 Years			6 Years			7 Years		
		♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.
20	1	—	—	—	1	—	1									
21	4	1	—	1	1	1	2	—	—	—	1	—	1			
22	9	2	1	3	5	1	6									
23	15	—	—	—	6	3	9	1	4	5	1	—	1			
24	13	—	—	—	4	—	4	—	2	2	4	1	5	2	—	2
25	6	—	—	—	—	—	—	1	—	1	—	3	3	1	1	2
26																
27	1	—	—	—	—	—	—	—	—	—	—	1	1			
Total	49	3	1	4	17	5	22	2	6	8	6	5	11	3	1	4

All these herrings were mature fish. 45 of them were just on the verge of spawning HEINCKES Stage V, 1 was in the act of spawning and 3 were just spent. .

The rim of the scales showed them to be in their physiological winter.

The table shows that these herrings grow very little after the majority of them have attained sexual maturity, and when size and age are compared to that of the Norwegian Spring Herring, the vast difference will at once be perceived.

Also the scale shows this difference very plainly. On pl. III, I have drawn some scales of different herring types. The scales are drawn in the proper proportion to one another, the baselines of the scales corresponding to the length of the fish. Fig. 2 represents the scale of a 5 years old Zuider sea herring. All the specimens in the sample presented

the same type of scale. As will be seen in the figures (Fig. 2, Pl. III) the growth of the first 2 years resemble the growth of the Norwegian Spring Herring (compare fig. 4 Pl. III); from the 2nd year there is a great deminution in growth and from the 4th year upwards the summer rings of the scale are very narrow indicating the very small growth.

d. Lowestoft Spring Herrings.

From the laboratory in Lowestoft I have, through the courtesy of Dr. GASTANG, received a sample of the small spring herrings which during spring are caught along that shore.

The sample was procured in the first days of April.

An analysis of the sample (52 individuals) works out as follows:

Born		1905			1904			1903			1902		
Length in cm.	Nr. of Ind. exam.	2 Years			3 Years			4 Years			5 Years		
		♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.
18	1	1	—	1									
19	—												
20	3	—	—	—	2	1	3						
21	18	—	—	—	8	8	16	1	—	1	1	—	1
22	10	—	—	—	4	1	5	4	1	5			
23	14	—	—	—	—	—	—	3	5	8	4	2	6
24	4	—	—	—	—	—	—	3	—	3	—	1	1
25	1	—	—	—	—	—	—	—	—	—	—	1	1
26	1	—	—	—	—	—	—	—	—	—	—	1	1
Total	52	1	—	1	14	10	24	11	6	17	5	5	10

4 specimens 18, 21, 21, 23 cm. long were immature. 4 specimens 23, 23, 24 and 25 cm. long were spents, and the rest all had swollen sexual organs (HEINCKES Stage IV, exceptionally V) and were within a short time of spawning.

The rim of the scales showed physiological winter structure.

As will be seen by comparison of the tables the individuals in the Lowestoft and Zuider sea samples are very similar as to size and age. The Lowestoft sample however does not contain any individuals older than 5 years.

The scales of which a figure is drawn in Pl. III (fig. 1) are in the main very like the scales of the Zuider Sea herrings, growth rapidly

decreasing from the 2nd year. A peculiar feature however is the very small central plate of the Lowestoft type and the relatively enormous growth in the second summer. All the scales examined showed this peculiar feature quite plainly excepting the scales of 3 individuals (spents), whose central plates were somewhat larger in proportion.

e. Norwegian Fiord Spring Herrings.

In some of the Norse fiords spawning herrings of unusually small size are regularly to be found in spring. A well known locality for such small spring herrings is the Trondhjem fiord and especially the inner basin of this fiord, the Beitstad-fiord. This year I procured a sample of 101 such small spring herrings from the Trondhjem fiord. Examination of the sample gave the following results:

Born		1904			1902			1903			1901			1900		
Length in cm.	Nr. of Ind. exam.	3 Years			4 Years			5 Years			6 Years			7 Years		
		♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.	♂	♀	Tot.
17	3	—	3	3												
18	20	8	8	16	1	2	3	—	1	1						
19	14	2	1	3	4	1	5	2	—	2	2	2	4			
20	25	—	1	1	3	2	5	2	4	6	9	4	13			
21	23	—	—	—	1	1	2	1	3	4	8	8	16	1	—	1
22	13	—	—	—	—	—	—	—	—	—	8	5	13			
23	3	—	—	—	—	—	—	1	—	1	2	—	2			
Tot.	101	10	13	23	9	6	15	6	8	14	29	19	48	1	—	1

All the herrings were with one exception (an individual of 19 cm.) sexually mature. They were either spent, spawning or in possession of highly swollen sexual organs. All had the winter-ring at the very margin of the scale except the immature individual, the scale of which had 2 winter rings and a narrow summer-belt at the margin.

In 59 of these specimens I counted the number of vertebrae, which prowed to vary from 54 to 59 in number. The average number was 56.44.

The above analysis shows us quite plainly, that these herrings differ very much from the ordinary Norse Spring Herring in size as well as age.[1]) They resemble the Zuider sea and Lowestoft spring herrings in

[1]) 2 herrings of 9 years 24 cm. long were found in a smallish sample chiefly consisting of young herrings from the Beitstadfjord, which last year were examined by cand. H. BROCH. Specimens of the scales have been placed at my disposal and I have used one of them for representing the 9 year old scale on Plate II.

that they are mainly young fish and that their rate of growth is very slow. Their growth is even slower than we found the growth to be in the above mentioned small spring herring types.

Scales of the Trondhjem fiord spring herrings are represented in Pl. II figs. 1, 2, 3.

If we compare them with the scales of the ordinary spring herrings, we shall observe, that they differ greatly. During the first one or two years their size and growth in some instances resemble that of the ordinary spring herrings scales, allthough in most cases their size and growth is considerably smaller. During subsequent years however the difference in growth becomes very great and from the 4th or 5th year the annual rings of the fiord herring are very narrow like the final annual rings in very old fish.

Summary.

Before summing up the main results of these preliminary investigations I wish to give prominence to the fact, that at the present moment no definite opinion can be expressed as to the sufficiency of the material as a whole. Consequently the results must also be considered from this point of view, and subject to the limitations due to the nature of the material.

Only in the case of the Norwegian spring herring, we may with some right assert, that the material probably represents the very stretch of coast and the very time, which it embraces. As regards the other herring types the bulk of the material examined has been relatively small, and we can hardly consider it as giving more than a mere rough representation of the types and their composition in respect of quantity. How much material we shall need to obtain a truly representative picture of the different types, is a question, which only future investigations can solve.

The difference in quality between the different types has however proved to be so great and of such a kind, that no material however great should be able to alter it essentially. The chief advantage of a large material will probably consist in enabling us to determine with greater accuracy the limits of variation in the different types and to obtain a safer standard of difference.

In the preceeding chapters we have seen that the Norwegian Spring Herring attained a very high age and a large size, ranging from 24 to 37 cm. in length and from 3 to at least 14 years in age. We have further

seen that none of the other herring-types examined attain such length in relation to age as the Norse Spring Herring.[1])

For comparison we shall consider the following table representing the size of all the 5 year old herrings found in the different samples.

Number of indiv. 5 years old.

Length in cm.	Norw. Spring Herrings	Skagerrack autumn spawners	Atlantic Herrings Roundstone	Lowestoft Spring Herrings	Zuider Sea Spring Herrings	Norw. Fjord Spring Herrings
17						
18	—	—	—	—	—	1
19	—	—	—	—	—	2
20	—	—	—	—	—	6
21	—	—	—	1	—	4
22	—	—	—	—	—	—
23	—	—	—	6	5	1
24	—	—	—	1	2	
25	—	2	—	1	1	
26	8	4	—	1		
27	23	4	—			
28	42	3	—			
29	61					
30	29	—	2			
31	8	—	1			
32						

The great difference in the rate of growth in the herrings of different localities is here clearly seen.

Our investigations have also shown, that while the Norwegian Spring Herrings grow evenly with increasing age until it is about 36 cm. long and 10—14 years old, in the other herring types growth is earlier arrested, and the individuals do not grow so large. Thus the autumn spawners of the Skagerrack and the North Sea rarely exceed 30 cm. in length. The largest Roundstone herrings were 32 cm. The Zuider Sea and the Lowestoft Spring-Herrings do not, according to the samples, exceed 26—27 cm. and the Spring Herrings of the Trondhjemsfiord hardly reach more than 23—24 cm. in length.

The investigations have also shown another fact of great interest. If we record the numbers of individuals of different age found in the samples, we get the following table.

[1]) Excepting the youngest age-groups of the Roundstone herrings. See page 26.

Number of individuals.

Age	Years											
	3	4	5	6	7	8	9	10	11	12	13	14
924 Norw. Spr. Herrings	15	205	171	137	116	179	31	21	16	20	8	5
136 Skagerrack aut. spawners	—	—	13	21	28	32	18	14	8	1	1	
47 Roundstone herrings	3	5	3	7	10	4	4	5	3	2	1	
49 Zuider Sea Spr. Herrings	4	22	8	11	4							
51 Lowestoft Spr. Herrings	24	17	10									
101 Norw. Fiord Spr. Herrings	23	15	14	48	1							

This table exihibits the peculiar fact, that the herring types which inhabit the open oceans[1]) consist of individuals which attain high age, while the smaller-sized herring types of the fiords and bays mainly consist of young fish, whose growth as previously mentioned has been much slower than that of the oceanic types.

This knowledge opens up new problems regarding the life history and economy of these different types or „tribes" of herring, and by means of developing the present method it should probably prove possible to approach these problems.

As we have seen, the scales of these different herring types grow very differently and contain as it were a sort of diagram representing the history of the growth of the fish. This diagram or picture is very often so different in the different herring types, that in certain cases the examination of a single scale taken from a herring will enable us to determine which type or kind the herring belongs to.

Thus the Norwegian Spring Herring and the autumn spawners of the North Sea kind are, as we have seen, in most cases easily distinguished by means of the scales alone. Undoubtedly the scales of the other types should in many cases be a quite deciding factor in distinguishing them from others, and at all events an examination of size, age, state of sexual organs and structure of scale probably will enable us fully to describe and recognise in all stages of life those herring types, which we have now treated.

Certain facts seem to indicate the possibility, that in future we shall be able to use the present method as a means of studying the

[1]) An examination of some Iceland Herrings has proved those also to be large and very old animals.

important question, whether the different fiord and coast types or kinds are wholly local and whether the typical characters are entirely constant, or dissolve into the oceanic types as they grow old.

Thus the examination of 924 Norwegian spring herring scales prowed the great majority of them to possess the regular structure described in Chapter II and depicted in Pl. I. A smaller number of these scales however proved to exhibit as it were two types of growth united in the one scale. The central part of the scale in fact might exhibit a growth, which for years was very much smaller than the ordinary growth of the spring herring scale. Then the subsequent annual rings would exhibit quite the normal growth. After a normal first year would follow perhaps one or two years of retarded growth, then for the rest of life normal growth. An exeedingly smal first and second year would be followed by normal growth during the rest of life and so on in a number of variations. In some instances these anomalies quite took the form of two types of growth contained within the same scale.

As an example of the most prominent case which I encountered I have on Pl. III fig. 5 represented the scale of a Norwegian Spring Herring the character of which is quite striking. As will be seen by examination of the plate, this scale for the first 5 years very much resembles the scales of the small spring herrings of the fiord or coast types. (The scale of the Zuider Sea spring herring represented on the same plate is nearly identical). From the 5th to the 9th and last year of its life this anomalous scale however records the splendid typical growth of the Norwegian Spring Herring.[1])

We may safely draw the conclusion that this individual undoubtedly has lived under very varying conditions of growth and evidently has gone through several important epochs of growth.

The two first years have been fairly normal. From the 2nd to the end of the 5th year the growth has been very small and sexual maturity has in all probability been attained during these years, when the individual was much smaller than a normal Spring Herring from the west coast. Then the individual has entered on a period of normal growth.

---

[1]) Of she sample taken from this individual, I examined a great number of scales. They all showed the same peculiar growth as here described.

As another example of scales recording two types of growth in the same individual I may mention the scales of one of the Roundstone herrings 30 cm. long, 13 winters old. The scale is represented in Fig. 8 pg. 36.

This figure plainly shows that the herring during the first 6 years of its life has grown like an ordinary North Sea herring. Then follow two good years of „Atlantic" growth and then growth is again arrested. It looks exactly as if a small North Sea herring had emigrated and, profiting by the Atlantic conditions, had become an Atlantic herring.

It would of course be quite premature to consider these examples, which on account of their prominence I have picked out, as more than illustrations of the above mentioned anomalies in the scales of herrings.

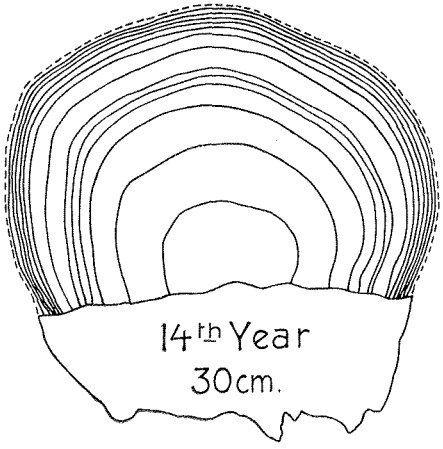
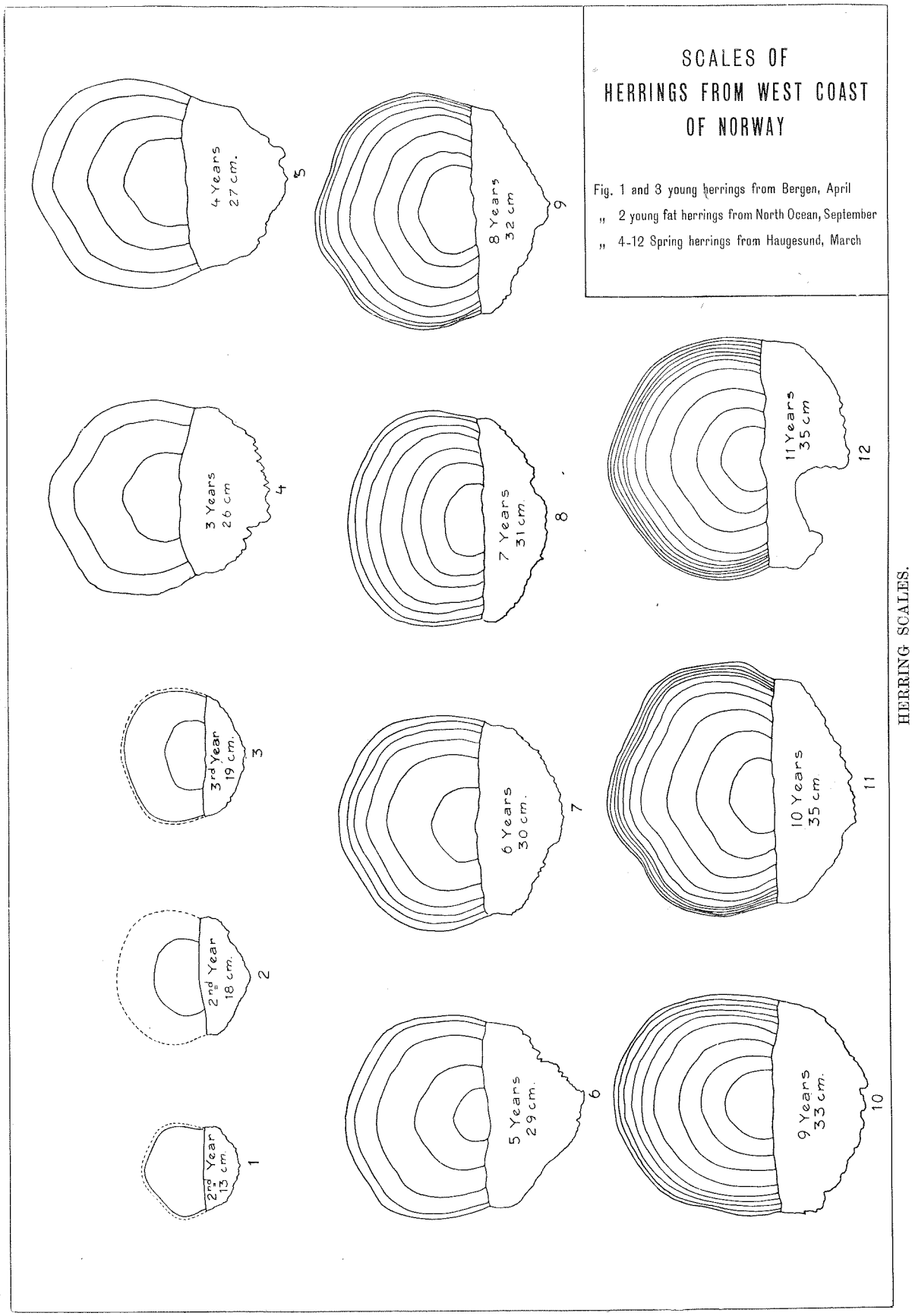


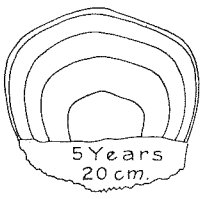
Fig. 8. Anomalous scales of Roundstone herring.

The actual existence of these anomalies and their great similarity to the typical features of other herringtypes must however invite our efforts and induce us to a closer and more detailed study of their nature and occurence in connection with the problem of the immutability of the herring types of the fiords, coastal waters and open oceans.

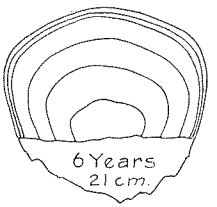


HERRING SCALES.

Norwegian Fiord Spring Herrings.



1



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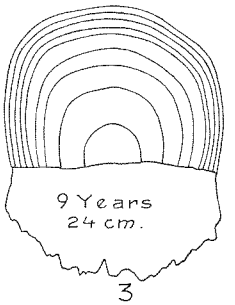
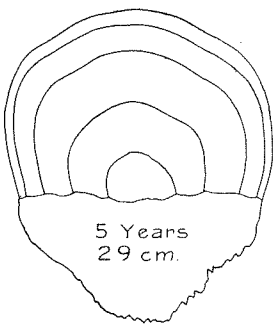


3

Norwegian Spring Herrings.



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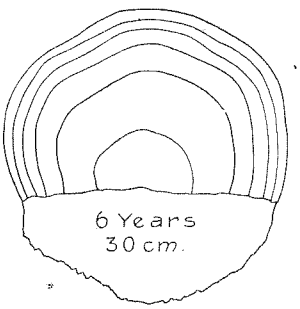

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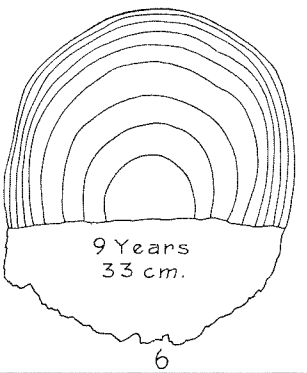
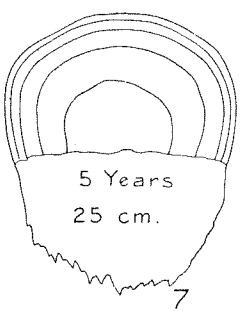


6

Skagerak Herrings (Autumn Spawners)



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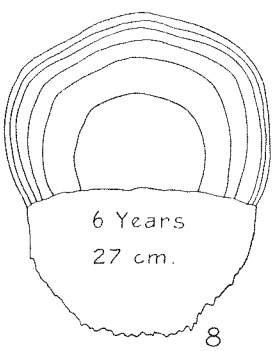

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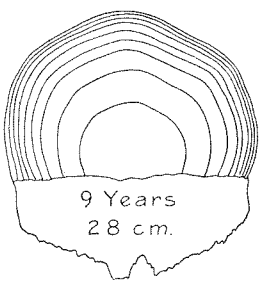
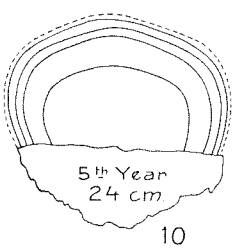


9

North Sea Herrings (Autumn Spawners.)



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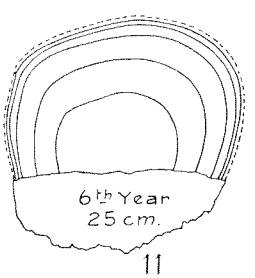

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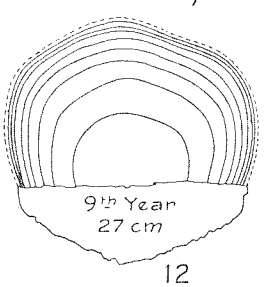
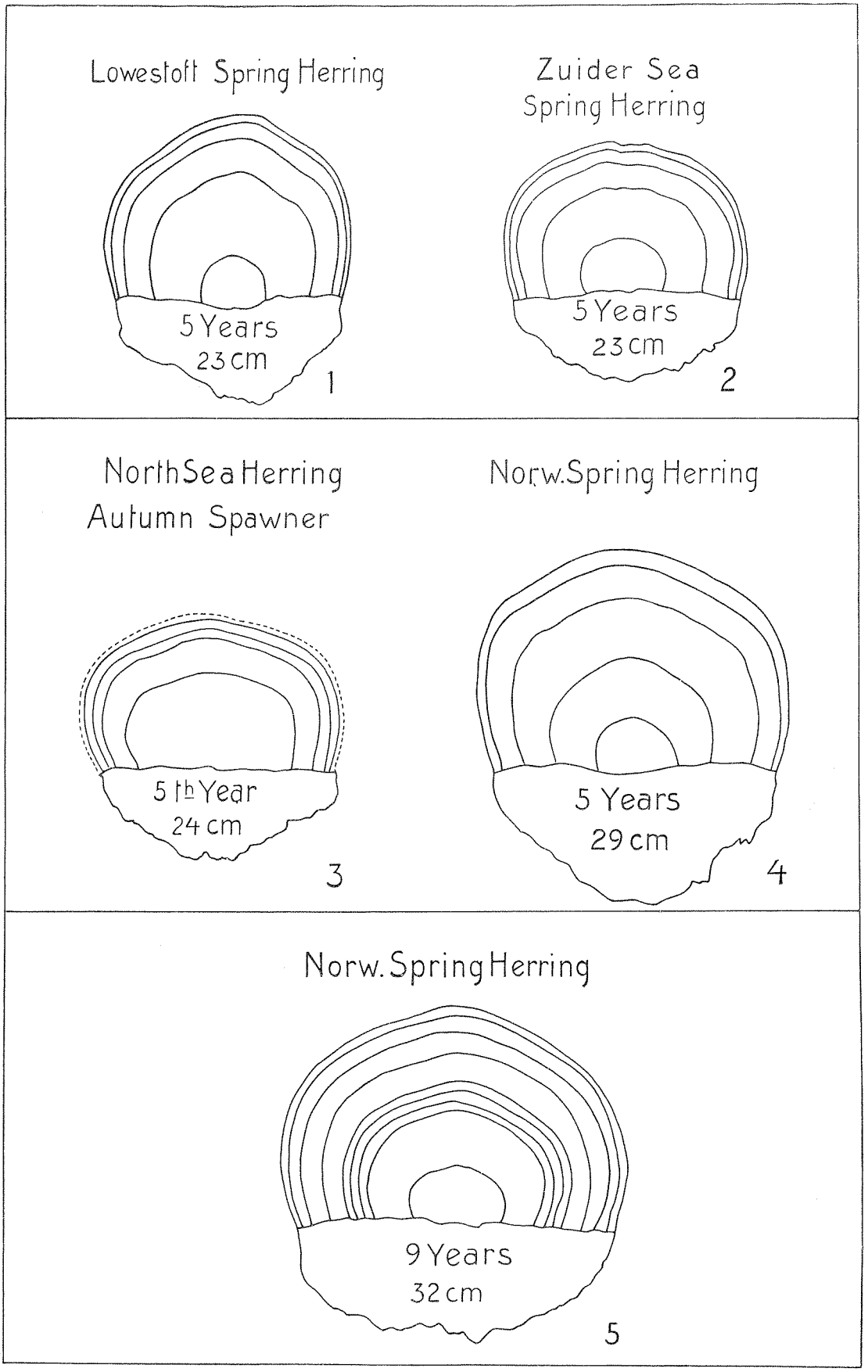


12

HERRING SCALES.



HERRING SCALES.