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A Study on the Life History and Migrations of the Norwegian Spring-Herring based on the Analysis of the Winter Rings and Summer Zones of the Scale

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CONTENT.

Introduction.

When it was discovered that the bony parts of fish were built up in layers it was suggested that it might be possible to determine the age of the specimen by counting these layers. In the case of the herring the Norwegian investigators Hjort, Dahl, Broch have made important investigations on this subject at the beginning of this century which led to the result that the scale was selected for age determination. Subsequently an extensive collection of herring samples was organized. Lea has made further fundamental investigations on the method of age determination and on the structure of the scale. As Lea (1918) mentions we have no experimental proof of the fact that the so-called winter rings on the scales of the herring actually are annual rings. But, as the observations on the Norwegian stock of herrings through several years indicate, the statistical observations point so emphatically to the correctnes of this supposition, that it will hardly seem possible to otherwise explain the regularity revealed by the observations.

Lea had also the idea that, if in addition to counting the winter rings on the scales the distance between them is measured, these measurements will enable us to calculate how each fish has grown from year to year. Lea indicated that there exists a definite connection between the growth of the scale and the growth of the fish.

The introduction of the scale analysis in the herring investigations led not only to the discovery of the great fluctuations in the numerical strength of the year classes but also increased highly our understanding of the life history and migrations of the Norwegian Spring herring. The great work of Johan Hjort (1914) on »The Fluctuations in the Great Fisheries of Northern Europe« shows the important results of the intensive work in the first years after the introduction of the new methods.

Lea who had an intimate knowledge of the scale of the herring soon made the experience that the appearance of the winter rings varied

in different ways. The rings found in a single scale are rarely quite alike and there is a difference between the corresponding rings in the scales of herrings from different waters.

In a short paper on the herring scale as a certificate of origin L e a (1929 I) attempts to answer the question as to what may be the reason why the rings look different. L e a writes: »In general it may be said that the peculiarities that may be observed on the scales of a herring, taken together, form a picture of the dependence of the herring, its reaction to the environment in which it has lived and which it has passed through during the course of its life..... Viewed from this angle the annual rings on the scales reflect or become symptomatic of the reaction of the herring to the annually repeated changes in the environment.... A winter ring will under any circumstances be a sign of stagnation in growth, similarly as a summer zone is a sign of growth.« L e a concludes that »the appearance of the rings, the character of them, is a consequence of the influence on the organism, just as was the breadth of the summer zone. The rings differ because the environment differed in the period when they were formed.« As a proof on the correctness of this assumption L e a mentions that the rings are as a rule sharper in the young herrings taken in the fjords of Finnmarken than in the herrings taken at the southern part of the west coast. However, L e a does not document his opinion with a large material but only touch upon the matter in the preliminary report previously mentioned.

While the age composition and rate of growth have been used by several investigators to characterize herring from different localities, the study of the character of the winter rings have not been utilized for this purpose. It is, however, apparent that if the environment »marks« the winter rings of the herrings in a manner characteristic for a particular locality one will here have a valuable method to follow the later migrations of these herrings. Unfortunately L e a retired from the fishery investigations before he had made a systematical investigation of the method on a large material.

From the year 1930 I have continued the Norwegian herring investigations. Observations on the fluctuations in the numerical strength of the year classes of the spring herring have been continued in the same manner as in previous years. In the last five years a very large material of vertebral counts and growth measurements have also been collected in order to study the life history of the Norwegian spring herring. These investigations have been combined with observations on the spawning grounds in order to localize the spawning places along the Norwegian coast and the area of distribution of the pelagic larvae. Continual observations on the quantitative distribution of the herring

roe have been instituted on the spawning grounds by means of the bottom grab, and the hydrographical conditions are likewise examined during the immigration of the spawning shoals to the coast.

While working with the scale analysis I soon understood that an analysis of the character of the winter rings in the meaning of L e a combined with growth and racial investigations would be of great value for the study of the migrations of the Norwegian herring. While the number of vertebrae as a racial character to a certain extent can tell us from which spawning grounds the herrings originate, the scale analysis may give us information on the further fate of each individual, during its life cycle.

In the present paper I give a treatise on the analysis of the character of the winter rings, the growth and the bearing of these factors on the life history and migrations of the Norwegian spring herring.

Chapter 1.

Short review of the life history of the Norwegian spring herring and the hydrographical conditions in the area.

We are to a great deal indebted to Johan Hjort and his collaborators for our knowledge about the natural history of the Norwegian herring. Hjort has given a review of the results in the work from 1914 previously mentioned, and Lea (1921 II) has then strongly increased our knowledge through the discovery of the intermediate oceanic stage in the life history of the Norwegian herring. My investigations on the distribution of newly hatched herring larvae (1934 II) have furthermore shown that the spawning of the herring is not limited to the well known spawning places at the west coast only but also extends to more northern localities than previously supposed. Spawning takes place along the entire coast at least as far north as Lofoten and Vesterålen. My racial investigations (1933, 1935, 1936) have also indicated the existence of different spawning communities along the coast. In a paper on the growth of the Norwegian herring also Ottestad (1934) is of the opinion that the type of growth definitely indicates the existence of two Norwegian herring stocks, a southern and a northern one, in agreement with my results.

I will here sketch the main features in the life history of the Norwegian herring mainly based on the description by Lea (1929 II) but with addition of the results of later investigations on this subject.

The herring spawns along the whole Norwegian coast at least as far north as Lofoten and Vesterålen, but the most intensive spawning probably takes place at the southwestern part of the coast, the so called »spring herring district«. As regards the age composition there can be recognized two contingents of herrings immigrating to the spawning places. The contingent of older herrings which have spawned in previous years is encountered by the fishermen some distance off the coast and

some time before they are ready to spawn. The herrings in this stage are called »large herring« and were formerly mainly caught off the Møre coast and the southern part of the Trøndelag coast. This region was

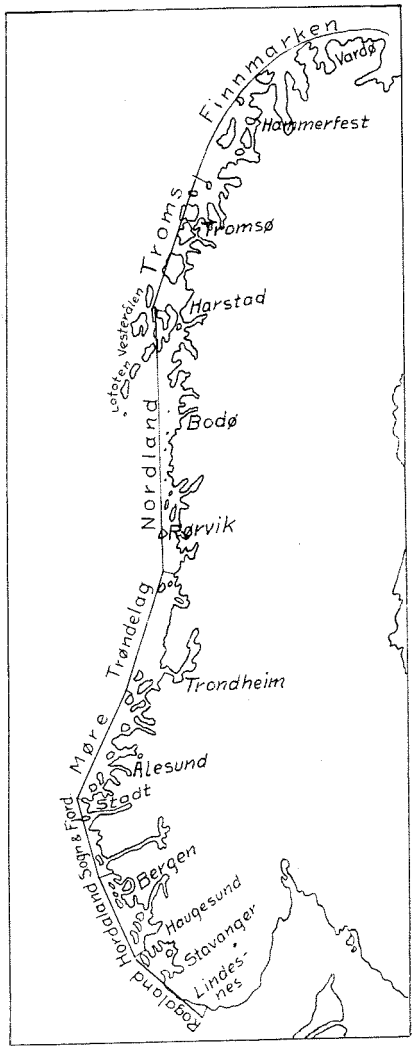

Fig. 1.

therefore called the »large herring district«. In later years, however, the greatest large herring fishery has taken place off the coast between Bergen and Stat (compare the chart fig. 1). When the herrings have arrived at the spawning grounds and are ready to spawn they are called »spring herring.« The second contingent arrives usually at the

end of the spawning season. This group is composed of younger individuals which spawn for the first time and are therefore by L e a called »recruit spawners«.

The main spawning time is February and March, but spawning can, however less extensively, also take place in first half of April. The young herring fry are observed along the whole coast to the most northern part of Norway, but we do not know exactly to what extent the different spawning places contribute to the production of these fry. It is probable that some of the fry found in the northern Norway have been transported by currents from more southern spawning grounds.

The small herring, which at the end of its first year of life are called »mussa« and in the second year »bladsild«, seem to develop in the fjords and coastal waters without undertaking any extensive migrations. According to L e a and O t t e s t a d the small herring have a slower growth rate in the northern part of Norway than at the west coast.

In its third year of life the herring disappears from the west coast. In northern Norway, however, the main part of the herring remains in the coastal waters and constitutes and essential part of the fat herring shoals. In the fourth or fifth year of life also the herrings in northern Norway disappear, but the age at which the young herring leaves the coastal waters seems here to vary.

When the herring leaves the coast it adopts an oceanic mode of life and the development of sexual products begins. The duration of the oceanic stage may vary from one to three years, and the age at which they reappear as recruit spawners on the spawning grounds varies from three to about seven years.

L e a means that the slight information which we possess points to the region north-east of the Faroe Islands as a possible central area for the oceanic group of young herring and L e a apparently supposes that herring from the whole coast frequents this area in the oceanic stage. This was in good accordance with the assumption of a single spawning community, viz. the spawning taking place at the west coast of Norway.

From the discovery of spawning shoals in northern Norway I must assume that herrings develop to maturity also in more northern regions, and the Russian investigator S. A w e r i n z e w (1935) has recently observed oceanic young herring of Norwegian origin in the Barents Sea.

When the herrings have spawned on the coastal banks they seem to undertake very extensive migrations in the Norwegian Sea. Large herrings have been found during the summer off Bear Island and Spitzbergen in the North and along the northern edge of the North Sea plateau and off Faroe Islands in the South, and they can migrate across the great oceanic deep between Norway and Jan Mayn (comp. S. R u n n s t r ö m 1936).

We have seen that the Norwegian herring spawns and grows up along the entire Norwegian coast and it is obvious that the young herring must live under rather dissimilar conditions for instance at the west coast and at the remotest parts of northern Norway.

As regards the hydrographical conditions we find along the Norwegian coast two water masses of different origin (fig. 11, page 89) namely Atlantic water, with salinities above 35,0 ‰ and coastal water with salinities below 35,0 ‰ (Helland-Hansen and Nansen 1909). The Atlantic water passing through the Faroe-Shetland Channel and the opening between the Faroes and Iceland advances through the eastern part of the Norwegian Sea as the Norwegian Atlantic Current. The coastal water is on the whole moving along the coast of Norway, as a continuation of the Baltic Current, from the Skagerak to the Barents Sea. The Atlantic water in the fjords and over the continental shelf is always covered by the coastal water.

The spawning and the growth of the young immature herring takes place in the coastal water whereas the development of the gonads of both the oceanic young herring as well as of the older individuals in the interim between spawning periods apparently takes place in Atlantic water.

The salinity of the coastal water is, according to Helland-Hansen and Nansen on the whole increasing along the rout northwards owing to intermixing with the Atlantic water. Of the same reason the coastal water has salinities which constantly increase from the shore seawards. The temperatures of the intermediate strata of the coastal water vary very much along the coast. This is according to Helland-Hansen and Nansen chiefly due to the origin of the waters and the encounter with other waters. »The waters of the Baltic Current are cooled to a low temperature in winter, and the intermediate temperature found in the Skagerack in May is very much lower than farther to the west and north, where the cooling in winter is much less, owing to the effect of the Atlantic water in the Norwegian Sea.«

Figur 2 demontrates the distribution of the temperature in the intermediate strata of he coastal water along the Norwegian coast in spring based on observations carried out by the Directorate of Fishery with the M/S »Johan Hjort« in 1932. We see that the temperature increase slightly along the west coast and reach a maximum in the area north of Ålesund which is in accordance with the fact pointed out by Helland-Hansen and Nansen, viz. that the coast north of Stat is approached nearer by the Atlantic Current than the other parts of the coast.

Further north the temperature decreases continually and the lowest

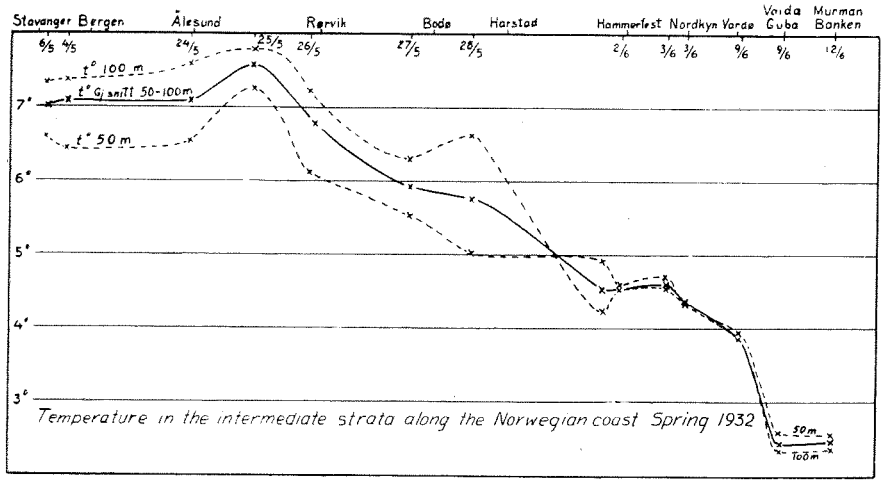
Stavanger Bergen Ålesund Rørvik Bodø Harstad Hammerfest Nordkyn Vardø Vardø Guba Murman Banken
6/5 4/5 24/5 25/5 26/5 27/5 28/5 2/6 3/6 3/6 9/6 9/6 12/6
t° 100 m
t° Gj.snitt 50-100m
t° 50 m
7°
6°
5°
4°
3°
Temperature in the intermediate strata along the Norwegian coast Spring 1932
50m
100m

Fig. 2.

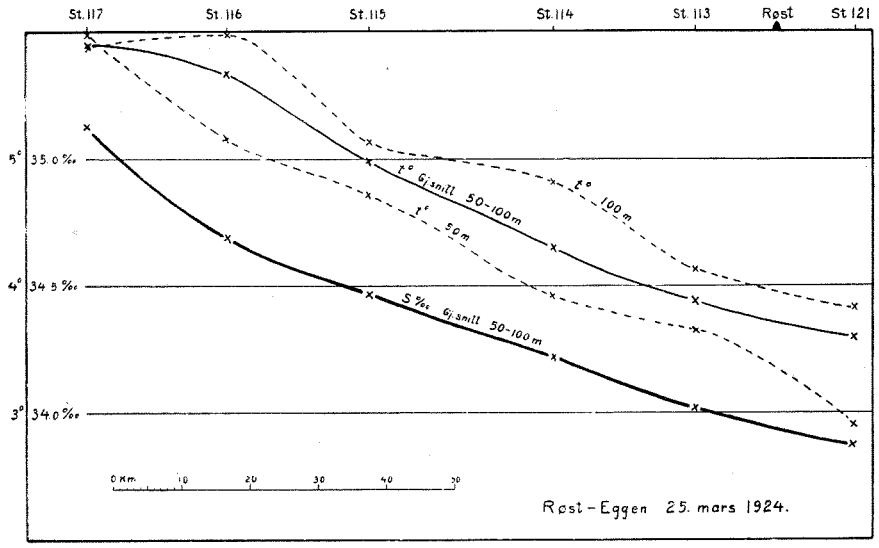
St. 117 St. 116 St. 115 St. 114 St. 113 Røst St 121
5° 35.0 ‰
4° 34.5 ‰
3° 34.0 ‰
t° Gj.snitt 50-100m
t° 100 m
t° 50 m
5 ‰ Gj.snitt 50-100 m
0 Km 10 20 30 40 50
Røst-Eggen 25. mars 1924.

Fig. 3.

values are found on the Murman Bank. There are thus rather great differences in the conditions of temperature at the west coast and for instance at Finnmark and in the Barents Sea.

Fig. 3 demonstrates the continual rise in temperature and salinity in the intermediate strata from the coast seawards based on a hydrographical section carried out by the M/S »Johan Hjort« in March 1924 from the southern part of Lofoten to the continental slope. At the outermost station 117 the water represents Atlantic water with salinity above 35,0 $^{0}/_{00}$.

It is thus apparent that the young herring which lives in the coastal water can grow up under rather varying conditions along the Norwegian coast. The herring will also encounter quite different surrounding conditions when they migrate from the coastal water into the open ocean.

Chapter 2.

Analysis of the character of the winterings on the scale of the Norwegian herring.

I will in the following make a systematical analysis of the character of the winter rings on a large material in order to determine if the differing appearance of the rings can be connected with the various localities at which the herring grows up. If this is the case it is reasonable to assume that the varying surrounding conditions in the area, the existens of which was demonstrated in Chapter 1, influence the character of the rings. Nature has then carried out a »marking« experiment on a large scale which can be utilized in the study of the life history and migrations of the herring.

The appearance of the winter rings belongs to those characters which cannot be expressed by exact figures in contrary to characters as for instance age, growth rate and number of Vertebra. One must therefore try to find out if there exist definite types of rings which can be described and defined, and if herring from different localities can be classified according to these ring types. The classification into different ring types will of course to a certain degree be attached to the subjective elements in experience and there will be a greater or less number of cases where the decision must be based more or less upon personal judgment. It is therefore of great importance in such investigations to have a good experience in the peculiarities of the scale by long continued observation.

The Directorate of Fishery, Bergen, has every year collected a large material of herring samples representing various stages of life. From each herring have been taken scales which are mounted on object slides with data on length, sex, ripeness of gonads etc. and we have now records of many thousands scales representing a continuous series from 1907 up to the present year. This material has been utilisized for

age- and growth determinations but gives of course also a rich material for the study of the present problem.

The analysis of the character of the winter rings, presented in this paper, comprises a material of about 14 000 herrings, and all the estimations of the ring types are carried out by myself. I have, however, often confronted my estimations with estimations on the same material carried out by my assistent Th. Rasmussen, who has many years experience in scale reading, and I have on the whole found a good accordance in the readings thus made by two observers.

As the first step in the investigation one ought to choose a stage in the life history of the herring when the herring is stationary at the different growth places along the coast and before they have begun greater migrations. Such a stage is represented by the small herring. As the herrings in the first summer of life have not yet got a winter ring on the scale I will begin with herring in the second year of life, the so called »bladsild«. These have the first summer zone and the first winter ring completely developed and the second summer zone commenced. Then the character of the new winter rings in the additional stages will be analysed.

Small herring.

The herrings in its second year of life are as »bladsild« taken by the fishermen along the whole coast of Norway and it is therefore possible to get a representative material from all the various growth places in northern as well as in southern Norway.

Lea (1929 I) has made the experience that the scales on the young herring from northern Norway have rings which as a rule are sharply defined, whilst herring from the southern part of the west coast have scales with more vaguely defined rings. Lea (1929 II) illustrates the nature of the distinguishing peculiarities in photographs of two scales which, in Plate I figures 1 and 2, are reproduced from the paper by Lea. Fig. 1 represents a scale from a young herring captured in the northern Norway and fig. 2 one from a herring from the west coast. The scales have the first summer zone and the first winter ring developed and have nearly completed the second years summer zone. Lea has termed these two different scale types »northern« and »southern«, but has not published any material to demonstrate the distribution of these types.

After studying a large material of young herring I must agree with Lea as to the correctness of his view. The two types of scales are as a rule very well distinguished.

Table I. Small herring $1^1/_2$ years old (Bladsild).

S = „Southern“ N = „Northern“ scale type.

District	1924		1925		1932		1933		1934		Total	
	S	N	S	N	S	N	S	N	S	N	S	N
Finnmark	—	—	—	—	—	—	—	—	—	180	—	180
												100%
Troms	—	—	—	—	—	—	15	379	38	436	53	815
							3,8%	96,2%	8,0%	91,9%	6,1%	93,9%
Nordland	—	—	11	69	—	—	12	144	58	409	81	622
			14,8%	86,3%			7,7%	92,3%	12,4%	87,6%	11,5%	88,5%
Trøndelag	—	—	—	—	—	—	33	58	—	—	33	58
							36,3%	63,7%			36,3%	63,7%
Møre	—	—	—	—	30	75	141	25	20	77	191	177
					28,6%	71,4%	84,9%	15,1%	20,6%	79,4%	51,9%	48,1%
Sogn & Fjordane	—	—	—	—	—	—	168	22	—	—	168	22
							88,4%	11,6%			88,4%	11,6%
Hordaland	281	60	216	24	380	14	474	10	—	—	1351	108
Rogaland	82,4%	17,6%	90%	10%	96,5%	3,5%	97,9%	2,1%			92,6%	7,4%

In table 1 I have given the results of an analysis of about four thousand young herrings in its second year of life captured in different years and in different localities. The most representative material is from the year 1933. The material has been arranged according to the districts along the coast from the north eastern part of Norway to the southern part of the west coast (compare the chart fig. 1). N and S in the table means »northern« and »southern« types.

Looking on the total material in the right column of the table one will find that in the most northern part of Norway, Finnmarken, all the young herrings have »northern« scaletypes. In the more southern parts of Northern Norway, Troms and Nordland, about 90 % also are of northern type. In the southern part of the west coast, Hordaland—Rogaland, however, more than 90 % of the young herrings have a winter ring of the »southern« type and about the same is found in the more northern part of the west coast, Sogn and Fjordane. In the intermediate area between northern Norway and the west coast, the Møre-Trøndelag district, one finds the two types more equally mixed.

From this analysis it is apparent that the »northern« type of winter rings are formed in the coastal waters of northern Norway and the »southern« type at the west coast. Probably through migrations of the young herring a certain intermixture of the two types can take place which is most pronounced in the intermediate area between northern Norway and the west coast.

I will in the following designate the young herring with one winter ring as N_1 and S_1 which means that the herring has one winter ring of respectively »northern« and »southern« coastal type.

Fat herring.

As mentioned in Chapter 1 the herrings disappear from the west coast in its third year of life. In northern Norway the main part of the herring remains in the coastal water through a varying number of years and are here caught as fat herring. According to L e a (1929 II), however, not all the herrings in their third year in the North remain near the coast, but a portion of them adopts an oceanic mode of life. In the succeeding year either all the herring can disappear or the same thing can happen as in the previous year, i. e. that some leaves, while others stay.

The age distribution in the fat herring samples can thus vary considerably and the fat herring fisheries must therefore undergo great fluctuations, both as regards quantity as well as the size of the herring. L e a (1929 II) writes: »Further, the results tend to strengthen the

impression given by the statistics of the Norwegian herring fisheries, namely that the presence of the large »fat herring« in the coastal waters and in the fjords ought not to be looked upon as something which may be expected every year. It looks more as if the socalled »large fat herring years« occur when the oceanic group of herring, or portions of them, are driven to the coast as consequence of circumstances, which at the present moment are unknown, or when the departure from the coast in order to take up an oceanic existence is, so to speak, delayed.«

Ottestad (1934) is also of the opinion that the fat herring stock in the coastal water may be of a complex nature in the sense of being composed of both coastal herring and of immigrating oceanic herring.

Also at the west coast, where as a rule no fat herring fisheries occur, fat herring shoals can be found more occasionally probably consequential of immigration from the ocean.

In table 2 (page 24) I have given the results of the analysis of immature small and fat herring from the coastal water arranged according to locality of capture in three regions: the west coast (Rogaland, Hordaland, Sogn and Fjordane), the Møre-Trøndelag and the northern Norway (Nordland, Troms, Finnmarken). The material represents the summary of observations on samples from some different years. In nature the small herring in their second year of life (bladsild) often form pure shoals unmixed with other year groups but they can also be found mixed either with herrings in their first year (mussa) or with fat herring. The material of »bladsild« in the table is taken mainly from pure shoals in the autumn when the herring had reached an age of about 1½ year. The shoals of fat herring in the present material are composed of individuals of different age, from the west coast 2½—3½ years, from the Møre-Trøndelag 2½—4½ years and from northern Norway 2½—5½ years.

In table 2 are represented thus young immature herrings from coastal waters with one to five winter rings on the scale.

I will at first discuss the appearance of the winter rings and then the distribution of the different scale types in the various regions.

As previously mentioned one finds that the »bladsild« with one winter ring on the scale represents two different types designated as S_1 and N_1 with respectively one »southern« and »northern« coastal winter ring. The 2½ years old herrings are in the third vertical column of table 2 under the head »Scale type« represented by four different scale-types.

The two types designated as S_2 and N_2 have winter rings of exactly the same appearance as the types S_1 and N_1 the only difference being that now two winter rings are formed instead of one. The identical

appearance of the two rings in each scale type seems to indicate that the herring has lived under the same conditions in the two winters when the rings were formed.

As regards the two types designated as S_{1+1} and N_{1+1} the first inner winter rings is of the »southern« or »northern« coastal type respectively. The second ring is, however, of the same appearance in both scale types and represents a quite new type which cannot be identified with the rings formerly found.

Especially in the scale type N_{1+1} the dissimilarity between the first sharp »northern« ring and the outer ring of the new type is very pronounced. The outer ring is broader and more undefined as if drawn with chalk and reminds of the winter rings on the scale of herring from Irish waters as described by L e a (1929 I). The fig. 1, Plate III illustrates the difference between the »northern« coastal rings and the ring of the new type. In this case we find three inner sharp »northern rings« and a fourth less defined outer ring (N_{3+1}), but it is difficult to illustrate the characteristic feature of the ring in a photograph. The difference between the »southern« coastal ring and the outer ring of the new type is less apparent, but the difference is enough pronounced to allow a separation of the two types of rings. While the vaguely defined »southern« coastal ring frequently is composed of several thin lines and present the appearance of double or manifold rings the other type mostly exhibits a more well defined ring, but with a broad »shadow«. The latter scale-type is illustrated in fig. 1, Plate II (S_{2+2}).

When one now will try to form an opinion of where this ring of the new type have been formed, and which was not present in the »bladsild« it is an obvious conclusion that this ring has been formed in another area than the coastal rings. It is then near at hand to think of the open ocean and assume that this ring has been formed under Atlantic conditions. A proof on the correctness of this view will be given in the analysis of the recruit spawners. This is also in good accordance with the supposition mentioned above that the fat herring shoals are composed of coastal and oceanic herring. I will therefore call this new type of winter ring »oceanic«. The similar appearance of the »oceanic« rings at the west coast with those in northern Norway in contrast to the »coastal« rings also speaks for the supposition that they are formed in Atlantic water where the conditions are more constant in the whole area than in the coastal water.

The types S_{1+1} and N_{1+1} would thus according to the above interpretation of the ring types mean that the herrings have lived in southern or northern coastal waters during their first winter, then they have migrated into the open ocean and lived under Atlantic conditions

during their second winter. At the end of the second summer they have immigrated to the coastal water. The herring of the types S_2 and N_2 have lived both winters in the coastal water.

				1 1/2	S 1	N 1	1 1/2				
			2 1/2	S 2	S_{1+1}	N_{1+1}	N 2	2 1/2			
		3 1/2	S 3	S_{2+1}	S_{1+2}	N_{1+2}	N_{2+1}	N 3	3 1/2		
	4 1/2	S 4	S_{3+1}	S_{2+2}	S_{1+3}	N_{1+3}	N_{2+2}	N_{3+1}	N 4	4 1/2	
5 1/2	S 5	S_{4+1}	S_{3+2}	S_{2+3}	S_{1+4}	N_{1+4}	N_{2+3}	N_{3+2}	N_{4+1}	N 5	5 1/2
6 1/2	S 6	S_{5+1}	S_{4+2}	S_{3+3}	S_{2+4}	S_{1+5}	N_{1+5}	N_{2+4}	N_{3+3}	N_{4+2}	N_{5+1}	N 6	6 1/2

When the young herring is characterized by scales with »southern coastal«, »northern coastal« and »oceanic« winter rings one may expect in herrings with 1—6 winter rings 42 different combinations of these three types of rings as shown in the present schedule. From table 2 one sees that all the supposed scale types are realized in nature in herring with 1—3 rings on the scale. Young herring older than four years with only »southern coastal« winter rings are seldom found, and the highest number of this type of rings met with in the material is three ones. The »northern coastal« rings are, however, represented by a number of up to six rings on the scale. The highest number of »oceanic« rings counted on one scale is three, but the most common is one or two.

This is in good accordance with the supposition by L e a that the young herring leaves the coastal water earlier at the west coast than in northern Norway and that the oceanic stage lasts from one to three years.

I will in the following discuss the distribution of the different scale types in the fat herring shoals from the three regions, the West coast, the Møre—Trøndelag and Northern Norway as shown in table 2 (page 24).

As already mentioned the herrings with one winter ring at the west coast are represented by about 92 % of individuals with »southern coastal« ring, and in northern Norway by 92 % of individuals with »northern coastal« ring. At Møre—Trøndelag both types are about equally represented.

In the fat herring shoals from the west coast one finds among the herrings with two winter rings 81 % with one or two »southern« rings (S total) and among the herrings in the fourth year of life with three winter rings 69 % with »southern« scale type. The rest of the herrings has one or more »northern coastal« rings on the scale. The material shows thus an increasing relativ number of »northern« scale-type with increasing age which seems to indicate an immigration of herring of more northern origin into the fat herring shoals at the west coast.

The majority of the fat herring at the west coast have scales with one or two oceanic rings indicating that they have adopted an oceanic mode of life which may have taken place in the second or third year of life. Due to the certain circumstances they have now again appeared at the coast. It cannot be decided if the herrings with coastal rings only (S_2, N_2 and S_3, N_3) have remained the whole time in coastal water or have joined the other herrings in the open sea in their last summer of life and then immigrated to the coast in company with the »oceanic« herring in the autumn. As regards the herrings of northern origin, however, it must be supposed that they have left the northern coastal waters in the last summer and joined the southern fat herring shoals.

In northern Norway the herrings 2½ years of age have about the same relative number of »northern« and »southern« types as the one year younger »bladsild«. The relative number of herrings with one or two »northern« winter rings is about 90 %.

Of the original types in the »bladsild« (N_1 and S_1) some herrings in the third year of life have got one oceanic ring (N_{1+1} and S_{1+1}), but the majority has remained in the northern coastal water also in the second winter (N_2). The individuals of the type S_2 must have emigrated from more southern parts of the coast in the third summer in the same manner as the »bladsild« of the type S_1 was supposed to have migrated northwards in the second summer.

Among the herrings 3½ years old in the northern fat herring shoals the fish with »southern« scaletypes have decreased and the »northern« types have here a relative value of about 97 %. Of the 2½ years old fish with two northern coastal rings (N_2) some has now got an »oceanic« ring (N_{2+1}) but the major part has remained in the coastal water also in the third winter (N_3). In the fifth year of life the fish with »southern« scale-types have practically disappeared from the northern shoals and the 5½ years old herring in northern Norway consist of 100% »northern« types. The most of these herrings have lived in the coastal water in all the five winters (N_5). Herrings more than 3½ years of age in fat herring shoals are, however, rather infrequent and are only found in more northern waters and here not regularly each year.

At the coast of Møre—Trøndelag, where »bladsild« of »northern« and »southern« types were equally represented, one find that the »northern« types also increase with increasing age and the 4½ years old herrings are composed of almost only »northern« types. The most of these herrings have got one or two »oceanic« rings which indicate that they have made more extensive migrations in the ocean.

On basis of the proof given by the analysis of the »bladsild« that the »northern« rings are formed in the coastal water of northern Norway and the »southern« rings at the west coast, and of the preliminary assumption that the »oceanic« rings are formed in the Atlantic water of the open sea, we can thus read the fate of each individual in the fat herring shoals.

We have seen that the young herring leave the coastal water at various stages of age. At the west coast they dissappear as a rule after the first and second winter and fish with three »southern coastal« winter rings are seldom encountered. In the northern Norway they may leave the coastal water in the second to the sixth or seventh year of life. In the first period of oceanic life some of the herrings may remain not far from the original growth places at the coast and can in certain seasons of the year immigrate to the coast and participate in the formation of the coastal fat herrings shoals. Others of the oceanic herring may carry out more extended migrations and in this manner herring of northern origin can join southern shoals of young herring.

The oceanic intermediate stage.

Already G. O. Sars (1873) found that the coastal fat herring represents the young immature stage in the life history of the Norwegian herring stock and which develop to mature spring herring. When the method of age determination was introduced in the herring investigations this assumption of Sars was confirmed. In the first period of investigations it was supposed that the transition from immature fat herring to mature spring herring was direct and of short duration. Lea soon recognized, however, that this assumption did not harmonize well with the observations on age, length and the growth history of the two groups. Lea (1929 II) writes: »The fact that the individuals composing the shoals of young herring present along the coast are too young, too small and too little sexually developed for the recruit spawners to be derived directly therefrom, cannot be properly understood save by assuming that the recruit spawners come from a group of the Norwegian race of herring, which is neither usually

observed nor gives rise to a coastal fishery. The conception that the herring during their development to sexual maturity pass through an oceanic intermediate stage arose as a natural consequence of the observations«.

By comparing and combining observations on the adult spawning herring and the immature fat herring L e a could in 1924 draw up a description of the characteristic features of the herring in the intermediate stage before a single sample of herring from the supposed oceanic group had been subjected to examination.

Not till the summer of 1927 L e a got an occasion to make more complete observations. »Along the coast in the neighbourhood of Bergen various herring appeared which the fishermen had difficulty in classifying amongst their »sorts« of herring. For the time and place the herring were large and the condition of sexual organs varied greatly from herring to herring«. An analysis of samples from these shoals showed that the herring had those very features which were to be expected if the premisses and assumptions as to the oceanic stage were correct and the existence of this phace in the life history of the herring was thus confirmed.

Through the herring was found close to the coast L e a assumed, owing to the infrequent occurrence of this group of herring in the coastal water, that they regularly are distributed in the open ocean.

In the vertical column farthest to the right in table 2 I have given the results of the analysis of the scale types of herring in the oceanic intermediate stage. The material comprises samples from 1927 completed with samples from shoals which occasionally have appeared at the west coast in later years.

From the table one find as to the age composition an apparent difference between the shoals of herring in the oceanic intermediate stage and the young herring commonly met with at the west coast. As mentioned before the immature herrings in the southern coastal water represent rather young age groups. The group of herring in the intermediate stage, however, is composed of six age groups representing an age from 1½ to 6½ years and reminds in this respect of the shoals of northern fat herring.

In regard to the scale types one finds in the intermediate stage the same types as in the fat herring shoals representing herrings with southern or northern origin which have lived one to three years in the ocean or which not till the last summer have left the coastal waters. To lay stress on the oceanic mode of life in the definition of this group of herring and call them »oceanic« young herring in contrast to the coastal fat herring as often made by L e a is not very striking. As we

Table 2.

Age	No. of winter rings.	Scale type	Small and Fat herring. West coast Nr.	%	Møre — Trøndelag Nr.	%	Northern Norway Nr.	%	Young herring in the oceanic intermediate stage Southern Norw. Nr.	%
1 1/2	1	S 1	1519	92.1	224	48.8	134	7.7	133	85,9
		N 1	130	7.9	235	51.2	1617	92.3	22	14.1
2 1/2	2	S 1 + 1	197		26		45		70	
		S 2	121		25		140		231	
		S total	318	81.0	51	35 9	185	10.9	301	78 7
		N 1 + 1	38		66		469		52	
		N 2	37		25		1046		30	
		N total	75	19.0	91	64.1	1515	89.1	82	21.3
3 1/2	3	S 1 + 2	43		13		19		51	
		S 2 + 1	89		14		12		123	
		S 3	5		—		—		20	
		S total	137	69.2	27	12.9	31	3.2	194	50.7
		N 1 + 2	7		16		33		13	
		N 2 + 1	46		67		175		99	
		N 3	8		21		734		77	
		N total	61	30.8	104	87.1	942	96.8	189	49.3
4 1/2	4	S 1 + 3					1		3	
		S 2 + 2			1		1		17	
		S total			1	1.3	2	1.8	20	13.4
		N 1 + 3					1		1	
		N 2 + 2			8		16		25	
		N 3 + 1			37		40		143	
		N 4			27		49		42	
		N total			72	98.7	106	98.2	211	86.6
5 1/2	5	N 2 + 3							1	
		N 3 + 2							15	
		N 4 + 1					5		43	
		N 5					24		12	
		N total					29	100.0	71	100.0
6 1/2	6	N 3 + 3							1	
		N 4 + 2							2	
		N 5 + 1							1	
		N 6							1	
		N total							5	100.0

Table 3.

Recruit spawners from the Westcoast

Age	No. of Winter rings	Scale type	Nr.	%
3	2	S 1 + 1	1	100.0
		N 1 + 1	—	
4	3	S 1 + 2	12	
		S 2 + 1	64	
		S total	76	80.8
		N 1 + 2	5	
		N 2 + 1	13	
		N total	18	19,2
5	4	S 1 + 3	2	
		S 2 + 2	131	
		S 3 + 1	14	
		S total	147	43.2
		N 1 + 3	—	
		N 2 + 2	71	
		N 3 + 1	123	
		N total	194	56 8
6	5	S 1 + 4	—	
		S 2 + 3	3	
		S 3 + 2	5	
		S total	8	4.9
		N 1 + 4	—	
		N 2 + 3	—	
		N 3 + 2	81	
		N 4 + 1	72	
		N total	153	95.1
7	6	N 2 + 4	—	
		N 3 + 3	6	
		N 4 + 2	45	
		N 5 + 1	12	
		N total	63	100.0
8	7	N 3 + 4	—	
		N 4 + 3	—	
		N 5 + 2	2	
		N 6 + 1	8	
		N total	10	100 0

have seen the fat herring shoals may also be composed of »oceanic« and »coastal« herring.

I will therefore lay more stress on the term i n t e r m e d i a t e, also introduced by L e a, as an expression of the fact that this group forms a transitionary stage between the young immature herring and the mature spring herring.

I will now in the following show that the group of herring in the oceanic intermediate stage is composed in a very characteristic manner as regards the relative number of the different scale types in each year group.

The 1½ and 2½ years old herring contains mainly fish of southern origin with one or two »southern coastal« winter rings. The relative number of »southern «and »northern« types is about the same as in the corresponding age groups of the young herring from the west coast as seen in the column farthest to the left of table 2.

The 3½ years old herrings are represented by an equal number of »southern« and »northern« types thus differing from the composition of the corresponding year class of the fat herring from the west coast as well as from northern Norway. There has in the intermediate stage apparently taken place a more extensive intermixing of herring of southern and northern origin, than what is the case in the fat herring shoals.

The 4½ to 5½ years old herring represent year groups which in the fat herring shoals were only present in northern Norway. These year groups have also a composition as regards the scale types very similar to that of the corresponding age groups of the fat herring in northern Norway. In the 4½ years old fish the »northern« types are dominating and the 5½ years old fish are all of »northern« type. Also the group of 6½ years old fish is exclusively represented by individuals with the rings of »northern coastal« type. This year group is not represented in my material of fat herring from northern Norway, but herrings of this age have been observed in northern coastal water in certain years.

From the analysis of the scale types it is thus apparent that the group of herring in the oceanic intermediate stage in the southern area is composed of two contingents of different origin.

The one contingent which consists of younger fish mainly of an age from 2½ to 3½ years has grown up at the west coast. The other contingent which have migrated southwards from northern Norway, is mainly represented by 3½ to 4½ years old fish but also by a smaller number of older fish. These results agree very well with the analysis of this group by L e a (1929 II). L e a is, however, of the opinion that the 1½ year old herring represents an admixture to the oceanic group in the

coastal water where the samples have been taken. My analysis of the recruit spawners shows, however, that one must expect a small number of this year group in the oceanic intermediate stage.

It is evident from the analysis given in table 2 that one must assume that herring of the same age and of the same scale type are split up in at least two groups. The one group occurs in the fat herring shoals in the coastal water. The herring of this group can have remained in the coastal water or have migrated into the ocean but not farther than that they more or less regularly in certain seasons of the year take part in the formation of the coastal fat herring shoals. The other group contains more developed fish which have migrated into the ocean where they in the period of the oceanic intermediate stage undergo the process of maturing. It seems that the herring from the west coast reach the stage of maturing at an earlier age than the herring in northern Norway. These two contingents mix in the open sea and form shoals of very characteristic features as to age and size and composition of scale types. In regard to the sexual development of the fish in the intermediate stage analysed in table 2 the herrings were not so far developed that one can expect them to take part in the spawning next spring following the summer when they were caught. The shoals represent apparently an early phase in the intermediate stage and one may therefore expect that these herrings will remain a second year in the ocean before they appear at the coast as recruit spawners. If this assumption is correct all these herrings must get a new winter ring in addition to those now present before they spawn and as the herrings in this stage live in the open sea this winter ring must be of »oceanic« type.

Recruit spawners.

The young mature herrings, which come to the coast in order to spawn for the first time, are by L e a called recruit spawners. They appear as a rule later in the spawning season in spring than do the older spawners and separated from the latter. It is therefore possible to get pure samples of recruit spawners. In the columns of table 3 (page 25) I have analysed the composition of a shoal of recruit spawners from the west coast as to the age and scale types.

As these herrings are caught in early spring they have the last summer zone completed and have begun the formation of a winter ring on the edge of the scale, which, however, is not as yet clearly visible. The three years old herrings have thus two visible winter rings, those four years old have three winter rings etc.

As seen in table 3 the shoal is composed of 6 year groups representing fish of an age from 3 to 8 years. The 3 and 8 years old fish are present in rather small numbers and the 5 to 6 years old herrings are best represented. In comparing the recruit spawners with the group of herring in the oceanic intermediate stage in table 2 one finds exactly the same number of year groups. The difference is that the recruit spawners are throughout 1½ years older than the fish of the other group. This is exactly what was expected according to the state of the sexual development of the fish in the intermediate stage as previously discussed.

As regards the scaletypes of the recruit spawners one finds a very striking feature, namely that all the herrings have scales with at least one outer »oceanic« winter ring. The fish which in the early phase of the oceanic intermediate stage had only coastal rings of the types S_1—S_3 and N_1—N_6 are now in the 1½ years older fish represented by the types S_{1+1}, S_{2+1}, S_{3+1} and N_{1+1}, N_{2+1}... N_{6+1}. The types with one oceanic ring, for instance S_{1+1}, in the intermediate stage have now got an additional oceanic ring (S_{1+2}) and so on.

The assumption previously made that all the recruit spawners must have at least one outer ring of »oceanic« type is thus realized and this is a proof on the correctness of the view that this type of winter rings really is formed under oceanic conditions.

Concerning the relative number of fish with »southern« and »northern« scale types in each year group one finds that the 3 and 4 years old herrings are mainly of southern origin. The 5 years old herrings represent an equal mixture of both types and the 6 years old individuals consist mainly of fish with »northern« scale types. The 7 and 8 years old herrings consist exclusively of fish of northern origin. Thus one sees that the composition of each year group as regards the scale types is exactly the same as found in the corresponding 1½ year younger year groups of herring in the oceanic intermediate stage.

The herrings in the early phase of the intermediate stage have thus grouped themselves in a shoal of a definite composition identical with the spawning shoal. The young herrings can have lived one or two winters in the open sea or have emigrated from the coast after the last winter before grouping themselves in this characteristic manner which is determined by the sexual development. All the herrings of this group, which is composed of individuals of different age and different origin develop during the next 1½ year in the ocean into mature fish, and then arrive in spring to the spawning grounds at the coast as recruit spawners. As seen from the composition of the recruit spawners the individuals reach the stage of maturity at an age which varies greatly, and the

herrings of southern origin do so at an earlier age than the herring of northern origin.

I have now discussed the composition of a group of recruit spawners as it appears at the coast in a spawning season. As we have seen such a group is composed of various year groups representing different year classes. I will in the following try to follow the immigration of a single year class, i. e. fish born in the same year, to the spawning grounds at the west coast. Through the analysis of a great number of samples from different spawning grounds each year the age composition of the spawning shoals and the fate of each year class have been controlled during a long series of years. I have here selected the year classes 1923 and 1925 which have been best represented in the spawning shoals during the later years.

Year class 1923.

This year class appeared for the first time on the spawning grounds at the west coast in 1926 at an age of three years but only in very small numbers. The herring arrived in conjunction with other year classes forming a group of recruit spawners of the composition shown in table 3. All of the herrings of this year class which in the material (table 4) is represented by a number of eight individuals only, had the scale type S_{1+1} with one »southern coastal« ring and one outer »oceanic« ring. A third winter ring is now in formation at the edge of the scale, but this ring is not visible as yet. The character of this ring, which is being formed during the winter when the fish is spawning for the first time, can therefore not be defined. The scale type can thus be designed S_{1+1+0} which indicates that the herring has one »southern coastal« ring, one »oceanic« ring and at the edge one »spawning« ring the appearance of which is undefined. In the vertical column farthest to the left of table 4 I have noted the age at first spawning, which in this case is that of 3 years. In the next column I have noted the number of coastal and oceanic winter rings which in this case is S_{1+1}. In the first section of the third column has been noted the number of herrings three years old being present in the material in 1926, and in the upper part of this section is noted + 0 which denotes that one spawning ring as yet not visible is being formed in these individuals.

In the spring of the following year 1927 a new contingent of recruit spawners arrived at the coast containing a large group of the now 4 years old herrings of the year class 1923. This group is represented by individuals with the same scale types S_{1+2} etc. as those found in the 4 years old herrings of the recruit spawners in table 3 with a last ring of »oceanic« type. As the spawning ring under formation is still invisible

the herrings of this type are in the second section of the fourth vertical column of table 4 placed under the designation + 0.

Of the 166 herrings examined, however, 1 individual had a scale type which had not been observed before.

This herring had a scale with one »southern coastal« ring and one »oceanic« ring, but the third outer ring was not of an »oceanic« character as should be expected in the recruit spawners. This ring had a more well defined and sharper appearance than that of the oceanic ring and differed markedly from the latter one. This scale type will be designated S_{1+1+1}. The appearance of the outer ring of this new type is illustrated in fig. 2, Plate III which is a photo of a scale from a 7 years old herring. The three first rings are of »northern coastal« type followed by one »oceanic« ring. The last two rings represent the new type (N_{3+1+2}). Fig. 2, Plate II demonstrates the appearance of the rings in the type S_{2+2+2}

The type S_{1+1+1} apparently corresponds with the type S_{1+1+0} which was found among the recruit spawners in the preceding year with the difference that the first spawning ring which was formed that year now is visible in the one year older herring. I have therefore in table 4 placed the fish of the type S_{1+1+1} from the year 1927 in the first section in the same horizontal row as those spawning for the first time i 1926, and I have in the upper part of this section designated the presence of the first spawning ring with + 1.

We find thus in 1927 in the group of recruit spawners a small influx of herring which have spawned for the first time in the previous year. This admixture has probably taken place on the spawning ground.

The situation during the spawning season of the following year 1928 can be illustrated by fig. 4 which shows the age composition of the spawning shoals throughout the season. In the early part of the season (January) one finds an age composition in the various shoals which agrees with the average age distribution calculated for the whole of the foregoing season. The shoals constitute a mixture of older spawners and of recruit spawners from the preceding year. One sees, however, that the relative number of younger fish increases throughout the season, this being caused by the influx of recruit spawners to the shoals of older spawners already present.

At the end of the season after the main part of older spawners has disappeared from the spawning grounds, one encountered rather pure shoals of recruit spawners with the now five years old fish of the year class 1923 dominating. From the presence of a small number of old herrings in these shoals one must, however, expect a slight admixture of herrings which already have spawned in previous years.

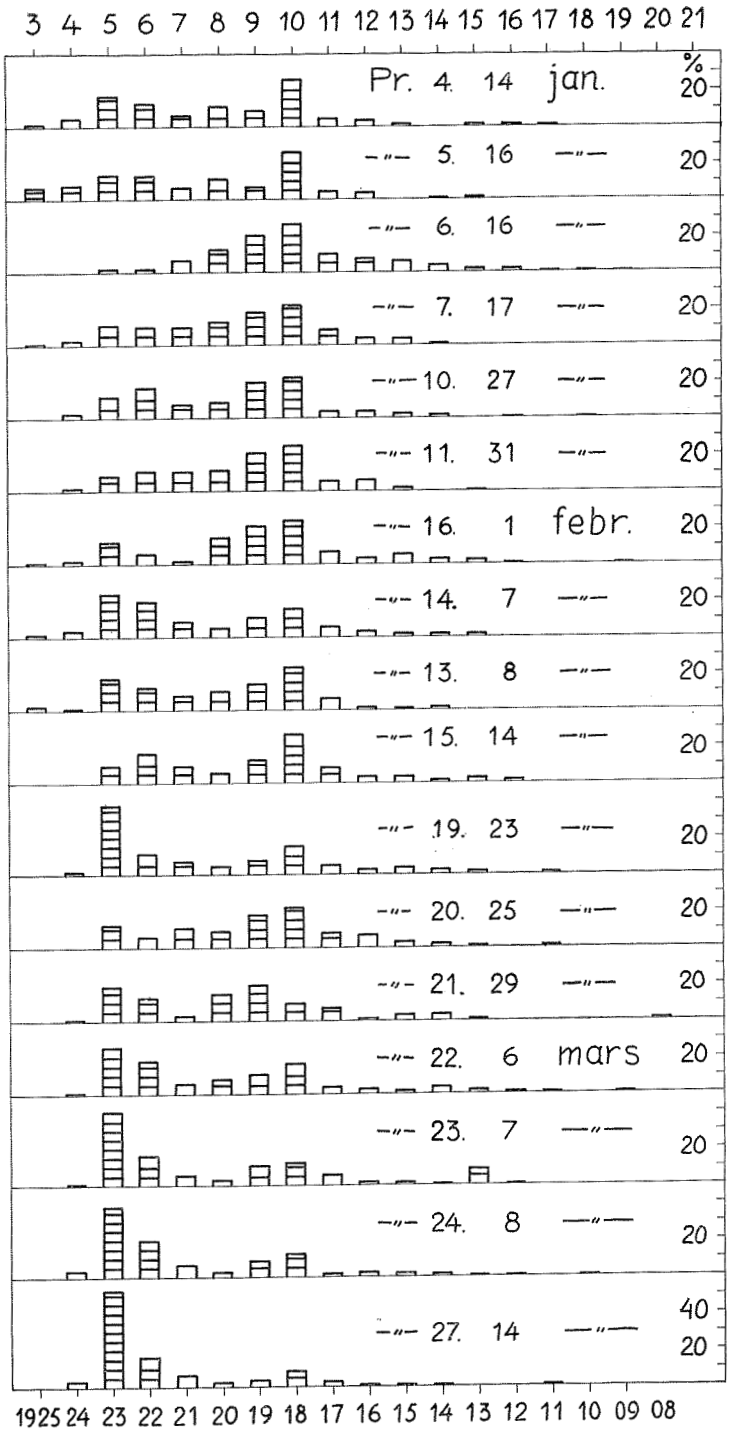

Fig. 4. Age composition of the spring herring throughout the season 1928.

Table 4. Immigration of the year-class 1923 to the group of spawners at the Norwegian West coast in the years 1926—32.

Age at 1st spawning	Scale type	Year of capture and age in years. 1926 3 years	1927 4 years	1928 5 years	1929 6 years	1930 7 years	1931 8 years	1932 9 years	1926—1932 Total
3		+ 0	+ 1	+ 2	+ 3	+ 4	+ 5	+ 6	
	S 1 + 1	8 100 %	1	—	—	1	—	—	10 90,9 %
	N 1 + 1	—	—	1	—	—	—	—	1 9,1 %
4			+ 0	+ 1	+ 2	+ 3	+ 4	+ 5	
	S 1 + 2		17	1	1	4	2	8	33
	S 2 + 1		108	10	11	14	6	113	262
			125 75,8 %	11	12	18	8	121 93,1 %	295 83,1 %
	N 2 + 1		40 24,2 %	5	4	1	1	9 6,9 %	60 16,9 %
5				+ 0	+ 1	+ 2	+ 3	+ 4	
	S 1 + 3			1	—	—	—	—	1
	S 2 + 2			54	8	29	4	140	235
	S 3 + 1			10	—	2	—	8	20
				65 35,5 %	8	31	4	148 70,1 %	256 52,7 %
	N 2 + 2			58	5	5	1	15	84
	N 3 + 1			60	6	27	5	48	146
				118 64,5 %	11	32	6	63 29,9 %	230 47,3 %

Table 4. Cont.

Age at 1st spawning	Scale type	Year of capture and age in years. 1926 3 years	1927 4 years	1928 5 years	1929 6 years	1930 7 years	1931 8 years	1932 9 years	1926—1932 Total	
					+ 0	+ 1	+ 2	+ 3		
	S 2 + 3				1	—	—	2	3	
	S 3 + 2				4	—	—	12	16	
6					5 4,2%			14 11,1%	19	7,2%
	N 2 + 3					1	—	—	1	
	N 3 + 2				56	9	4	60	129	
	N 4 + 1				52	4	5	53	114	
					108 95,8%	14	9	113 89,0%	244	92,8%
						+ 0	+ 1	+ 2		
7	N 3 + 3					6	2	2	10	
	N 4 + 2					39	4	37	80	
	N 5 + 1					9	—	1	10	
						54 100%	6	40 100 %	100	100%
							+ 0	+ 1		
	N 3 + 4						1	—	1	
8	N 4 + 3						2	—	2	
	N 5 + 2						—	3	3	
	N 6 + 1						—	—	—	
							3 100%	3 100%	6	100%

The analysis of the herring of the year class 1923 from the end of the season 1928 (table 4) shows that the main part of the fish has scales with the last winter ring of »oceanic« type (under the head + 0 in the table) and with scale types corresponding to those represented in the five years old recruit spawners in table 3. A smaller number of herrings (16 ind.) has, however, scale types (S_{1+2+1}, S_{2+1+1} and N_{2+1+1}) which in regard to coastal and oceanic rings correspond to the types found in the four years old recruit spawners in 1927. They have now got on outer ring of the new type previously mentioned. In the same manner one finds one single herring with the scale type N_{1+1+2}

The herrings with the last winter ring of »oceanic« type represent the recruit spawners in this season, and the fish with one or two outer rings of another type represent apparently an admixture of herrings which have spawned once or twice before in the years 1927 and 1926, and which in the year 1928 therefore have one or two visible spawning rings.

At the end of the season 1929 one finds in the same manner a main group of recruit spawners without a visible spawning ring intermixed with groups having one or two spawning rings. One should have expected also a group of herrings with 3 spawning rings which spawned for the first time at an age of three years. As herrings spawning at such an early age are rather rare we have not been able to get them represented in this sample. In 1930 groups with none or one to four spawning rings are found. Still in 1931 one finds a small group of recruit spawners without a visible spawning ring on the scale.

In the material from 1932 the year class 1923 is represented in all the samples of spawning herring covering the whole season. The analysis shows that no further immigration of recruit spawners of this year class has taken place now. All the fish have at least one visible spawning ring.

We have thus followed the immigration of the various groups of recruit spawners of the year class 1923 in the period from 1926—1931, represented in table 4 by the 0-groups arranged diagonally from the left upper part to the right lower part of the table. It has been demonstrated that the individuals of one year class reach their first maturity at an age varying from 3 to 8 years. This is in accordance with the age composition of a pure shoal of recruit spawners within one season as found in table 3. This shoal was composed of 6 different year classes of an age from 3 to 8 years representing an assemblage of the earlier developed individuals of the younger year classes and the later developed ones of the older year classes.

As regards the scale types it was found in table 3 that the younger herrings in the group of recruit spawners are mainly of southern origin and the older ones of northern origin. It must therefore be expected that the individuals of the year class 1923 reaching their first maturity at an early age mainly have »southern« scale types and those arriving as recruit spawners at a later age mainly »northern« scale types.

This is also really the case, as seen in table 4. The recruit spawners of the year class 1923 which arrived at the coast in 1926 at an age of three years only, consist of individuals which have lived their first winther in southern coastal water. The new immigration in 1927 represents mainly individuals with southern scale types (about 75 %). In 1928 a greater contingent of northern origin appeared mixed with herring of southern origin. In 1929 the new contingent of this year class was mainly of northern origin (96 %) and in 1930 and 1931 one meets exclusively recruit spawners with northern scale types. This is also in accordance with the phenomenon demonstrated in table 3, that the herring, which grow up at the west coast, develop to mature fish at an earlier age than the herring from northern Norway.

In the horizontal rows of table 4 one finds all the individuals which spawned for the firts time at an age of 3, 4, 5.... 8 years. In 1927 one finds for instance in the second row a group of recruit spawners of the type S_{2+1} which have lived their two first winters in southern coastal water and their third winter in the ocean. In the fourth winter they have arrived at the spawning grounds and form now their fourth winter ring. In the following year 1928 one finds in the same horizontal row fish of the same type S_{2+1} but now with one outer ring which was formed in the previous spawning season, and having another appearance than that of the oceanic ring. These herrings spawn apparently for the second time. In the next year (1929) the same group appears for the third time at the spawning grounds and now with 2 spawning rings on the scale. In 1930 they have got three, in 1931 four and 1932 five spawning rings. The herrings of the type S_{2+1+5} in 1932 have thus previously spawned five times and have now arrived at the coast in order to spawn for the sixth time. The photo in fig. 2, Plate III illustrates the type N_{3+1+2} which appeared in the year 1930. This herring spawned for the first time in 1928 at an age of 5 years and appears in 1930 at an age of seven years in order to spawn for the third time. The fig. 2 Plate II illustrates a spawning herring of the type S_{2+2+2} with two spawning rings, which according to the table 4 spawned for the third time in the year 1930.

While the winter rings which are formed in the spawning season are of another appearance than that of the »oceanic« rings one can thus

in old spawners by the number of »spawning« rings determine the age at first spawning and the number of spawning seasons in which the herring has participated.

One must now expect that all the herrings which spawned for the first time at an age from three to eight years show the same composition as regards the »southern« and »northern« scale types as that of the recruit spawners independent of the age at which they were captured. In the vertical column on the extreme right in table 4 the total number of herring of the year class 1923 from the period 1926—1932 which spawned for the first time at an age of 3, 4, 5.... 8 years is recorded. The year class 1923 is here thus divided in six spawning-groups according to the age at first spawning but independent of the age at the time of capture. One sees that the spawning-group 3 consists of 91 % of fish with »southern« scale types and the spawning-group 4 of 83 % of »southern« types. The spawning-group 5 constitutes an equal mixture of »southern« and »northern« types. The spawning-group 6 consists of 93 % of northern types and the spawning-groups 7 and 8 exclussively of northern types. The spawning-groups of this year class show thus a composition as to the relative number of herrings of southern and northern origin exactly corresponding to the composition of the recruit spawners found in the same table and in table 3. This shows that the classification of the older spawners in spawning-groups according to the number of »spawning« rings on the scale has been correct.

Year class 1925.

In table 5 I have analysed the year class 1925 in the same manner as the year class 1923 in table 4. The material from the years 1929—1931 comprises mainly recruit spawners from the end of the seasons, but the material from 1932 represents recruit spawners as well as older spawners from the whole season. In the table one finds exactly the same composition as regards the relative number of »southern« and »northern« scale types of the various groups of recruit spawners and of the spawning-groups in accordance with the results demonstrated in table 4.

Older spawners.

In the preceding section I have demonstrated that the individuals can be divided according to the number of »spawning« rings on the scale into different spawning-groups representing fish which have reached the first maturity at different stages of age. In the same manner one can arrange the whole material from one season comprising many different year classes into a certain number of spawning-groups according to the age at first spawning.

Table 5. Immigration of the years-class 1925 to the group of spawners at the Norwegian west coast in the years 1928—32.

Age at 1st spawning	Scale type	Year of capture and age in years					1928—1932 Total	
		1928 3 years	1929 4 years	1930 5 years	1931 6 years	1932 7 years		
3		+ 0	+ 1	+ 2	+ 3	+ 4		
	S 1 + 1	—	—	—	—	1	1	100 %
4			+ 0	+ 1	+ 2	+ 3		
	S 1 + 2		10	1	—	4	15	
	S 2 + 1		65	2	2	62	131	
			75 66.4%	3		66	146	76.1%
	N 1 + 2		1	—	—	—	1	
	N 2 + 1		37	—	3	5	45	
			38 33.6%				46	23.9%
5				+ 0	+ 1	+ 2		
	S 2 + 2			49	3	82	134	
	S 3 + 1			2	—	6	8	
				51 46 4%		88	142	56.8%
	N 2 + 2			15	—	13	28	
	N 3 + 1			44	1	36	80	
				59 53.9%		49	108	43.2%
6					+ 0	+ 1		
	S 2 + 3				—	2	2	
	S 3 + 2				—	5	5	
						7	7	3.3%
	N 3 + 2				30	111	131	
	N 4 + 1				29	18	47	
					59 100%	129	178	96.3%
7						+ 0		
	N 3 + 3					3	3	
	N 4 + 2					16	16	
	N 5 + 1					1	1	
						20 100%	20	100%

This is done in table 6 with the total material of spring herring from the west coast in the year 1932. This material includes about two thousand individuals representing fish at an age from 3 to 19 years of the year-classes 1929, 1928, 1927.... 1913. The table is divided in six horisontal sections representing all the individuals which spawned for the first time at an age of three to eight years arranged according to the composition as to »coastal« and »oceanic« winter rings.

Table 6. Group of Spawners. Norwegian West coast 1932.

Age at 1st. spawning.	Scale type	Spawning classes and number of spawning-rings.						
		1932 0	1931 1	1930 2	1929 3	1928 4	1927 5	1926 6
3	S 1 + 1	—	1	1	—	1	2	1
4	S 1 + 2	3	—	1	4	4	8	3
	S 2 + 1	13	—	17	62	32	113	24
	N 2 + 1	1	—	1	5	1	9	1
5	S 2 + 2	1	20	82	27	140	35	46
	S 3 + 1	1	1	6	6	8	1	3
	N 2 + 2	—	2	13	4	15	8	9
	N 3 + 1	2	15	36	11	48	32	9
6	S 2 + 3	—	2	—	2	—	2	—
	S 3 + 2	2	5	1	12	5	4	4
	N 2 + 3	—	—	—	—	—	1	—
	N 3 + 2	15	111	19	60	24	11	13
	N 4 + 1	—	18	11	53	25	4	4
7	N 3 + 3	3	—	2	—	—	—	—
	N 4 + 2	16	9	37	14	2	—	1
	N 5 + 1	1	—	1	4	—	—	—
8	N 5 + 2	—	3	2	—	—	—	1
	S	20	29	108	113	190	165	81
	N	38	158	122	151	115	65	38
Total		58	187	230	264	305	230	119

In vertical sections of the table the material is arranged according to the number of spawning rings. One finds from left to the right fish with 0 to 15 spawning rings and spawning in the year 1932 for the first to the sixteenth time. The fish with 0 »spawning« ring spawn for the first time in the 1932, the fish with 1 »spawning« ring spawned

Table 6. (Cont.) Group of Spawners. Norwegian West coast 1932.

Spawning classes and number of spawning-rings									Total	
1925 7	1924 8	1923 9	1922 10	1921 11	1920 12	1919 13	1918 14	1917 15		
—	—	—	—	—	—	—	—	—	6	100 %
3	1	—	5	—	—	1			33	
22	15	6	36	—	2	—	—	1	343	
									376	89.5 %
1	4	4	16	1	—	—	—	—	44	
									44	10 5 %
31	16	66	4	2	2	—	—	—	472	
1	5	6	2	2	—	—	—	—	42	
									514	56.7 %
11	6	33	1	4	—	1			107	
15	13	95	5	5	—	—	—	—	286	43.3 %
									393	
—	—	1	—	—	—	—	—	—	7	
—	2	2	2	—	—	—	—	—	39	
									46	8.7 %
—	1	—	—	1	—	—	—	—	3	
8	46	8	3	—	—	—	—	—	318	
1	13	1	1	—	—	1	—	—	132	
									453	91.3 %
1	—	—	—	—	—	—	—	—	6	
4	4	—	—	—	—	—	—	—	87	
1	—	—	—	—	—	—	—	—	7	
									100	100 %
—	—	—	—	—	—	—	—	—	9	100 %
57	39	81	49	4	4	1	—	1	942	48.6 %
42	87	141	26	11	—	2	—	—	996	51.4 %
99	126	222	75	15	4	3	—	1	1938	

for the first time in the year 1931, the fish with 2 spawning rings in 1930 an so on. All the herrings which spawned for the first time in the same year form a spawning-class and each spawning-class can be divided in spawning-groups comprising individuals of the same age at first spawning. Thus one finds that the spawning-class 1932 (all

fish with 0 spawning rings) is composed of the spawning-groups 4 to 7. As to age and scale types this spawning-class represents the composition of recruit spawners in the year 1932 and as this year also is the year of capture the actual age of the fish is 4 to 7 years. The spawning-class 1931 in the vertical section next on the right comprises the spawning-groups 3 to 8 which spawned for the first time in 1931 at an age of 3 to 8 years. The actual age in the year of capture (1932) was thus 4 to 9 years. The composition of the different spawning-classes can in this manner be followed in the vertical sections from left to the right. As the number of individuals of the older spawning-classes is rather small they do not give a representative picture of the composition. As each spawning-class represents the recruit spawners which immigrated to the spawning shoals in that particular year one must expect the same relative number of southern and northern scale types in each spawning-group as found in the corresponding spawning-groups of the group of recruit spawners in table 3 (page 25). In the vertical column on the extreme right in table 6, which records the sum of all spawning-classes in the whole material, one finds that this is really the case.

The percentage values of »southern« and »northern« scale types of each spawning-group correspond exactly with those found in table 3, 4 and 5. The younger spawning groups consist mainly of fish of southern origin, the older ones mainly of fish of northern origin and the spawning group 5 of an equal mixture of both types. This very good agreement is a proof on the correctness of the determination of the »spawning« rings in this material which was composed of many year classes with varying numbers of »spawning« rings.

Summary.

I have in this chapter on a large material, given a proof on the correctness of L e a' s view that the winter rings on the scale of the young herring have another appearance in northern Norway than at the west coast. One can thus distinguish »northern« and »southern« coastal winter rings. By following the formation of winter rings through the different stages in the life history of the herring I have further substantiated that the rings which are formed in the oceanic stage and in the spawning seasons are dissimilar in appearance. One can thus on the scale of older herrings distinguish »coastal«, »oceanic« and »spawning« rings. This is a fact based on direct observations and not a hypothetical interpretation. L e a has apparently taken notice also of the two latter ring types and has in a popular article in the

Norwegian language (1927) given a right interpretation of these rings but without to give any proof on the correctness of the interpretation or to discuss the matter. As regards the »spawning« rings we have also an example in the peculiar appearance of the spawning zones in the otoliths of the Norwegian cod stated by R o l l e f s e n in an interesting preliminary report in 1933. The assumption of a definite zone type as »spawning« zones led to important conclusions as regards the recruitment and mortality of the stock of Norwegian cod (R o l l e f s e n 1933, 1934, 1935).

As regards the Norwegian herring it is possible to read the life history of each individual on its scale. We have seen that the young herrings leave the coastal water of southern Norway at an earlier age than is the case in northern Norway. In the ocean the younger herrings originating from the West coast mixe with older herrings emigrated from northern Norway into shoals with a definite composition as regards age and scale types.

The formation of these shoals is connected with the inception of sexual development. Fish born in the same year reach this stage at varying age and the herrings grown up at the west coast are earlier developed than those from northern Norway. The shoals of maturing herring are thus composed of individuals which have reached the same stage of development in the same year but at differing age. It was found that the shoals were composed of sixe age- groups constituting 1½ to 6½ years old fish.

The oceanic intermediate stage lasts 1½ year and the herrings then appear on he spawning grounds in spring in order to spawn for the first time. The group of recruit spawners has exactly the same composition as that of the shoals which were formed in the early phase of the oceanic intermediate stage with the difference that all the fish are now older by 1½ year. The recruit spawners, which all have lived the preceding winter in the ocean, have at least the latest formed visible winter ring of »oceanic« type. In the succeeding year this group will return to the spawning grounds in company with older spawners in order to spawn for the second time and all the fish have then one visible »spawning« ring on the scale. In the following year they spawn for the third time and have two spawning rings and so on. By counting the number of spawning rings the mature herrings on the spawning grounds can be divided into groups of fish which spawn for the first, second, third time and so on representing spawning-classes comprising fish which spawned for the first time in the same year. These spawning-classes show as regards age at first spawning and scale types the same composition as do the pure shoals of recruit spawners. They are

composed of six spawning-groups representing fish which spawned for the first time at an age of 3—8 years. The fish which spawned for the first time at an early age are mainly of southern origin and those which spawned for the first time at an older stage of northern origin.

The immigration to the spawning shoals thus takes place at an age of 3 to 8 years and in the nineth year of life all the herrings of a particular year-class has been transfered from the stock of young herring to the stock of mature herring.

It is apparent that a statistical analysis of the numerical strength of the different spawning-groups in shoals of older spawners gives important information concerning the rules for the renewal of the stock of mature herring as will be discussed in a later chapter. It is also possible to analyse in which proportion the herrings of southern and northern origin take part in the formation of the shoals spawning on the different grounds along the coast.

Chapter 3.

Analysis of the growth of the Norwegian herring.

Lea (1910) has shown that the relation between the size of a certain scale and the length of the fish is sufficiently constant to render it possible to calculate the length of the fish from the size of the scale. Lea concluded from this that it must be possible to estimate how each individual has grown from year to year by measuring the growth increments between each separate winter ring on the scale.

I will not here give a discussion of the contributions on this subject which have been published since that time, but Ottestad (1934) has recently discussed the problem more thoroughly.

The method of calculating the growth of the herring by measuring the growth zones on the scale is, however, now generally used in the herring investigations. The growth rate of the herring in different waters has been studied on a large material, and it has been demonstrated that the herring which inhabit different regions, can be characterized by different growth types. Hjorth and Lea (1911) had already at an early stage of the growth investigations a clear understanding of the fact that also one and the same herring group whose mature individuals spawn together may be composed of several growth types, and that extraordinary growth phenomena may be utilized for the special investigation of the inner composition of a single herring group and its migration. They expected especially to find this realized in the Norwegian herring, »whose region of distribution extends over 13 degrees of latitude and embraces many different kinds of external conditions«. Hjort and Lea (1911) give an example on a marked growth difference which appeared in the year class 1904 of the Norwegian herring. In all the samples of fat herring from northern Norway a great number of fish of this yearclass had in their third year an abnormally small increment of growth which was smaller than the

increment in the fourth year. This phenomenon was by the authors utilized in the same manner as an artificial marking and the migrations of the fish thus »marked« by nature was studied.

Ottestad (1934) has later shown in regard to the Norwegian herring that the appearance of »marked« individuals is a feature common in all year classes. In addition to the two growth types described by Hjort and Lea, Ottestad demonstrates the presence of a third growth-type characterized by a larger increment in the third year than in the second. By analysing these three growth-types in the shoals of fat herring and mature herring Ottestad has drawn rather far reaching conclusions as to the migrations of the Norwegian herring.

It is apparent that the method of reading the life history of each single individual from the appearance of the winter rings on the scale as demonstrated in the previous chapter offers a method for a more thorough study of the growth phenomena. The growth can be analysed according to the different fates of the individuals, — the different feeding grounds visited by the young herring, the time when they adopted an oceanic mode of life, the inception of sexual development etc. It will in this manner be possible to trace the various growth types which may exist in a group of herring and the environmental factors which may cause the formation of these growth types.

A description of the method of growth measurement is given by Lea (1910). The actual length of the herring is called L. The calculated total length of a fish at the formation of the first, second, third etc. winter ring is called 1_1, 1_2, 1_3 etc. The increase in length which the herring has undergone in the growth season of the first, second, third etc. year is called t_1, t_2, t_3, etc., t_1 is thus equal to 1_1; t_2 is equal to $1_2—1_1$ etc.

The growth of the young herring from different feeding grounds along the Norwegian coast.

Ottestad (1934) has on a material of »bladsild«, which was collected by the Directorate of Fishery in the summer 1933, compared the seasonal growth in the second year of life in the coastal waters of southern and northern Norway. The growth curves demonstrated by Ottestad show that there is an essential difference between the seasonal growth in the two areas. The duration of the growth-season is about 7 months in the southern area (April—October) and about 3½ months in the northern area (May—August). The total growth in the southern area is about 8 cm while in the northern area it is only about 5.3 cm. According to Ottestad the cause of this difference in growth must be sought in the temperature. According to my

analysis of the appearance of the winter ring on the same material (1933) given in table 1 (page 16) the herrings from northern Norway have almost exclusively »northern« scale types (N_1) and those from southern Norway »southern« scale types (S_1).

The dissimilarity in the appearance of the winter ring in the northern and southern area is thus also connected with a dissimilarity in growth.

Table 7. Year class 1932 as "Bladsild" in the year 1933.

Northern Norway					Southern Norway				
Date	Nr.	L	t 1	t 2	Date	Nr.	L	t 1	t 2
					6 V	58	13.66	11.74	1.92
					13 V	66	14 36	12.12	2.24
					22 V	69	15 31	12.25	3.06
					30 V	48	16.90	13.17	3.73
10 VI	44	11.44	10.45	0.99	7 VI	75	16 60	12 09	4 51
					15 VI	98	16 39	11.89	4.50
					20 VI	86	16.25	10.97	5.28
					28 VI	88	17.29	11.15	6.14
					2 VII	96	16 91	10 61	6.30
17 VII	56	14.64	10.32	4.32	18 VII	70	18.07	11.30	6.77
3 VIII	94	13.43	8.72	4.71	22 VIII	71	19.25	10.82	8.43
					8 IX	90	17.96	10.27	7.69
					27 IX	36	20.78	11.50	9.28
18 X	71	13 56	8.55	5.01					
24 X	42	13.96	8.70	5.26					
30 X	95	14.42	8.89	5.53	30 X	36	20.07	10.83	9.24
15 XI	63	16.82	10 67	6.15					

In table 7 I have given the average values for the total length (L) and the growth increments in the first and second year (t_1; t_2) of the »bladsild« from 1933. This table demonstrates the difference between the growth in both areas in the second year of life as found by O t t e s t a d. One find, however, also a certain growth difference in the first year of life between herring from both areas. The average value of t_1 for the material from the whole season is in northern Norway 9.4 cm while in southern Norway 11.0. Through the still greater growth difference in the second year the herring in the southern area reach essentially a larger size at the end of the second season than do the herrings in northern Norway.

The values for t_1 throughout the summer 1933 in table 7 demonstrate, however, another interesting phenomenon. One finds in both

areas that the samples from the earlier part of the season contain herrings which have had a greater increment of growth in their first year of life (t_1) than that of the herrings in the samples from the later part of the season. The same experience has L e a (1911) made by studying the growth dimensions of herrings in their third year of life through all the seasons of the year at the west coast. L e a found that the fish in the first samples from each year had a little larger 1_1, 1_2 and t_2 than those later on in the summer, and L e a says that »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 and by the appearance in waters in which they can be caught«.

From the growth calculations in table 7 it thus looks as if small herring from a rather restricted area, born in the same year and of the same scale type can have had a differing growth already in the first year of life. Measurements of the actual length of herrings at the end of their first year of life from different shoals caught at the same time and on neighbouring localities have confirmed that this is really the case.

In September 1935 samples of »fry« from Andfjord had an average length of 9,9 cm while samples from Tysfjord had an average length of 8,2 cm. The herring fry from these two localities in northern Norway had thus a difference in length which completely corresponds to the difference in the calculated values for t_1 among the »bladsild« from northern Norway in table 7. The larger fry were caught in a fjord which has a direct connection with the open sea and great shoals of herring fry were observed in the open sea outside the fjord. It thus looks as if the fry had immigrated from the ocean.

The smaller fry were caught in a fjord situated at the inner end of the Vestfjord and rather distant from the open sea. It is probable that the fry had been stationary here for a longer time. It thus seems that one already at this early stage can distinguish between fry living in the fjords and in the open sea, and the difference in size is probably caused by the different mode of life.

In the second year of life the difference in size is still more pronounced and one can in a restricted area find groups of »bladsild« of very different average size. The size attained seems to decide the shoaling of the fish. Table 8 demonstrates the composition as to age and size of the shoals of which the 1½ year old »bladsild« took part in the autumn 1934. The average size of the »bladsild« in the various samples, which all were taken in a rather restricted area in the Troms District in northern Norway, varies from 14,1 to 20,9 cm. The smallest »bladsild« from Ulsfjord (L = 14,1 cm) occurred intermixed with one year younger fry. The next size group of 18,0 cm.

formed pure shoals of »bladsild« and the larger size groups were found intermixed with older herring. Of these groups the »bladsild« with an average length of 19,0 cm. had only a small admixture of one year older fat herring with an average length of 20,1 cm, but the shoal which contained the bladsild of largest size (20,9 cm.) was mainly composed of older fat herring with 2½ year old fish (average length 22,8 cm) dominating.

Table 8. Composition of Small- and Fatherring shoals in northern Norway 1934 as regards age and length (L).

Month	Locality	½ year		1 ½ years		2 ½ years		3 ½ years		4 ½ years		5 ½ years	
		Nr.	L	Nr.	L	Nr.	L	Nr.	L	Nr.	L	Nr.	L
XI	Ulsfjord	205	8.6	199	14.1	—	—	—	—	—	—	—	—
XI	Kalfjord	—	—	188	18.0	—	—	—	—	—	—	—	—
XII	Vengsøy	—	—	159	19 0	30	20.1	—	—	—	—	—	—
X	Andfjord	—	—	329	19.5	247	22.2	3	24.7	5	26.8	—	—
IX--X	—„—	—	—	198	20.9	690	22.8	20	25.4	54	26.1	1	26.0

One thus finds that also in a restricted area the herrings in their second year are split up in different size groups and that the smaller herring of a year brood attach themselves to younger fish and the larger herring to older fish. It looks as if the size attained rather than the age determines the formation of the young herring shoals. This is in good accordance with the observations by L e a (1918) on the length of 2½ years old herring in northern Norway 1915.

In accordance with the distribution of the two size groups of the fry in 1935 one finds that the shoals with large »bladsild« were caught in the outer part of the coastal region near the open sea while the small »bladsild« occurred in a deep fjord in the inner part. The older fat herring assembled with the large »bladsild« had for a great part scales with one oceanic winter ring thus indicating that they had lived the last winter in the ocean.

The tables 7 and 8 thus demonstrate that there is not only an essential growth difference between small herrings grown up in southern and northern Norway but also that the small herrings in a restricted area are dissociated in different size groups. The larger herrings represent probably individuals which have adopted an oceanic mode of life and which in certain seasons more or less regularly appear in coastal waters. The dissociation in faster growing oceanic herring and slower growing coastal herring as demonstrated by L e a (1929 II) and O t t e s t a d (1934) in regard to the fat herring seems to take place already at a very early stage.

The growth history of some separate year-classes.

I will in the following analyse the growth of herring born in the same year through all the different stages in the life history from the first appearance as young herring on the feeding grounds in northern and southern Norway, through the oceanic intermediate stage until they appear as recruit spawners on the west coast. It will be examined if the herring with different origin and life history according to the appearance of the winter rings also have a different growth history. The yearclasses 1923 and 1925 will be analysed in this manner and of the yearclasses 1918 and 1904, which both have taken a great part in the stock of Norwegian herring, older spawners will be analysed.

Year-class 1923.

In table 9 (page 49) I have given the growth values for the different types of young herring in northern Norway and fish in the oceanic intermediate stage at the west coast.

From the year 1923 the material of the year class is represented by a large number of fry captured in the autumn of the first year of life in northern Norway. The fry had an average length of 8,6 cm. The 1½ year old »bladsild« from the same area have in the next autumn reached an average length of 14,64 cm. One sees, however, that these herrings represent fish which had a smaller growth in the first year of life ($t_1 = 7{,}56$) than the fry caught in 1923. A selection seems to have taken place in such a manner that only the slow growing fish have remained in the coastal water. The average length of the »bladsild« in 1924 agrees with the smallest »bladsild« from 1934 in table 8, and it is probable that a group of larger individuals of the year class 1923 now had disappeared from the coastal water.

One sees from the table that a small group of southern origin (S_1) has immigrated to the shoal in northern Norway and these fish have a larger size (17,28 cm) than the fish (N_1) which have grown up in the area (14,45 cm).

From the year 1925 192 individuals of the now 2½ years old herring from northern Norway have been analysed. The fish have now reached a length of 17,4 cm. As seen from the growth values for t_1 and t_2 these fish have had a still slower growth in the first two years of life than the group of »bladsild« from 1924. It is apparent that a group of faster growing herring again have disappeared from the coastal water in the meantime in the same manner as in the previous year. The main part of the herring has lived the last two winters in

the northern coastal water (N_2) but one finds also a small admixture of herrings of southern origin (S_2) and of herrings which have lived the last winter in the ocean (N_{1+1}, S_{1+1}). One finds that the »oceanic« herrings have grown faster than the coastal herrings.

We have thus found that the growth values of the young herring in northern coastal water decrease with increasing age apparently owing to an earlier emigration of the more fast growing individuals than of the slow growing ones. These results are in accordance with the observations made by L e a (1913).

Table 9. Year-class 1923. Young herring.

Region	Year of capture	Scale type	Nr.	L.	Growth increments.				
					t 1	t 2	t 3	t 4	t 5
Northern Norway	1923		598	8.60					
	1924	S 1	7	17.28	8.47	8.81			
		N 1	94	14.45	7.49	6.96			
			101	14.64	7.56	7.08			
	1925	S 1 + 1	1	20.0	8.40	5.70	5.90		
		S 2	22	17.91	6.97	5.21	5.73		
		N 1 + 1	7	18.42	7.21	4.76	6.46		
		N 2	162	17.27	6.67	4.82	5.77		
			192	17.40	6.74	4.87	5.79		
Southern Norway	1925	S 1 + 1	134	23.87	10.32	9.08	4 46		
		S 2	72	21.29	9.28	7.63	4.38		
		N 1 + 1	11	22.91	9 82	8.42	4.67		
		N 2	9	20.22	8.27	6.91	5.04		
			226	22.85	9 88	8.50	4.47		
	1926	S 1 + 2	5	25.40	12.14	7.64	3.10	2.52	
		S 2 + 1	16	26 31	9.56	7 44	5.36	3.95	
		S 3	1	26.00	11.70	5.50	5.30	3.50	
		N 2 + 1	14	25.43	9.10	6.54	5.17	4.62	
		N 3	20	24.55	8.90	5.79	4.77	5.09	
			56	25.38	9.48	6.61	4.90	4.39	
	1927	S 2 + 2	18	26.78	9.92	7.60	4.71	2.77	1.78
		N 2 + 2	13	26.30	9.03	6.35	4.30	3.74	2.88
		N 3 + 1	80	25.82	8.99	4.95	3.95	4.37	3.56
		N 4	24	25.83	8.40	5.19	4.11	4.49	3.64
			135	26.02	9.05	5.50	4.11	4.10	3.26

From the year 1925 one finds in the table 9 also a group of the year class 1923 from southern Norway. This group will probably now participate in the formation of a shoal in the oceanic intermediate stage,

and begin the sexual development. This group contains herrings mainly of southern origin with a small admixture of herrings emigrated from more northern regions. Comparing the average length of this southern group (22,85 cm) with the length of the group from the same year in northern Norway (17,40 cm) one finds a discrepancy betweeen the two groups of more than 5 cm. One sees that the southern group had considerably greater growth increments in the two first years of life (t_1, t_2) than the northern group.

Of the various elements in the southern group the »southern« types have had better growth than the corresponding »northern« types, and the fish which have lived the last winter in the ocean (S_{1+1}, N_{1+1}) have had greater growth increments than the fish which have lived in the coastal waters (S_2, N_2). One finds further that the herring of northern origin which have immigrated to the southern group (N_{1+1}, N_2) have had a considerably faster growth than the fish of corresponding types which have remained in the northern waters. They represent apparently some of the fast growing elements which were supposed to have disappeared from the northern Norway. The growth increment in the first year (t_1) of these fish is equal to or greater than the lengh of the fry found in northern Norway at the end of their first year of life in 1923. This thus confirms the assumption previously made that faster growing individuals emigrate from the northern waters earlier than the slower growing ones.

In the following summer 1926 one encounters a new group of the now 3½ years old fish of the year class 1923 which has joined a shoal of herring in the oceanic intermediate stage in southern waters. This group is composed of an equal number of fish of southern and of northern origin. This group is represented by fish with smaller growth values in their first and second year (t_1; t_2) than those of the group which began the sexual development in 1925. In 1927 a new group of maturing herring appears, mainly of northern origin with still smaller growth values.

In fig. 5 (upper section) I have given the growth curves for the groups of young herring here analysed demonstrating the increments in each year (t_1 t_2 etz.) according to the figures in table 9. These diagrams illustrate clearly the varying growth history of the different groups of the year class 1923 which began the sexual development in 1925, 1926 and 1927. The more fast growing individuals reach this stage at an earlier age than the more slow growing ones. The slow growing fish which in 1925 still remained in northern Norway have, however, until 1927 not yet appeared in the southern shoals of herring in their oceanic intermediate stage.

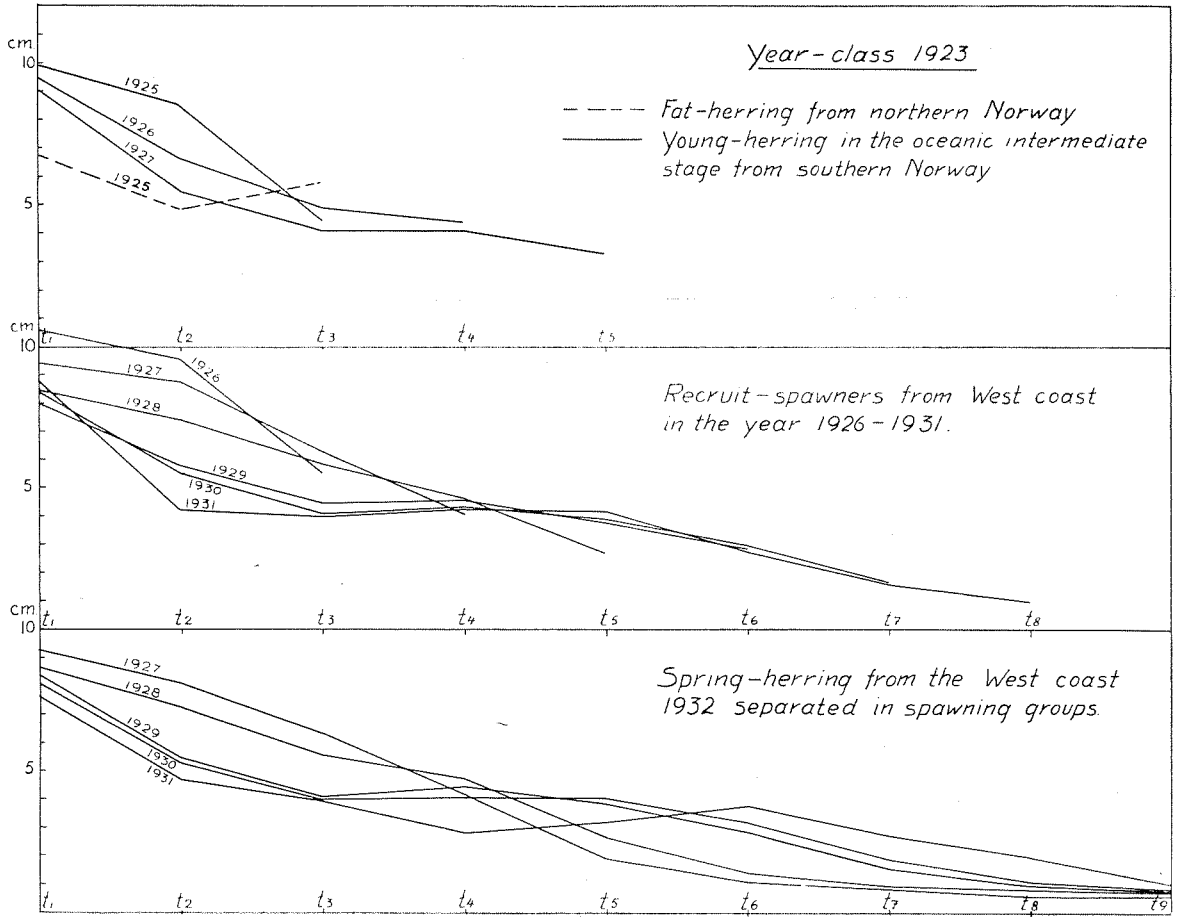
Year-class 1923
Fat-herring from northern Norway
Young-herring in the oceanic intermediate stage from southern Norway
cm
10
5
1925
1926
1927
1925
t1 t2 t3 t4 t5
Recruit-spawners from West coast in the year 1926-1931.
1926
1927
1928
1929
1930
1931
t1 t2 t3 t4 t5 t6 t7 t8
Spring-herring from the West coast 1932 separated in spawning groups.
1927
1928
1929
1930
1931
t1 t2 t3 t4 t5 t6 t7 t8 t9

Fig. 5.

Table 10. Year class 1923. Recruit spawners.

Year of capture	Age	Scale type	Nr.	L	Growth increments							
					t 1	t 2	t 3	t 4	t 5	t 6	t 7	t 8
1926	3	S 1 + 1	8	25.67	10.60	9.55	5.53					
1927	4	S 1 + 2	17	27.94	9.84	9.30	5.25	3.55				
		S 2 + 1	108	28.71	9.44	8.91	6.36	4.00				
		N 2 + 1	40	28.13	9.12	8.06	6.39	4.56				
			165	28.49	9.41	8.74	6 25	4.09				
1928	5	S 1 + 3	1	27.0	9.50	6 40	4.10	3.70	3.30			
		S 2 + 2	54	29.15	8.78	8.22	5.98	3.91	2.26			
		S 3 + 1	10	29 10	8.66	7.86	5.23	4.77	2.58			
		N 2 + 2	57	29 12	8.34	7.12	6.40	4.81	2 46			
		N 3 + 1	59	28.75	8.34	6.87	5.26	5.15	3.13			
			181	28.99	8.49	7.40	5 82	4.64	2.63			
1929	6	S 2 + 3	1	30.0	7.50	8.00	7.70	3.80	1.40	1.60		
		S 3 + 2	4	30.25	8.35	6.45	4.43	4.95	3.38	2.70		
		N 3 + 2	56	29.62	8.07	6.06	4.63	4.85	3 47	2.54		
		N 4 + 1	52	29.06	7.92	5 39	4.17	4.29	4 14	3.15		
			113	29.39	8.01	5.78	4.44	4.58	3.76	2.82		
1930	7	N 3 + 3	6	30.50	7.60	5.43	4.60	5.57	3.75	2.25	1.30	
		N 4 + 2	39	30.72	8.53	5.45	3.99	4 31	3.91	2.88	1.66	
		N 5 + 1	9	30.78	8.48	5.91	4.13	3.78	3.18	3 40	1.90	
			54	30.70	8.41	5.52	4.08	4.36	3.77	2.89	1.65	
1931	8	N 3 + 4	1	—	—	—	—	—	—	—	—	—
		N 4 + 3	2	31.00	8.85	4.20	4.05	4.30	4.20	2.75	1.65	1.00

I will in the following examine the growth of the groups of recruit spawners of this year class immigrating to the spawning grounds in the years 1926—1931. The results are given in table 10 and fig. 5 (middle section). The composition as to the scale types of these recruit spawners is already discussed in the previous chapter and the material is the same one presented in table 4.

The small group of herring which spawned for the first time in the spring 1926 is represented by very fast growing individuals of southern origin. These herrings have reached a larger size than the young herring which were found in southern Norway at the end of the growth season in 1925. In the autumn of 1925 there must have existed at least three different groups of the year class 1923. One group of small herring in the northern coastal water (table 9), one group of larger individuals with beginning sexual development in the southern waters

(table 9) and a small group of mature herring ready to spawn in the spring of 1926 representing a selection of the largest fish (table 10).

According to the analysis of the scale types in the foregoing chapter the group of the fish in the early stage of sexual development found in the autumn of 1925 will appear as recruit spawners in the spring of 1927. The new group of herrings in this stage which appeared in the autumn of 1926 will spawn in 1928 and so on.

According to our knowledge of the growth of these groups one must expect that the groups of recruit spawners succesively immigrating to the spawning grounds will show decreasing growth values with increasing age at the first spawning. This phenomenon is very well illustrated by the diagrams in fig. 5.

Comparing the growth curves for the recruit spawners with the curves for the young herrings in the upper part of the figure one finds also that the recruit spawners from 1927 agree well with the young herrings found in southern Norway in 1925, the recruit spawners from 1928 with the young herring from 1926 and the recruit spawners from 1929 with the young herring from 1927. The agreement is as good as may be expected by studying the average values of a comparatively small number of individuals.

I have thus demonstrated that the different groups of recruit spawners of one year class represent different growth types. The earliest immigrating groups of mainly southern origin consist of fast growing fish and the later immigrating groups of mainly northern origin consist of slow growing fish.

As shown in the foregoing chapter all the groups of recruit spawners of the year-class 1923 had joined the shoals of older spawners in 1932. The spring herring of this year class is then in the year 1932 composed of six spawning-groups each with a different growth history. The growth values for the herring in 1932 is thus an average for many different growth types. If one now by means of the number of »spawning« rings separates the different spawning-groups which in 1932 are mixed in the same shoals, it must be possible to isolate the different growth types. This is done in table 11 and the average growth values for the different spawning-groups of which the spawning herring are composed in the spring of 1932 are demonstrated by the diagrams in the lower part of fig. 5. All the herrings are of the same age, but are isolated in groups which spawned for the first time in 1927, 1928 etc. The small group which spawned for the first time in 1926 is not represented.

Comparing in fig. 5 the growth of the various spawning-groups among the nine years old spring herring in 1932 which spawned for

the first time in the years 1927—1931 with the growth of the recruit spawners directly observed in the corresponding years one finds a very good agreement between the values for t_1, t_2, t_3 etc. One reencounters among the older spawners the same growth types as represented by the different groups of recruit spawners.

Table 11. Year-class 1923. Group of spawners in the year 1932.

Age at 1st spawning	Scale type	Nr.	L.	L. at 1st spawning	Growth increments.								
					t 1	t 2	t 3	t 4	t 5	t 6	t 7	t 8	t 9
3	S 1 + 1 + 6	—	—	—	—	—	—	—	—	—	—	—	—
4	S 1 + 2 + 5	7	32.57	28.51	10.14	9.76	5.37	3.24	1.54	0.89	0.63	0.46	0.54
	S 2 + 1 + 5	101	32.81	27.92	9.31	8.06	6.39	4.16	1.87	1.08	0.75	0.60	0.59
	N 2 + 1 + 5	9	32.11	26.93	8 31	7.33	6.41	4.88	2.20	1.11	0.79	0.53	0.54
		117	32.74	27.88	9.28	8.11	6.33	4.16	1.87	1.07	0.75	0.59	0 59
5	S 2 + 2 + 4	129	32.81	29.52	8.86	8.03	5.81	4.44	2.38	1.21	0.82	0.67	0.59
	S 3 + 1 + 4	6	33.17	29.83	8.52	7.08	5.90	5.52	2.82	1.40	0.90	0.60	0.43
	N 2 + 2 + 4	12	32.17	28.64	8.37	6.15	6.53	5.10	2.49	1.38	0.84	0.69	0.62
	N 3 + 1 + 4	44	32.45	27.72	8.26	6.15	4.52	5.29	3.49	1.91	1.18	0.90	0.75
		191	32.70	29.06	8.68	7.45	5.56	4.72	2.65	1.39	0.91	0.72	0.62
6	S 2 + 3 + 3	2	32 0	28.85	8.00	6.05	3.40	5.60	2.05	3.75	1.75	0.70	0.70
	S 3 + 2 + 3	10	32.40	29.71	7.93	6.10	4.55	5.36	3.38	2.39	1.21	0.79	0.69
	N 3 + 2 + 3	56	32.39	29.29	8.57	5.42	4.03	4.64	3.93	2.65	1.44	0.91	0 75
	N 4 + 1 + 3	50	32.18	28.72	8.36	5.38	4.02	4.01	3.89	3.06	1.73	0.99	0.74
		118	32.30	29.08	8.42	5.47	4.08	4.45	3.83	2 82	1.55	0.93	0.74
7	N 3 + 3 + 2	2	33 0	30.95	9.85	4.55	3.75	4.10	3.40	3.20	2.10	1.15	0.90
	N 4 + 2 + 2	36	32.25	30.38	8.00	5.31	3.99	4.08	4.05	3.13	1.83	1.06	0.81
	N 5 + 1 + 2	1	32.00	30.90	8.80	4.40	3.30	4.80	3.60	4.90	2.10	0.60	0.50
		39	32.29	30.43	8.11	5.25	3.96	4.10	4.01	3.17	1.85	1.05	0.80
8	N 5 + 2 + 1	3	31.67	30.67	7.63	4.70	3.97	2.77	3.20	3.77	2.70	1.93	1.00
Total		468	32.57		8.71	6.91	5.24	4.45	2.87	1.83	1.12	0.78	0.66

Each spawning-group is, however, not homogenous in regard to the life history of the individuals, but one finds groups of fish with differing fates during the earlier years of life, as seen from the scale types in table 11, and these groups represent somewhat different growth types. The shoals of older spawners is thus built up in a very complicated manner by a great number of different growth types

corresponding to the different life histories of the individuals. By sorting the fish according to the scale types it is possible to separate these growth types.

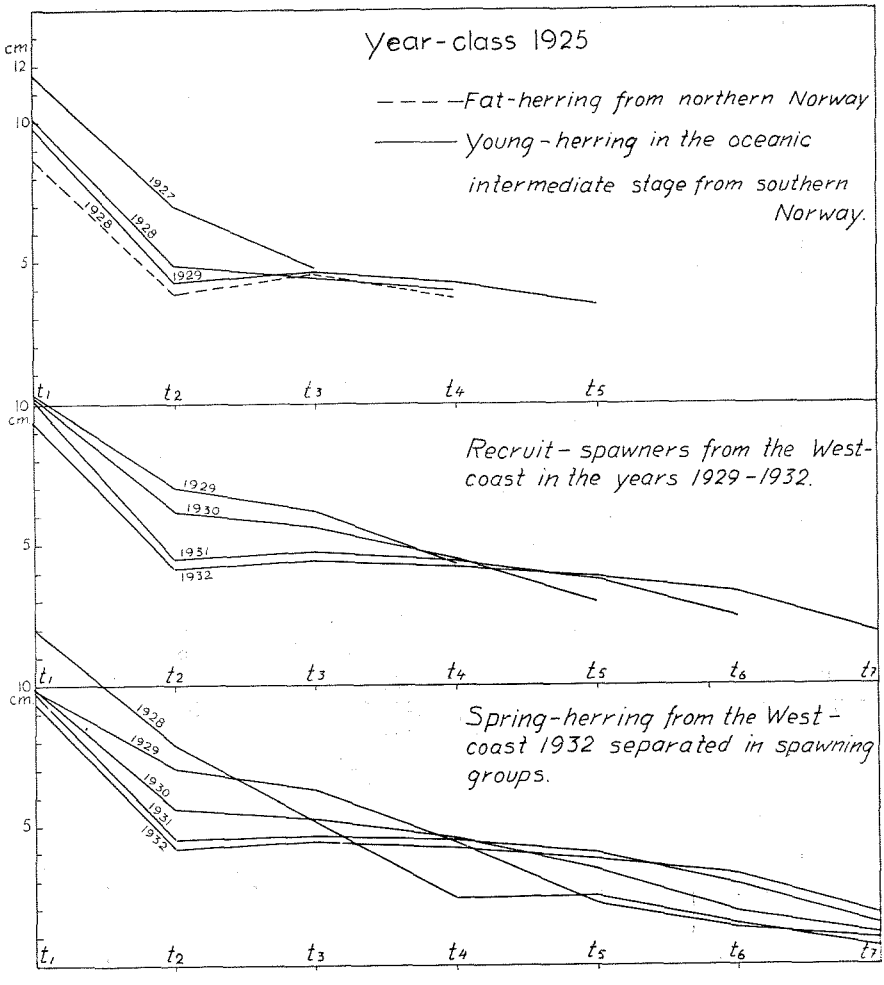

Fig. 6.

Year-class 1925.

The analysis of the growth of the young herring, recruit spawners and older spawners of this yearclass is given in tables 12, 13 and 14 and is illustrated by diagrams in fig. 6. The growth curves for the young herrings in the upper part of the figure demonstrates that the 3½ years old fat herring found in northern Norway in 1928 are represented by slow growing fish.

The herrings in the oceanic intermediate stage found in southern Norway in 1927 represent a selection of the most fast growing individuals which now begin their sexual development. The groups which reach this stage in the years 1928 and 1929 show decreasing growth values with increasing age.

Table 12. Year-class 1925. Young herring.

Region	Year of capture	Scale type	Nr.	L.	Growth increments				
					t 1	t 2	t 3	t 4	t 5
Northern Norway	1928	S 2 + 1	4	21.25	8.38	4.15	4.95	3.78	
		S 3	5	21.20	8.68	4.56	4.42	3.54	
		N 1 + 2	1	22.00	10.30	4.20	4.50	3.00	
		N 2 + 1	51	21.22	8.95	3.88	4.59	3.79	
		N 3	244	21.09	8.81	3.96	4.60	3.73	
			305	21.12	8.83	3.96	4.60	3.73	
Southern Norway	1927	S 1 + 1	46	23.63	11.64	7.38	4.62		
		S 2	140	23.54	11.74	7.01	4.80		
		N 1 + 1	41	23.44	11.62	6.97	4.84		
		N 2	18	22.72	11.67	6.01	5.04		
			245	23.48	11.69	7.00	4.79		
	1928	S 1 + 2	29	24.07	11.04	6.07	4.13	2.82	
		S 2 + 1	96	23.44	9.90	4.89	4.68	3.97	
		S 3	16	23.69	10.44	4.96	4.30	3.98	
		N 1 + 2	9	24.44	11.50	6.11	3.59	3.24	
		N 2 + 1	58	23.29	10.30	4.48	4.53	3.98	
		N 3	49	23.10	9.73	4.43	4.39	4.55	
			257	23.47	10.18	4.89	4.47	3.93	
	1929	N 2 + 2	1	27.8.	12.00	5.90	4.70	2.70	2.50
		N 3 + 1	9	26.96	9.96	4.54	4.66	4.28	3.52
		N 4	7	25.75	9.33	3.76	4.69	4.40	3.57
			17	26.51	9.82	4.30	4.67	4.24	3.48

In the next section of the figure 6 one reencounters these groups as recruit spawners on the west coast in the years 1929—1931. In 1932 a group of recruit spawners appears at the west coast composed of herring exclusively of northern origin. This group has a growth history very similar to that of the fat herring found in northern Norway.

The growth curves in the lower part of the figure demonstrates the growth history of the different spawning-groups of which the seven years old spring herring are composed in the year 1932. The spawning-groups are separated according to the number of »spawning« rings

Table 13. Year class 1925. Recruit spawners.

Year of capture	Age	Scale type	Nr.	L	Growth increments						
					t 1	t 2	t 3	t 4	t 5	t 6	t 7
1928	3	S 1 + 1	—	—	—	—	—				
1929	4	S 1 + 2	10	28.10	11.44	7.45	5.22	3 99			
		S 2 + 1	65	27.82	10.17	6.98	6.39	4.28			
		N 1 + 2	1	27.75	10.14	6.95	6.36	4.30			
		N 2 + 1	37	27.59	10.22	7.01	6.01	4.36			
			113	27.76	10.32	7.02	6.15	4.28			
1930	5	S 2 + 2	48	30,25	10.00	7.02	6.29	4.32	2.57		
		S 3 + 1	2	31.50	9.25	8.00	6,20	4.75	3.30		
		N 2 + 2	15	29.87	10.27	6.27	5.87	4 63	2.81		
		N 3 + 1	44	28.77	10.64	5.51	3.72	4.58	3.33		
			109	29.61	10.28	6.33	5.60	4.48	2.92		
1931	6	S 2 + 3	—	—	—	—	—	—	—	—	
		S 3 + 2	—	—	—	—	—	—	—	—	
		N 3 + 2	28	30.03	10.08	4,54	4.70	4.56	3.73	2.44	
		N 4 + 1	28	29.82	10.30	4.41	4.74	4.12	3.83	2.43	
			56	29.93	10.19	4.48	4.72	4 34	3.78	2.43	
1932	7	N 3 + 3	4	31.25	10.33	4.85	4.35	4.78	3.60	2.43	0.93
		N 4 + 2	15	31.00	9.04	4.03	4.42	4.23	3.89	3.42	2.08
		N 5 + 1	1	31.00	9.90	2 70	4.70	3.90	3.00	4.60	2.20
			20	31.05	9.34	4.13	4.42	4.25	3.79	3.28	1.86

on the scale. One finds here exactly the same growth types which were represented by the different groups of recruit spawners. One recognizes here also the fish which spawned for the first time in 1928 and which were not represented in the material of recruit spawners. The curves demonstrate in the same manner as for the year class 1923 that the fast growing individuals reach sexual maturity earlier than the slow growing fish, and that the older spawners are composed of many different growth types.

Table 14. Year-class 1925. Group of spawners in the year 1932.

Age at 1st. spawning	Scale type	Nr.	L	L at 1st spawning	Growth increments						
					t 1	t 2	t 3	t 4	t 4	t 5	t 7
3	S 1 + 1 + 4	1	32.00	24 90	12.00	7.80	5.10	2.40	2.50	1.50	0.70
4	S 1 + 2 + 3	5	31.60	27.24	10.54	7.28	5.28	4.14	2.18	1.20	0.98
	S 2 + 1 + 3	55	32 07	27.61	9.74	7.09	6 38	4 39	2.19	1.35	0.93
	N 1 + 2 + 3	—	—	—	—	—	—	—	—	—	—
	N 2 + 1 + 3	5	32.60	27.44	10.34	6 22	6.14	4.74	2.48	1.48	1.20
		65	32.08	27.56	9.83	7.04	6.28	4.40	2.21	1.34	0.96
5	S 2 + 2 + 2	79	31.91	28.97	9.79	5.90	5.49	4.49	3.30	1.84	1.10
	S 3 + 1 + 2	4	32.00	28.23	8.65	5.95	4.90	4.88	3.85	2.28	1.50
	N 2 + 2 + 2	12	32.42	29.31	10.07	5.76	5.59	4.54	3.35	1.94	1.17
	N 3 + 1 + 2	31	31.77	28.33	10.39	4.83	4.50	4.80	3.80	2.15	1.29
		126	31.67	28.59	9.85	5.85	5.20	4.55	3.42	1.93	1.16
6	S 2 + 3 + 1	1	32.00	31.00	9.40	8.00	5 70	3.20	2.10	2.60	1.00
	S 3 + 2 + 1	3	31.33	29 93	10.07	4.27	4.03	4.43	3.97	3.17	1.40
	N 3 + 2 + 1	103	31.82	30.41	9.78	4.57	4.64	4.67	4.01	2.75	1.41
	N 4 + 1 + 1	18	31.94	30 04	9.65	4.15	4.62	3.95	4.51	3.75	1.91
		124	31.82	30.35	9.72	4.50	4.63	4.55	4.06	2.89	1.47
7	N 3 + 3 + 0	4	31.25		10.33	4.85	4.35	4.78	3.60	2.43	0.93
	N 4 + 2 + 0	15	31.00		9.04	4.03	4.42	4.13	3 89	3.42	2.08
	N 5 + 1 + 0	1	31.00		9.90	2.70	4.70	3.90	3.00	4.60	2.20
		20	31.05		9.34	4.13	4.42	4.25	3.79	3.28	1.86
	Total	336	31.77		9.78	5.39	5.15	4.50	3.44	2.25	1.28

Year-class 1918.

In table 15 I have analysed the growth history of 255 herrings of this year class at an age of seven years and spawning at the west coast in the spring of 1925. The growth curves for the different spawning-groups separated according to the number of »spawning« rings are given in the upper part of fig. 7. One finds that the different spawning-groups represent fish with differing growth histories. The herrings of southern origin which earliest reach sexual maturity have had a better growth in their first years than the later maturing herring of northern origin.

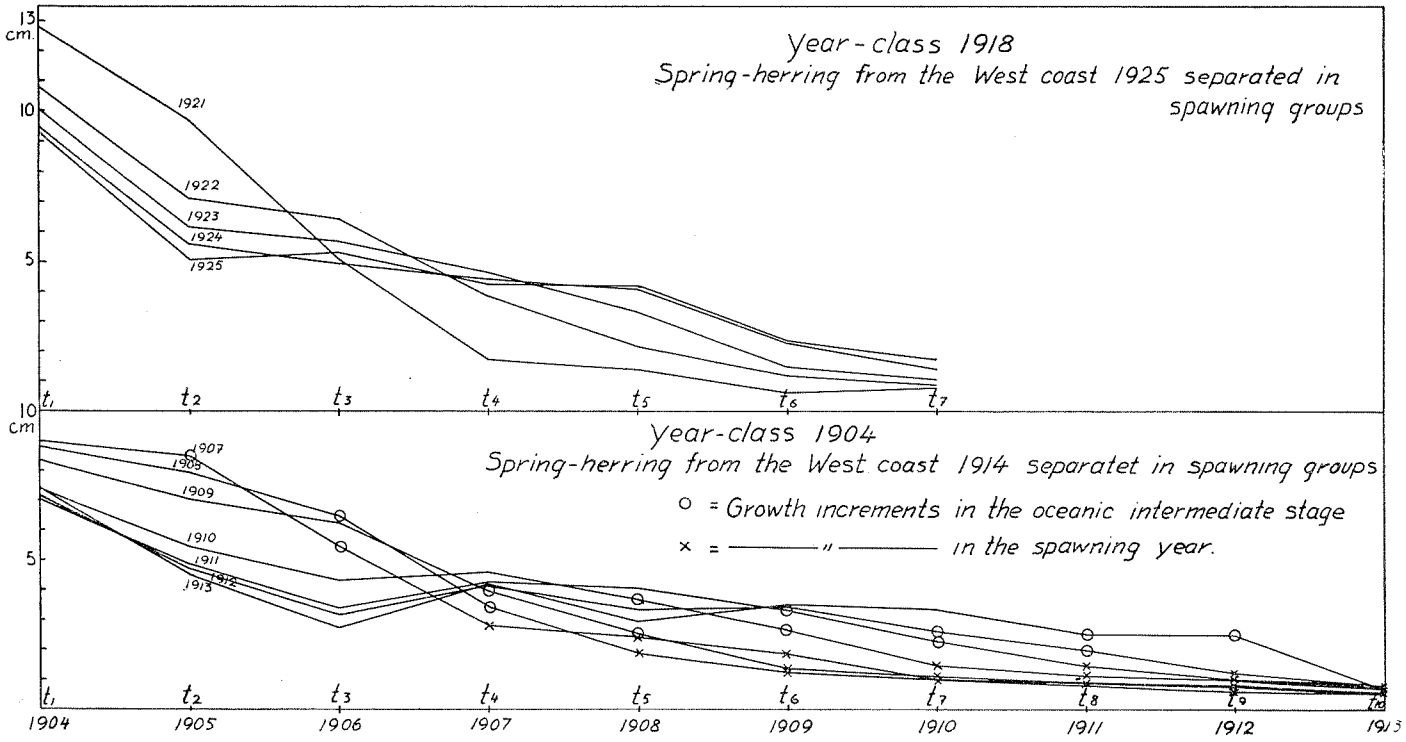
Year-class 1918
Spring-herring from the West coast 1925 separated in spawning groups
cm.
13
10
5
1921
1922
1923
1924
1925
t1 t2 t3 t4 t5 t6 t7
Year-class 1904
Spring-herring from the West coast 1914 separatet in spawning groups
o = Growth increments in the oceanic intermediate stage
× = ——— " ——— in the spawning year.
cm
10
5
1907
1908
1909
1910
1911
1912
1913
t1 t2 t3 t4 t5 t6 t7 t8 t9 t10
1904 1905 1906 1907 1908 1909 1910 1911 1912 1913

Fig. 7.

Table 15. Year-class 1918. Group of Spawners in the year 1925.

Age at 1st spawning	Scale type	Nr.	L	L. at 1st spawning	Growth increments						
					t 1	t 2	t 3	t 4	t 5	t 6	t 7
3	S 1 + 1 + 4	1	32.00	27.50	12.70	9.70	5.10	1.70	1.40	0.60	0.80
4	S 1 + 2 + 3	4	31.75	27.62	10.30	8.80	5.20	3.33	2.08	1.20	0.85
	S 2 + 1 + 3	11	32.55	28.62	11.76	7.60	5.83	3.43	2.05	1.08	0.80
	N 2 + 1 + 3	20	32.45	28.00	10.37	6.45	6.99	4.20	2.27	1.25	0.94
		35	32.40	28.15	10.80	7.08	6.42	3 86	2.18	1.19	0.88
5	S 2 + 2 + 2	30	32.57	30.40	10.65	7.05	6.00	4.08	2.62	1.19	0.97
	N 2 + 2 + 2	64	32.31	29.84	10.27	6.13	6 03	4 31	3.10	1 45	1.03
	N 3 + 1 + 2	85	32.21	29.50	9.73	5.78	5 26	5.02	3.70	1.59	1.12
		179	32.31	29.77	10 08	6.12	5.66	4.61	3.30	1.47	1.06
6	N 2 + 3 + 1	1	33.00	32.40	11.30	5.80	6 40	4.20	3.10	1.60	0.60
	N 3 + 2 + 1	23	32.17	30.84	9.35	5.69	4 93	4.62	3.99	2.27	1.33
	N 4 + 1 + 1	8	31 88	30.18	9.68	5 04	4.79	3.79	4.51	2,38	1.70
		32	32.13	30.73	9 49	5.53	4.94	4.40	4.09	2.28	1.40
7	N 4 + 2 + 0	8	32.00	—	9.33	5.05	5.28	4.23	4 20	2.24	1.69
Total		255	32.29		10.09	6.16	5.06	4.46	3.27	1.55	1.10

Year-class 1904.

This yearclass which have played a very great part in the stock of Norwegian herring through many years, has previously often been analysed by Norwegian investigators in connection with growth and age problems. I have in table 16 given an analysis of the 10 years old herring of this year class in the spawning shoals at the west coast in the year 1914. According to the scale types the fish are composed of seven spawning-groups which immigrated as recruit spawners in the years 1907—1913. In 1914 all the individuals of the year class have been transfered from the stock of immature fish to the spawning shoals. In the lower section of fig. 7 the growth history of the different spawning-groups are demonstrated by diagrams. One finds here conditions corresponding to those in the year classes previously analysed. The fish which in the first years of life have had the best growth assemble in spawning-groups at an early age, and the fish with slower growth at a later age.

Table 16. Year-clas 1904. Group of spawners in the year 1914.

Age at 1st spawning	Scale type	Nr.	L	L at 1st spawning	Growth increments									
					t 1	t 2	t 3	t 4	t 5	t 6	t 7	t 8	t 9	t 10
3	S 1 + 1 + 7	4	32.75	22.80	8.98	8.43	5.40	2.78	2.38	1.85	0.98	0.83	0.58	0.58
4	S 1 + 2 + 6	7	33.57	27.24	9.47	8.89	5.87	3 01	1.86	1.52	0.91	0.80	0.74	0.50
	S 2 + 1 + 6	57	32.77	26.85	8.81	8.09	6.54	3.41	1.72	1.21	0.97	0.76	0.78	0.48
	N 2 + 1 + 6	15	31 87	25.48	8.49	6.77	6.57	3.65	1.72	1.20	1.13	0.91	0 85	0.57
		79	32.67	26 63	8.81	7.91	6.49	3.42	1.74	1.23	0.99	0.79	0.79	0.50
5	S 2 + 2 + 5	120	32.45	28·27	8.37	7.46	6.55	3.56	2.34	1.22	0.96	0.74	0.76	0.49
	N 2 + 2 + 5	40	32.50	27.64	8.41	6.46	6.08	4.24	2.45	1.43	1.13	0.90	0.86	0.54
	N 3 + 1 + 5	32	32.38	27.24	8.13	6.06	5.17	4.94	2.95	1.58	1.17	1.01	0.77	0.62
		192	32.45	27.97	8.34	7.02	6.22	3.93	2.47	1.33	1.03	0.82	0.78	0.52
6	S 2 + 3 + 4	3	32.67	30.13	8.67	7.57	6.73	3.36	2.03	1.76	0.80	0.60	0.63	0.50
	S 3 + 2 + 4	1	30.00	26.80	6.00	5.30	6.70	4 80	2 20	1.80	0.90	1.00	0.90	0.40
	N 2 + 3 + 4	3	33.00	29.87	7.30	6.97	7.93	3.83	2.50	1.33	1.00	0.80	0.93	0.40
	N 3 + 2 + 4	72	32.29	28.20	7.51	5.42	4 29	4.87	3.65	2.46	1.39	1.07	0.97	0.66
	N 4 + 1 + 4	35	31.91	27.26	7.04	5.14	3.64	4.16	4.08	3.19	1.69	1.28	1.05	0.64
		114	32.18	27.99	7 38	5.43	4.28	4.58	3.69	2 63	1.45	1.11	0.98	0 64
7	N 3 + 3 + 3	3	32.33	29.37	7.47	4.57	4.37	4.57	4.10	2.63	1.67	1.20	1.10	0.67
	N 4 + 2 + 3	63	32.46	29.30	7.04	4.86	3.32	4.22	4.21	3.40	2.26	1.41	1.06	0.69
	N 5 + 1 + 3	9	32.00	28.56	7.02	5.12	3.34	4.47	3.20	3.04	2.36	1.64	1.18	0.62
		75	32.40	29.21	7.06	4.88	3.36	4.27	4.08	3.33	2.25	1.43	1.08	0.68
8	N 5 + 2 + 2	12	32.42	30.56	7.06	4.94	3.19	4.17	3.37	3.47	2.49	1.88	1.15	0.71
	N 6 + 1 + 2	2	32.00	29.75	7.85	3.85	2.80	3.75	3.20	2.65	3.15	2.50	1.40	0.85
		14	32.36	30.44	7 17	4.79	3.14	4.11	3.34	3.35	2.59	1.96	1.19	0.73
9	N 6 + 2 + 1	1	34.00	33.40	7.40	4.50	2.70	4.20	2.90	3.40	3.30	2.50	2.50	0.60
Total		479	32.42		7.96	6.39	5.25	4.05	2.92	2.00	1.37	1.02	0.89	0.58

The growth types A, B, C, introduced by Ottestad.

Ottestad (1934) has by studying the growth of the Norwegian herring separated three different growth types which he has designated as respectively A, B, and C types. The A-type is characterized by decreasing growth increments ($t_1 > t_2 > t_3$ etc.) with increasing age, the B-type by a greater growth increment in the third year than in the second ($t_2 < t_3$), and the C-type by a greater growth increment in the

fourth year than in the third ($t_3 < t_4$). These three growth types are demonstrated in the upper section of fig. 8 a (page 66).

The growth type C represents the »marked« herring found by Hjort and Lea (1911) among the year class 1904 mentioned in the introduction of this chapter.

Ottestad finds that all three growth types are represented among the fat herring in northern Norway. The A-type has, however, greater growth values in the first and second year of life (t_1 and t_2) than the other two types*) and this indicates according to Ottestad that the A-type is formed in an area of the coastal waters having more favourable growth conditions than those of the other types. The »marking« phenomenon of the B- and C-types must be induced by a migration from a less favourable area which will cause an increase of the growth increment in that certain season.

The three growth types are also represented among the spawning herring at the west coast. Ottestad finds here the same growth difference in the first years of life between the A-type and the two other types as that found in the fat herring, and he concludeds therefore that the herring must have spent their first years in different areas.

Ottestad finds, however, that the A-type of the spawning herring at the west coast has a greater growth rate than the corresponding growth type of the northern fat herring, and from this fact he concludes that the A-type of the fat herring in northern coastal waters is not identical with the A-type of the southern spring herring. The same is demonstrated as regards the C-type. Ottestad writes in this connection: »From these experiences the question arises whether the northern fat-herring join the southern large and spring-herring shoals at all«. and he means that the proof of such migrations given by Hjort and Lea founded on the »marked« herring of the year class 1904 does not hold good.

Ottestad demonstrates further that the growth increments in the first years (t_1 t_2) of the A-type of the northern fat herring show the same values as the corresponding increments of the C-type of the southern spring herring and from this observation he draws the following conclusion: »This agreement of growth cannot, however, be considered as a proof — without other statesments — that the C-type of the year-class 1918 as large and spring herring is identical with the A-type of the same year-class as fat-herring in the autumn of 1920. It may be that two different areas of the Norwegian coastal waters produce the same growth-rate, i. e., present the same growth conditions, But, at any rate,

*) That this is not always the case is demonstrated in fig. 8 a. Ottestad has, however, treating the same material in his fig. 10 excluded the B type.

Table 17. Growth types A. B. C.

Age at 1st Spawning	Scale type	Year class 1904 Spr. herr. 1914			Year class 1918 Spr. herr. 1925			Year class 1923 Spr. herr. 1932			Year class 1925 Spr. herr. 1932		
		A	B	C	A	B	C	A	B	C	A	B	C
3	S 1 + 1	4	—	—	1	—	—	—	—	—	1	—	—
4	S 1 + 2	7	—	—	4	—	—	7	—	—	5	—	—
	S 2 + 1	47	10	—	8	2	1	75	18	8	36	17	2
	N 2 + 1	8	7	—	5	15	—	6	3	—	1	2	2
		62	17	—	17	17	1	88	21	8	42	19	4
5	S 1 + 3	—	—	—	—	—	—	—	—	—	—	—	—
	S 2 + 2	90	26	4	26	3	1	96	12	21	27	31	21
	S 3 + 1	—	—	—	—	—	—	2	1	3	2	—	2
	N 2 + 2	21	16	3	34	28	2	3	8	1	5	4	3
	N 3 + 1	16	6	10	27	26	32	7	9	28	3	13	15
		127	48	17	87	57	35	108	30	53	37	48	41
6	S 2 + 3	2	1	—	—	—	—	—	—	2	1	—	—
	S 3 + 2	—	1	—	—	—	—	2	—	8	—	2	1
	N 2 + 3	—	3	—	—	1	—	—	—	—	—	—	—
	N 3 + 2	13	12	47	4	6	13	8	7	41	13	49	41
	N 4 + 1	1	4	30	—	3	5	10	3	37	—	12	5
		16	21	77	4	10	18	20	10	88	14	63	47
7	N 3 + 3	1	1	1	—	—	—	—	—	2	1	1	2
	N 4 + 2	—	4	59	1	5	2	5	2	29	1	9	5
	N 5 + 1	1	—	8	—	—	—	—	—	1	—	1	—
		2	5	68	—	—	—	5	2	32	2	11	7
8	N 3 + 4	—	—	—	—	—	—	—	—	—	—	—	—
	N 4 + 3	—	—	—	—	—	—	—	—	—	—	—	—
	N 5 + 2	1	—	11	—	—	—	—	—	3	—	—	—
	N 6 + 1	—	—	2	—	—	—	—	—	—	—	—	—
		1	—	13	—	—	—	—	—	3	—	—	—
9	N 6 + 2	—	—	1	—	—	—	—	—	—	—	—	—
	S	150	38	4	39	5	2	182	31	42	72	50	26
	N	62	53	172	71	84	54	39	32	142	24	91	73
Total		212	91	176	110	89	56	221	63	184	96	141	99

this agreement shows that if any migrations takes place from the fat herring shoals in the northern waters to the large and spring herring shoals in the southern waters, it is the A-type of the fat herring which undertakes this migration.«

I mean, however, that one is not allowed to draw the conclusions made by O t t e s t a d on the basis of his analysis of the three growth types. O t t e s t a d has in an earlier section of his paper demonstrated that the spring herring in southern Norway grows much faster than the fat herring in northern Norway and quite logically he writes: »This shows that the fat herring in the northern waters can at a later age form only a portion of the southern spring herring shoals, if they join these shoals at all. The other portion of the spring herring shoals must be recruited from other waters.« O t t e s t a d has thus taken notice of the possibility that the spring herring stock may be composed of two components of different origin and with different growth history. In discussing the growth types A, B, C, in the spring herring O t t e s t a d assumes, however, as a matter of fact that these growth types are homogenous. He does not discuss the possibility that these growth types in the spring herring also may be composed of components of different origin and with different growth rates.

The A-type of the southern spring herring may very well represent a mixture of fast growing fish from southern waters and slow growing fish from northern waters. The average growth values of the spring herring will then be greater than those of the northern fat herring.

That this is really the case will be shown in the following. In table 17 I have given the composition as regards the growth types A, B, C of the different components of older spring herring from the west coast separated according to the scale types. The material includes the year-classes 1904, 1918, 1923 and 1925.

Examining for instance the year class 1904 in spawning shoals from the year 1914 one finds that the fish of southern origin, which spawned for the first time at an age of three years, are represented by A-types. Of the herring appearing at an age of four years the fish of southern origin consist mainly of A-types with a small admixture of B-types. In the next spawning-group 5 all three growth types are represented among the herring of southern as well as northern origin. The later developed herring of northern origin which immigrated to the spawning shoals at an age of 6 to 9 years consist mainly of C-types with a small admixture of A and B-types. In the lowest section of the table one finds that the A-type of this year class in the spring herring is composed of fish of southern as well as northern origin. The same is the case for the B-type. The C-type, however, consists mainly of herring immigrated

from northern waters. In this particular case the C-type can thus be used in order to study the immigration of the northern fat herring to the spawning shoals as done by Hjort and Lea (1911). Concerning the year-classes 1923 and 1925, however, the C-type represents herring of northern as well as southern origin.

Table 18 a. Year-class 1904. Group of spawners in the year 1914. Growth type A.

Age at 1st spawning	Scale type	Nr.	L.	L at 1st spawning	Growth increments.									
					t 1	t 2	t 3	t 4	t 5	t 6	t 7	t 8	t 9	t 10
3	S 1+1+7	4	32.75	22.80	8.98	8.43	5.40	2.78	2.38	1.85	0.98	0.83	0.58	0.58
4	S 1+2+6	7	33.57	27.24	9.47	8.89	5.87	3.01	1.86	1.52	0.91	0.83	0.74	0.50
	S 2+1+6	47	32.74	27.03	9.01	8.39	6.35	3.28	1.63	1.15	0.95	0.75	0.76	0.48
	N 2+1+6	8	32.25	25.69	8.59	7.39	6.19	3.53	1.80	1.21	1.26	0.90	0.83	0.56
		62	32.77	26.88	9.00	8.32	6.27	3.28	1.68	1.20	0.99	0.77	0.77	0.49
5	S 2+2+5	90	32.50	28.41	8.49	7.79	6.41	3.46	2.27	1.18	0.95	0.72	0.76	0.48
	N 2+2+5	21	32.43	27.61	8.60	6.92	5.69	3.90	2.51	1.43	1.07	0.90	0.90	0.52
	N 3+1+5	16	32.06	27.49	8.32	6.56	5.39	4.51	2.72	1.37	1.08	0.93	0.65	0.54
		127	32.43	28.16	8.48	7.49	6.16	3.67	2.36	1.24	0.99	0.78	0.77	0.49
6	S 2+3+4	2	32.00	29.80	7.80	8.15	6.35	3.55	2.05	1.90	0.65	0.50	0.50	0.55
	S 3+2+4	13	32.38	28.92	7.85	6.42	5.31	4.59	2.85	1.90	1.03	0.85	0.93	0.65
	N 4+1+4	1	32.00	29.00	7.5	7.0	5.5	3.9	2.9	2.2	1.3	0.7	0.7	0.3
		16	32.31	29.04	7.83	6.68	5.45	4.42	2.75	1.92	1.00	0.80	0.86	0.61
7	N 3+3+3	1	32.0	30.1	7.2	6.1	5.9	4.2	2.8	2.2	1.7	0.6	0.9	0.4
	N 5+1+3	1	32.0	28.3	7.0	5.3	3.9	3.6	3.2	3.0	2.3	1.3	1.4	1.0
		2	32.0	29.2	7.1	5.7	4.9	3.9	3.0	2.6	2.0	0.95	1.15	0.7
8	N 5+2+2	1	33.0	30.7	8.0	5.1	3.9	3.7	3.6	2.5	2.0	1.9	1.3	1.0

One finds thus that all three growth types of the spawning herring in southern Norway are composed of fish of different origin and with differing life history. The A-type is, however, as a rule mainly composed of fish of southern origin and the C-type of fish of northern origin. This is to be expected when one accepts that the »marking« phenomenon is caused by migration from less favourable conditions to more favourable ones. The young herring from northern Norway with small growth in the first years of life will, when migrating to more southern waters, have a greater chance to obtain an increase in growth great enough to induce a »marking« phenomenon than will the young herring which emigrate from southern coastal waters to the ocean.

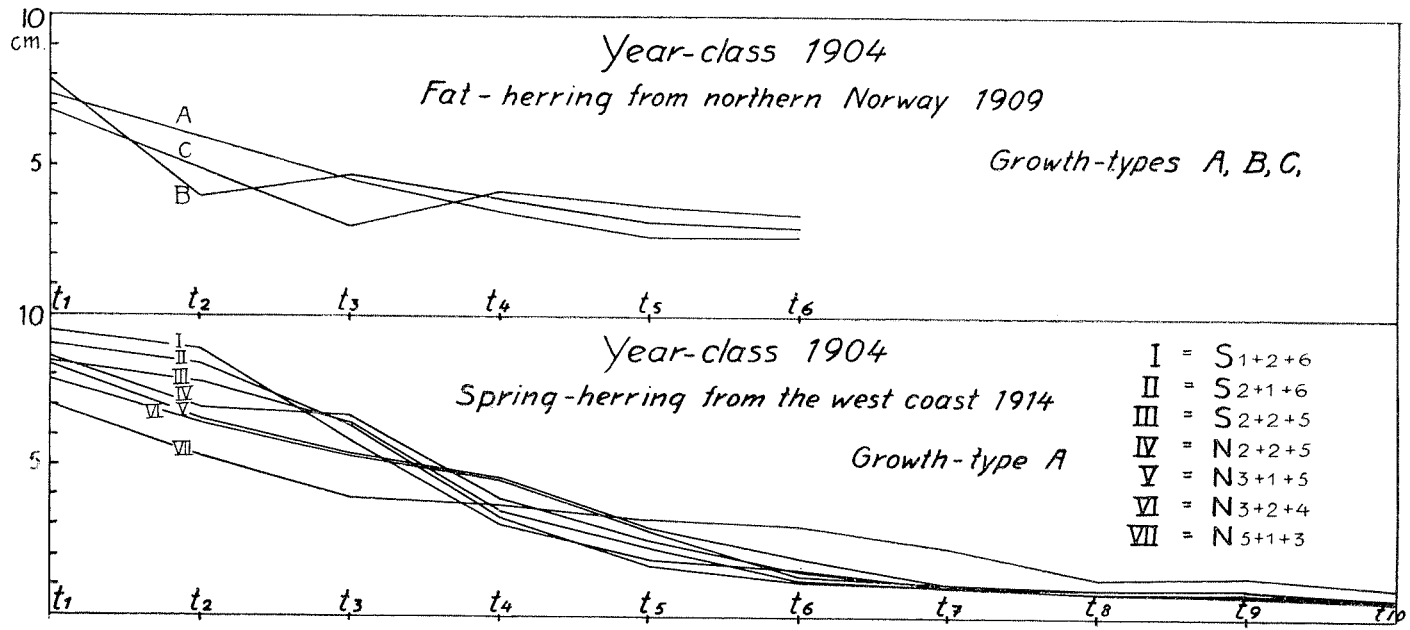
10
cm.
5
Year-class 1904
Fat-herring from northern Norway 1909
Growth-types A, B, C,
A
C
B
t_1 t_2 t_3 t_4 t_5 t_6
10
5
Year-class 1904
Spring-herring from the west coast 1914
Growth-type A
I = S 1+2+6
II = S 2+1+6
III = S 2+2+5
IV = N 2+2+5
V = N 3+1+5
VI = N 3+2+4
VII = N 5+1+3
t_1 t_2 t_3 t_4 t_5 t_6 t_7 t_8 t_9 t_{10}

Fig. 8 a.

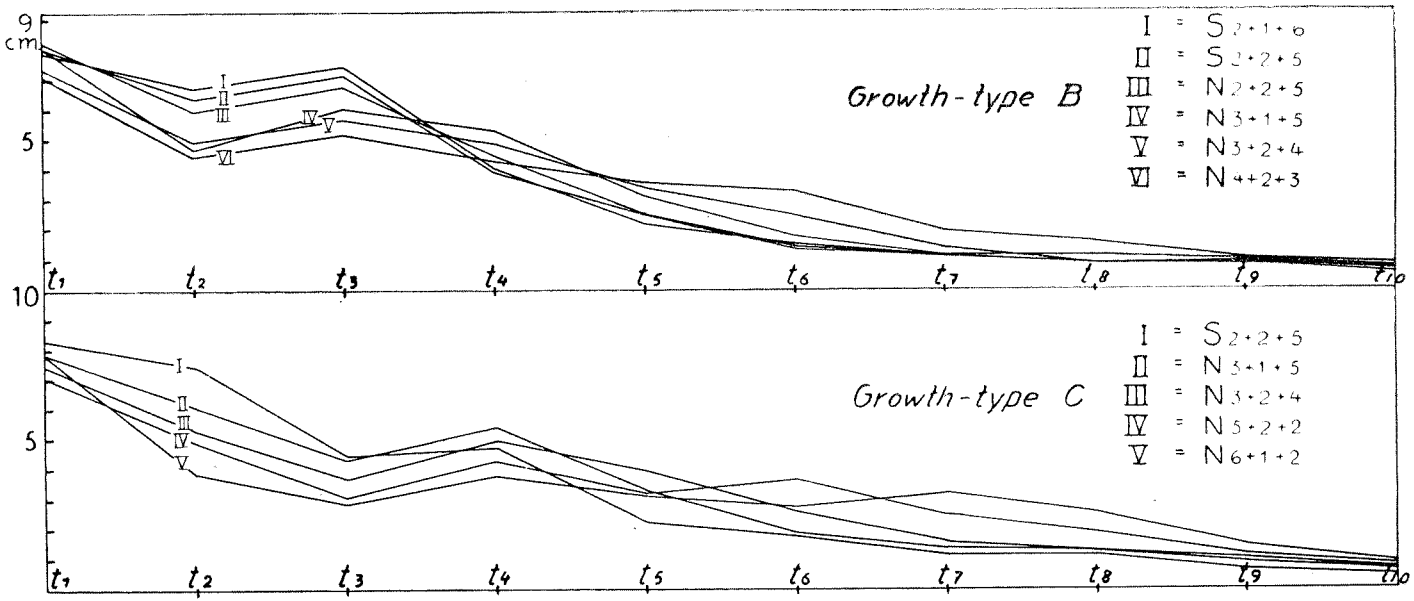
9
cm
5
10
5
Growth-type B
I = S 2+1+6
II = S 2+2+5
III = N 2+2+5
IV = N 3+1+5
V = N 3+2+4
VI = N 4+2+3
Growth-type C
I = S 2+2+5
II = N 3+1+5
III = N 3+2+4
IV = N 5+2+2
V = N 6+1+2
t1 t2 t3 t4 t5 t6 t7 t8 t9 t10

Fig. 8 b.

Table 18 b. Year-class 1904. Group of spawners in the year 1914. Growth type B.

Age at 1st spawning	Scale type	Nr.	L.	L. at 1st spawning	Growth increments									
					t 1	t 2	t 3	t 4	t 5	t 6	t 7	t 8	t 9	t 10
4	S 2+1+6	10	32.90	26.03	7.87	6.70	7.44	4.02	2.16	1.50	1.04	0.83	0.86	0.48
	N 2+1+6	7	31.43	25.24	8.39	6.07	7.00	3.79	1.63	1.19	0.99	0.93	0.87	0.59
		17	32.29	25.71	8.08	6.44	7.26	3.92	1.94	1.37	1.02	0.87	0 86	0 52
5	S 2+2+5	26	32.27	27.82	7.96	6 33	7.15	3.90	2.47	1.34	1.02	0.77	0.79	0 54
	N 2+2+5	16	32.50	27.83	8.24	5.93	6.79	4.42	2.44	1.44	1.03	0.82	0 82	0.57
	N 3+1+5	6	32.83	27.12	8.02	4.68	6.03	5.28	3.10	1.75	1.13	1.10	0.90	0.83
		48	32.42	27.73	8.06	5 99	6.89	4.25	2.54	1.42	1.04	0.83	0.81	0.59
6	S 2+3+4	1	34.00	30.8	10.4	6.4	7.5	3.0	2.0	1.5	1.1	0.8	0.9	0.4
	S 3+2+4	1	30.0	26.8	6.0	5.3	6.7	4.8	2.2	1.8	0.9	1.0	0.9	0.4
	N 2+3+4	3	33.0	29.87	7.30	6.97	7.93	3.83	2.50	1.33	1.00	0.80	0.93	0.40
	N 3+2+4	12	32.25	28.60	7.36	4.93	5.67	4.84	3.37	2.44	1.33	0.79	0.93	0.61
	N 4+1+4	4	31.75	27.45	7 30	4.95	5.58	3.50	3 68	2.45	1.45	1.23	0.95	0.68
		21	32.24	28.58	7.42	5.31	6.11	4.36	3.18	2.05	1.27	0.89	0.93	0.57
7	N 3+3+3	1	32.0	28.6	8.3	3.7	4.0	4.8	4.2	2.4	1.2	1.0	1.5	0.9
	N 4+2+3	4	32.75	29.53	7.08	4.43	5.13	4.25	3.53	3.23	1.90	1.53	1.00	0.70
		5	32.60	28.34	7.32	4.28	4.90	4.36	3 66	3 06	1.76	1.42	1.1	0.74

By analysing the scale types we have now a mean to separate the various components of the growth types A, B, C according to the differing life history of the fish. In order to study the growth history of each of these components I have made a further analysis of the material of the year-class 1904 as spring herring in the year 1914 according to the growth types A, B, C. The results are given in table 18, and figure 8 a, b.

In the upper part of fig. 8 a one finds the growth curves for the A, B, and C- types of the year-class 1904 as fat herring in northern Norway 1909 (locality: Leinæs, Hammerø). This material is the same as given by O t t e s t a d in his table 14 (sample no. 5).

In the lower section of fig. 8 a and in fig 8 b I have given the growth curves for the different components of the A, B and C- types of the same year class in the spring herring at the west coast 1914. The diagrams demonstrate that these growth types are not homogenous but that they represent a mixture of many biological groups each with a different growth history.

One finds that the fish of southern origin which reach their first maturity at an early age have had a better growth in their first years of life

Table 18 c. Year-class 1904. Group of spawners in the year 1914. Growth type C.

Age at 1st spawning	Scale type	Nr.	L	L. at 1st spawning	Growth increments									
					t 1	t 2	t 3	t 4	t 5	t 6	t 7	t 8	t 9	t 10
5	S 2+2+5	1	32.0	27.0	8.3	7.4	4.4	4.7	2.2	1.7	1.1	1.2	0.6	0.4
	N 2+2+5	3	33.0	26.80	8.03	6.03	5.00	5.67	2.07	1.43	2.10	1.33	0.77	0.57
	N 3+1+5	10	32.60	26.91	7.88	6.07	4.30	5.42	3.24	1 81	1.33	1.07	0.87	0.61
		14	32.64	26 89	7.94	6.16	4.46	4.62	2.91	1.72	1.48	1.14	0.83	0.59
6	N 3+2+4	46	32.26	27.90	7.46	5.28	3.66	4.99	3.93	2.58	1.52	1.19	0.98	0.66
	N 4+1+4	25	31.92	27.13	7.00	5.11	3.16	4.40	4.16	3.31	1.77	1.34	1.03	0.65
		71	32.14	27.63	7.30	5.22	3.48	4.78	4.01	2.85	1.61	1.24	1.00	0.66
7	N 3+3+3	1	33.0	29.4	6.9	3.9	3.2	4 7	5.3	3.3	2.1	2.0	0.9	0.7
	N 4+2+3	55	32.42	29.23	7.05	4.87	3.14	4.27	4.23	3.41	2.29	1.43	1.04	0.67
	N 5+1+3	8	32.0	28.59	7.03	5.10	3.28	4.58	3.20	3.05	2.36	1.69	1.15	0.58
		64	32.38	29 19	7.04	4.89	3.16	4.32	4.12	3.36	2.30	1.47	1.05	0.66
8	N 5+2+2	10	32.40	30.54	7.05	4.91	3.06	4.30	3.25	3.64	2.46	1.87	1.15	0.71
		2	32.0	29.75	7.85	3 85	2 80	3.75	3.20	2.65	3.15	2.50	1.40	0.85
		12	32.33	30.41	7.18	4.73	3.02	4.21	3.24	3.48	2 58	1.98	1.38	0.85
9	N 6+2+1	1	34.0	33.4	7.4	4.5	2.7	4.2	2.9	3.4	3.3	2.5	2.5	0.60

than the later mature herring of northern origin. As regards the A-type the spring herring of the type N_{3+2+4} have had a growth rather similar to the growth of the fat herring of the A- type in northern Norway 1909. And the fish of the type N_{5+1+3} show smaller growth values than the northern fat herring.

Among the groups of the B- type of the southern spring herring the fish of the scale type N_{4+2+3} show a growth curve corresponding to the growth curve for the B- type of the northern fat herring.

The C- type of the spring herring is composed of groups of northern origin which immigrated rather late to the spawning shoals, and the growth curve for the fish of the type N_{5+2+2} corresponds exactly to that of the C- type found in northern fat herring 1909.

I have thus demonstrated that all the three growth types A, B and C found in a certain year among the northern fat herring are later reencountered among the spring herring at the west coast, but here mixed with groups of southern origin. The view of O t t e s t a d that the B and C- types of the northern fat herring do not immigrate to the southern spawning shoals is thus not correct.

Table 19. Year-class 1904. Fat herring in Northern Norway (Leinaes) 1909.

Growth type	Nr.	L.	Growth increments					
			t 1	t 2	t 3	t 4	t 5	t 6
A	45	26.58	7.32	5.95	4.52	3.44	2.67	2.68
B	24	26.50	7 87	3.98	4.68	3.91	3 13	2.94
C	181	25.69	6.80	4.83	2.97	4.12	3.63	3.34

An analysis of the spring herring according to the growth types A, B, C cannot give any information in regard to the origin of the herring. These growth types represent mathematical averages for groups of herring with differing origin and life history.

The phenomenon of apparent change in growth rate.

This phenomenon is noted by Rosa M. Lee (1912) in treating the methods of growth determination. Lea (1913) has then treated the phenomenon which does not only exist in the case of the herring but which also can be traced in the case of other species of fish. Lea demonstrates the phenomenon as it appears in the material of the Norwegian herring stock.

Average increments of year-class 1904 of mature Norwegian herrings in different years. (from Lea 1913.)

Year of capture	Age	No. of samples	No. of individuals	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9
1907	3	1	4	11.0	9.5	4.5	—	—	—	—	—	—
1908	4	1	11	9.9	9.8	6.1	3.2	—	—	—	—	—
1909	5	1	33	8.8	7.8	6.7	3.5	2.3	—	—	—	—
1910	6	1	382	7.7	6.6	5.3	3.9	2.6	2.2	—	—	—
1911	7	3	1082	8.1	6.8	5.4	4.0	3.0	1.9	1.3	—	—
1912	8	4	802	7.9	6.5	5.2	4.2	2.9	2.0	1.2	1.0	—
1913	9	2	371	7.8	6.3	5.3	4.0	2.9	1.9	1.2	1.0	0.8

I have in the present table given the calculated values of the growth increments of mature herring of the year class 1904 in the years 1907—1913 according to Lea (1913). It is to be expected that

the calculated value of the increment in a specific year of life is constant and independent of the age of the herring in the year when they were caught. This is, however, not the case. As L e a demonstrates the values of t_1 and t_2 show a marked tendency to decrease with increasing age. But for t_3 t_4 and t_5 the decrease is preceded by an increase, while the following dimensions t_6—t_8 seem to remain rather constant. The values for the year 1910 form an exception being in most cases comparatively low and this is according to L e a due to the circumstance that the sample for this year is not quite representative.

By discussing this phenomenon L e a comes to the conclusion that the differences are not due to methodical errors as supposed by R o s a L e e. On the contrary they represent important features in the biology of the fish. According to L e a the phenomena actually taking place are:

»1) When a certain year class is approaching the period of sexual maturation, the larger individuals will develop their sexual products earlier than the smaller«.

»2) Those individuals which have reached maturity will congregate with the older spawning herrings«.

»3) Among the herrings remaining in an immature state some, and also in this case the larger ones, will be ready for spawning the next year and then congregate with the spawning herrings and so on until all herrings have become mature«.

»4) The development of the sexual products has the effect of depressing the length increment simoultanously taking place«.

The phenomenon described by L e a in the points 1—3 is just the same one clearly demonstrated by me in a previous section of this chapter. The mature herring of a year class do not represent a homogenous material, but are composed of different spawning-groups each with a different growth history and which immigrate to the shoals of older spawners in different years.

As regards the year class 1904 this is demonstrated in figure 7 (page 59). In 1914 when all the fish of this year class had become mature, the spawning herring were composed of seven spawning groups which immigrated successively in the years 1907—1913. Comparing the growth history of the various spawning groups one finds that the group reaching maturity in 1907 has greater growth values t_1 and t_2 than the one maturing in 1908, and the latter greater than that from 1909 and so on. It is apparent that the immigration of these groups to the spawning shoals will cause a gradual decrease of the average values of t_1 and t_2 in the years 1907—1913 as demonstrated by L e a in the table, page 70.

Considering now the growth value t_3 in the figure 7 one finds

that the spawning group immigrating in the year 1907 had a smaller value for t_3 than the groups immigrating in the years 1908 and 1909. The congregation of the new spawning groups in 1908 and 1909 with the herring which had spawned in 1907 will thus cause an increase of the average value of t_3. The spawning groups immigrating in the years 1910—1913 had, however, essentially lower values for t_3 which must cause a decrease in the average value for the spawning herring from 1910. This is exactly what takes place in the table from Lea.

In the same manner one can deduce from the growth curves that the growth value of t_4 must increase in the year 1908—1910 and decrease in 1911. This is not quite in accordance with the values from Lea's table, but as mentioned by Lea his material from the year 1910 is not representative and shows too low values. For the growth dimension t_5 one must expect increasing values in the years 1909—1911 and a decrease in 1912, a fact which is completely realized in the table. The inconstance of the growth values of the spring herring can thus be completely explained by the difference in growth in the different spawning-groups. Not till the year 1914 when all the spawning-groups with different growth history have joined the mature herrings one can expect constant average values for the growth dimensions of the year class 1904.

As previously mentioned Ottestad (1934) has shown that the stock of Norwegian spring herring does not constitute a homogenous body, but is composed of three different growth types (A, B, C- types).

Ottestad concludes from this that if Norwegian herring data are to be used for the purpose of verifying the growth hypothesis, a separation of the material into growth types must be made, and the study must be limited to one of these growth types only. Ottestad deals therefore in the further discussion only with the A- type, and by analysing the growth values of this growth type from the year class 1904 occurring as spring herring in the years 1909—1916, Ottestad finds that there is no increasing or decreasing tendency of the means with increasing age. The calculations give about the same mean values of the yearly increments in length at different ages. Ottestad means that his analysis indicates that Lea's hypothesis of a proportional relation between the growth of the fish and that of its scale, which form the basis for the growth calculations, is in accordance with the real facts.

As regards the phenomenon observed by Rosa Lee, Ottestad mentions only in a foot note that Lee »does not take heterogeneity of the material into consideration«. Ottestad does not cite the work by Lea (1913) where Lea just explains the phenomenon of apparent change in growth rate as due to the composition of the mature herring from groups with different growth rates. Lea

has here demonstrated that the immigration of the »marked« fish of the year class 1904 from northern Norway into the spawning shoals at the west coast causes a decrease in the mean values for t_1 and t_2 of the mature herring. These »marked« herring correspond to Ottestad's growth type C and by selecting the mature herring of the A-type Ottestad eliminates the depressing effect on the mean values due to the immigration of the slow growing northern herring.

Recently Michael Graham (1935) has in a short note drawn attention to the fact that Ottestad's own selected material appears also to show the phenomenon described by Rosa Lee, although to a small degree. Graham says that »it seems rash to regard it as nonexistent or due to »heterogeneity of material««.

As I have clearly demonstrated in fig. 8 (page 66), however, even the A-type of the Norwegian spring herring does not represent a homogenous material but being composed of several groups with different growth history and origin and having reached maturity at different age. As seen from table 18 a (page 65) the A-type of the year class 1904 can be separated into 6 spawning groups immigrating to the stock of mature herring in the years 1907—1912. The fish immigrating in the years 1907 and 1908 represent the fast growing fish of southern origin. The new spawning-group in 1909 represents less fast growing fish of southern origin with a rather large admixture of slow growing fish from northern Norway. The majority of the fish of the A- type had in 1909 reached maturity but there is, however, in the years 1910—12 a slight immigration of later developed fish of northern origin, and these fish had according to table 18 a smaller growth than those mature in 1909.

Ottestad has in his analysis of the A- type of the year class 1904 examined spring herring from the years 1909—1916. Through the new immigration of the slow growing fish in the years 1910—1912 one must expect a decrease in the mean values of the first year's growth with increasing age of the spring herring. As the spawning-groups immigrating subsequent to the year 1909 were of small importance the phenomenon appears, however, only in a small degree. If Ottestad had examined the A- type also from the years 1907 and 1908 he would have found a rather considerable decrease in the growth values from the period 1907—1909. However, beginning with the year 1909 when the main part of the various components of the A- type already had congregated with the mature herring Ottestad happened to find relatively constant growth values. It is thus apparent that the selection of one of Ottestad's growth types A, B, C, fails to eliminate the phenomenon of apparent change in growth rate because these growth

types do not represent a homogenous material, and the attempt to verify the growth hypothesis made by O t t e s t a d has therefore no value.

My analysis of the growth of the herring founded on the different life history of the fish according to the appearance of the winter rings has, however, completely confirmed L e a's explanation of the change in growth rate with increasing age.

The effect of the sexual development on the growth and the phenomenon of compensatory growth.

L e a (1913) has shown that the individuals which have developed their sexual products have simultanously had a smaller growth increment than those of the same year class which have remained undeveloped, and he concludes that the development of sexual products has the effect of retarding the length increment simultanously developing.

It is apparent that the method of determining the age at first maturity by means of the number of spawning rings allows a thorough analysis of the changes in growth which may take place in connection with the maturing.

I will then again return to figur 7 (page 59) in order to study the effect of the sexual development on growth on the material of the 10 years old spawners of the year-class 1904. The material is separated according to the age at first spawning in seven groups which spawned for the first time in the years 1907—1913.

The curves show the yearly length increments (t_1 t_2 etc.) of the different spawning-groups. The increments in the years when the fish have spawned are designated by an x. As I have mentioned in the previous chapter the development of the sexual products begins already in the oceanic intermediate stage 1½ year before the fish appears on the spawning grounds at the coast in the spring. The length increment in the two growth periods immediately preceding the year of first spawning is designated by a circle.

In the first of these two growth periods the fish enter the oceanic intermediate stage and begin the sexual development. The main process takes place, however, in the second growth period of the intermediate stage, and at the end of this period all fish are mature and ready to spawn in the immediately following spring.

Studying the growth in the two first years of life (t_1, t_2) one finds that the fish which have spawned for the first time in a particular year had larger increments than those of the fish spawning in the immediately following year. All the fish were in the second year (1905) immature and only the group spawning in 1907 had by then entered the oceanic intermediate stage.

In the third year of life (1906) the group spawning in 1907 had a smaller length increment (t_3) than that of the groups spawning in 1908 and 1909. Both the 1907 and 1908 groups are now in the oceanic intermediate stage and live under the same conditions, but the sexually more developed fish of the 1907 group which are ready to spawn in the next spring had a smaller increment than that of the fish of the other group which just have begun the development of sexual products. The difference in growth thus cannot be explained by different external growth conditions but must be due to the effect of varying sexual development.

The growth values in the fourth year of life (t_4) in 1907 show that the fish which now had spawned for the first time (1907 group) had a smaller increment than that of the mature fish in the second period of the oceanic intermediate stage (1908 group) and the latter group a smaller increment than that of the sexually less developed fish which in this year entered the oceanic intermediate stage (1909 group). The immature herring of the groups spawning for the first time in the years 1910—1913 which are almost exclusively of northern origin had in this year got an increase in growth probably caused by the circumstance that the majority of the fish had migrated to areas with more favourable growth conditions. In the year 1908, however, the 1910 group which now entered the oceanic intermediate stage got a smaller increment (t_5) than that of the groups of still immature herring. In the year 1909 one finds that the groups which have spawned previously had smaller growth increments (t_6) then those of the fish in the oceanic intermediate stage and the latter again a smaller growth than that of the still immature herring, and the same conditions will be found in the following years. In 1913 when all the fish had reached maturity the growth increment (t_{10}) is about the same in all spawning-groups.

By analysing the growth history of the different spawning-groups of older spring herring I have thus demonstrated that the inset of sexual development has a retarding effect on the growth of the fish. This phenomenon can be observed already in the oceanic intermediate stage before the fish have appeared on the spawning grounds. This retarding effect will set in earlier in the fish with a great initial growth and maturing at an early age than in the fish with a smaller initial growth and maturing at a later age. This phenomenon causes the crossing over of the growth curves for the different spawning-groups typical for all the year classes investigated. The fish with smaller initial growth tend to add relatively larger annual increments in subsequent years than those with a larger initial growth.

This is in fact an example on the phenomenon of compensatory

growth described in regard to the herring by Watkins (1927) Farran (1928) and Ford (1928). Watkins characterizes this phenomenon in the following way: »It also seems to be a general feature that the herring should approach a certain length at the completion of each of the various year's growth. If for some cause or other the fish was unable to complete this amount of growth in a particular year than it will in some measure make up the deficiency the following year, so that what may be called the phenomenon of compensatory growth is characteristic of the herring.«

Ford has on a sample from Sussex demonstrated that this herring were composed of two types, one with $1_1 = 8{,}5$ cm and another with $1_1 = 11{,}5$ cm. The fish with the smaller values of 1_1 had larger annual increments in subsequent years than those with the greater values of 1_1. Hodgson (1929) means, however, that these two groups represent broods from different spawning periods from the winter and autumn. The fish with the smaller 1_1 were at the formation of the first winter ring one year old, but the other group which was supposed to be hatched in the autumn had reached an age of about 15 months before a winter ring was formed. Hodgson concludes from this »that compensatory growth is singly explained as the natural result of comparing growth of fishes which are at different ages. There is no question of a difference in growth-rate or any kind of compensatory growth.« Hodgson means that the curve for »ability to growth« is the same in both groups. »The sole explanation is that the curve has started at a different point in time on the time-axis. With increase of age there is less ability to increase length and consequently the larger and older fish of any given growth period will grow less than smaller and younger fish.«

The compensatory growth in the stock of Norwegian spring herring is also illustrated by figure 9. The curves demonstrate the calculated length at the end of each growth period (1_1 1_2 etc.) of five different spawning-groups of the year-class 1904 in the spring 1914. The length at the different spawning periods is designated by an x.

As the stock of Norwegian herring has a rather limited spawning period in spring the difference in length in the first years of life cannot be due to a difference in age as supposed by Hodgson. But this difference is as previously demonstrated really caused by a different growth rate due to the different growth conditions on the feeding grounds along the coast. The herring spawning at an early age consist mainly of fast growing fish of southern origin and the later developed herring of less fast growing fish of northern origin. While the fast growing southern individuals get a retardation in the growth rate at

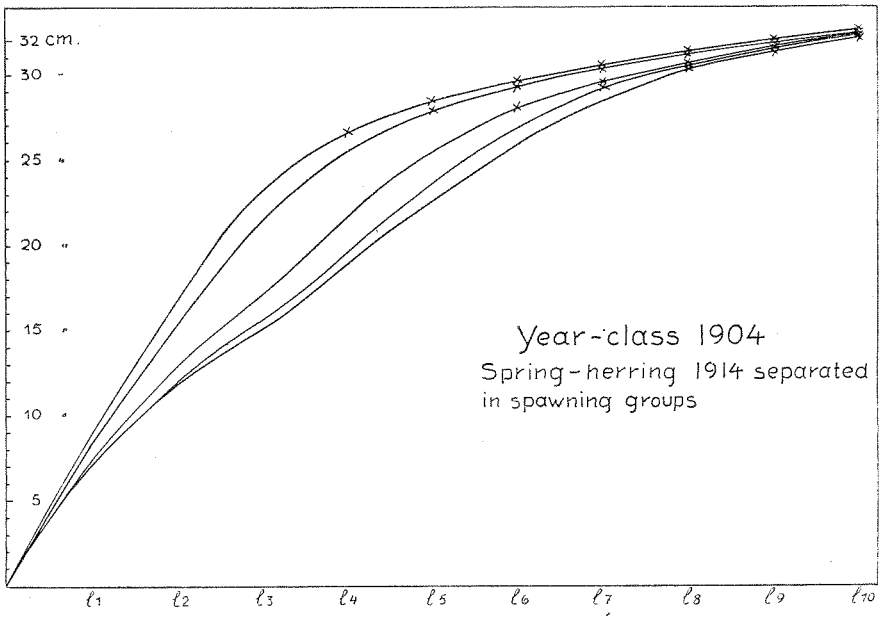

Fig. 9.

an early age through the inception of maturity, the slow growing northern immature herring get an increase in the growth rate caused by the southwards migration to areas with more favourable growth conditions, and at first at a later age a decrease takes place due to the development of the sexual products. The result is that all the herring have reached about the same length at an age of 10 years (1_{10}).

The phenomenon of compensatory growth thus seems to be explained by a correlation between the growth and the time for inception of sexual development. The fast growing fish mature earlier than the slow growing fish and get therefore a retardation in the growth rate earlier than the later ones. The effect of this phenomenon is that mature fish with dissimilar growth history tend to reach the same length at a certain age.

Summary.

In the present chapter it has been demonstrated that the different external conditions on the feeding places along the Norwegian coast influence the growth of the young herring in the manner that the fish in northern Norway have a slower growth rate than those at the west coast. The environment thus stamps the growth zones as well as the appearance of the winter rings on the scale in a manner characteristic for the locality.

But also within a limited area there is a variation in the growth of the young herring probably due to the different growth conditions in the more open parts of the coastal waters and in the fjords, and a selection takes place in different groups according to the size attained. The more fast growing groups of a year brood seem to disappear from the coastal waters at an earlier age than the slow growing fish.

By an analysis of the appearance of the winter rings it was found that the herrings in the oceanic intermediate stage and the recruit spawners at the west coast of Norway were composed of fish of southern as well as northern origin and the study of the growth has confirmed this conclusion.

Following the immigration of one and the same year class to the group of spawners at the west coast it has been demonstrated that the stock of young herring is split up in groups with different growth and origin which attain maturity at different age. The spawning groups first appearing at an age of 3 and 4 years are composed of very fast growing fish of southern origin. At an age of 5 years a new group composed of less fast growing fish of southern as well as northern origin appears and at an age of 6 and 7 years the more slow growing fish of northern origin arrive. It thus seems to be a correlation between the growth rate and the time for the attainment of sexual maturity.

When all the young herring of a year class have been transferred to the group of spawners this group must represent a mixture of different growth types. Through the peculiar appearance of the »spawning« rings on the scale we have a mean to divide the older spawners in the original spawning-groups according to the age at first spawning. The groups separated in this manner represent not only the same composition as regards southern or northern origin, but also the same growth types as actually observed in the different groups of recruit spawners immigrated in the preceeding years. This is a final proof on the correctness of the determination of the »spawning« rings.

According to the fact that the fast growing young herring attain maturity at an earlier age than the slow growing fish one must expect decreasing values for the first years growth with increasing age when treating the younger age groups of mature herring where an immigration takes place. Not till all the fish of a year class have reached maturity one can expect constant values. This confirms the explanation given by L e a for »the phenomenon of apparent change in growth rate«. When the fish have begun the development of the sexual products a decrease in growth takes place and one can thus distinguish between periods of vegetative and propagative growth. Fish with a small initial growth, has a longer vegetative growth period than that of fish with

a great initial growth where the early maturity depresses the growth at an earlier age. In this manner a phenomenon of compensatory growth occurs and the difference in length of the fish with different initial growth will disappear with increasing age.

It has further been demonstrated that the growth types A, B, C of the spawning herring are not homogenous but represent a mixture of fish of different growth types and origin which can be separated according to the scale types. It has been shown that all the growth types found among the fat herring in northern Norway can be reencountered in the group of spawners at the Norwegian west coast, and the opinion of O t t e s t a d that only fish of the A type of the northern fat-herring migrate to the spawning grounds at the west coast does not hold good.

Owing to the heterogeneity of the A, B and C types a selection of one of these growth-types, by treating the growth of the younger age groups of mature herring, can not eliminate »the phenomenon of apparent change in growth rate.«

The analysis of the growth has thus confirmed the interpretation of the different appearance of the winter rings and the conclusions drawn as regards the migration of the young herring and the immigration to the group of spawners at the west coast. Combined observations on the types of winter rings and on the growth calculated from measurements on the summer zones have also elucidated some growth problems of general biological interest.

Chapter 4.

A comparison of the spawning herring from northern and southern Norway.

In the previous discussion of the composition and origin of the Norwegian spawning stock I have exclusively treated the herring spawning at the west coast.

The common opinion has been that the total stock of Norwegian herring spawns at the west coast. The large herring appearing off the Møre—Trøndelag coast in the winter were supposed to migrate southwards for spawning later in the season at the south west coast.

My investigations on the distribution of the spawning places based as well on the occurrence of newly hatched larvae as on direct localizings of the herring roe on the coastal banks by means of the bottoum grab have, however, shown that spawning takes place along a great part of the Norwegian coast. One finds spawning centers at the West coast, at the Møre—Trøndelag coast and in northern Norway as far north as Vesterålen.

My racial analyses (1933, 1935, 1936) of the spring herring from the southwest coast and from the more northern spawning places have shown a real difference in the mean number of vertebrae which fact indicates that we here have to do with different groups of spawners with more or less independent zones of migration. In the same manner I have shown that the large herring shoals which appear north of Bergen and at the Møre coast are not identical with the spawning shoals at the southwest coast, but must migrate to other spawning grounds.

The Norwegian spring herring stock thus seems not to be so homogenous as formerly supposed but is composed of different groups of spawners immigrating to different spawning centers along the coast. Of special interest is the existence of spawning herring in northern Norway.

O t t e s t a d (1934) means that his analysis of the growth of the Norwegian herring confirms my supposition of a northern spawning group. O t t e s t a d writes: »The opinion at which we have arrived of the life history of the herring differs from the preliminar description by H j o r t (1914) therein that the growth definitely indicates the existence of two Norwegian herring stocks, a southern and a northern one. This opinion is based on the fact that there is only a portion of the northern fat-herring stock, viz. the individuals of the A-type or only a portion of them, which later join the southern large and spring herring shoals. This agrees well with the results arrived at by investigations of the spawning grounds. As pointed out by R u n n s t r ö m (1933, I) the chart showing the occurrence of newly hatched herring larvae, reproduced in fig. 28 is not complete. But still we must be entitled to suppose that there are, broadly speaking, two separate large areas for the spawning of the herring.«

Through the conclusions of O t t e s t a d to a certain degree confirm my opinion I must state that the proof on the existence of a northern herring stock given by O t t e s t a d does not hold good. As I have shown i chapter 3, all the three growth types A, B, C found among the northern fat herring by O t t e s t a d can be reencountered among the spring herring in southern Norway and the basis for O t t e s t a d's far reaching conclusions thus fails. In spite of this the existence of spawning places in northern Norway remains a fact and it was of course of great interest to trace these northern shoals and examine representative samples of the herring. There has in later years often appeared spent or recovering large herring some time after the end of the spawning season in northern Norway. L e a (1929 II) was of the opinion that this herring represented fish which had spawned earlier in the season at the southwest coast and which then were migrating northwards.

Especially in the year 1932 I got a good material of this herring. They appeared in Lofoten and Vesterålen rather early in the season in the middle of April, and although the majority of the fish were spent the existence of some yet ripe herring indicated that they must have spawned a rather short time before they were caught. With the knowledge of the spawning grounds at the westside of Lofoten and Vesterålen I suspected that this herring really represented the northern spawning group. During my later investigations in this area I have been credibly informed that the herring found in that year at first appeared on the outer side of Vesterålen where they were caught by the fishermen with ground nets as spawning herring. Then the herring immigrated to the inner parts of Vesterålen and Lofoten where a fishery with purse seines on the spent fish took place.

In the last three years I have made cruises with M/S »Johan Hjort« in northern Norway in the spring in order to localize the spawning grounds more thoroughly. In 1934 I tried to find the herring roe with the bottom grab on the banks in the open sea outside Vesterålen, but hard weather and the vast extension of the banks made this a very difficult task.

When I visited this district in the following year 1935 I received the information that an unusual fishery occurred in the inner parts of the Andfjord a short distance north of Vesterålen. This district is a typical fat herring district and the fishermen were surprised to find a »sort« of herring which was strange to them.

I could personally state that we here had to do with real spring herring which had immigrated into the fjords in order to spawn there. The nets were covered with fertilized herring roe from the ripe herring. The spawning herring occurred here from the end of March to the beginning of April. It is probable that special conditions in this year have caused an immigration into the fjords of herring which normally spawn on the banks outside the coast. I could then in April state the occurrence of spawning herring in the outer parts of the skjærgård along the Nordland coast and northern Trøndelag. A great material of herring samples from various localities was collected.

In this year (1936) large herring were observed in Vesterålen and Troms already in January, but an immigration of spawning herring into the fjords later in the season similar to that in the previous year did not take place in this district. However, single small catches showed that spawning herring were present but in small amounts. The herring have apparently in this year spawned at a farther distance from the coast, but some cruises made on the open sea in order to localize herring shoals by echo soundings failed to give positive results.

The investigations in northern Norway have thus given a sure proof on the presence of a northern group of spawners and we have got a good material for comparison with the southern groups. The mean number of vertebrae is slightly lower than that of the spring herring from the Møre coast, but the herring from both these areas show a marked difference from the spring herring at the southwest coast (Rogaland— Hordaland) (compare Runnström 1936. A more extensive report on the racial analysis will be given in a later work). As regards the age composition the herring from northern Norway in 1932 were represented by the same year classes as those of the spring herring from the more southern spawning grounds. The spring herring from northern Norway and Møre coast were, however, characterized by the dominance of the year class 1922 which year class played a less important part

among the spring herring from the west coast. In the year 1935 the herring from northern Norway consisted mainly of the year class 1930 which also appeared in great amounts as recruit spawners on the southern spawning grounds.

Table 20. Spring herring 1932. Composition as regards southern (S) and northern (N) origin.

Age at 1st spawning	Scale type	West Coast		Møre-Trøndelag		Northern Norway	
		Nr.	%	Nr.	%	Nr.	%
3	S	6	100.0	3	100.0	—	
	N	—		—		—	
4	S	376	89.5	84	88.5	22	75.9
	N	44	10.5	11	11.6	7	24.1
		420		95		29	
5	S	514	56.7	103	40 7	34	30.9
	N	393	43.3	150	59.3	76	69.1
		907		253		110	
6	S	46	9.2	2	1.0	5	3.9
	N	453	90.8	199	99.0	122	96.1
		499		201		127	
7	S	—		—		—	
	N	100	100.0	41	100.0	46	100.0
8	S	—		—		—	
	N	6	100.0	3	100.0	3	100.0
9	S	—		—		—	
	N	—		—		1	100.0
Total	S	942	48.6	192	32.2	61	19.3
	N	996	51.4	404	67.8	255	80.7
		1938		596		316	

In table 20 I have given the composition of the spring herring from the three regions: the West coast, the Møre-Trøndelag and northern Norway in the year 1932 according to an analysis of the winter rings. The material is separated in different spawning groups according to the age at first spawning and in each spawning group the individuals are divided according to southern (S) or northern (N) origin based on the appearance of the coastal rings.

As previously demonstrated the spring herring from the west coast are composed of about equal parts of fish grown up in southern and

northern Norway (S = 48,6 %, N = 51,4 %). In the lowest section of table 20 one finds, however, that the spawning herring from Møre—Trøndelag for the most part are recruited from young herring of northern origin (N = 67,8 %) and in northern Norway the spawning herring consist of about 81 % of fish of northern origin.

As regards the scale types it thus seems that the different spawning communities are composed of components of as well southern as northern origin and that is only a quantitative difference in the composition in the manner that the relative number of herring of northern origin is increasing northwards.

The young herring with coastal winter rings of the »northern« type cover, however, a very large area from Trøndelag to Finnmarken and the appearance of the winter rings does not tell anything about in which part of this area the herring have grown up.

We also know from Russian investigations that a considerable stock of young herring exists at the Murman coast. According to Awerinzew (1935) these herrings represent unripe fish of an age seldom more than four years, and mature fish have never been observed. Herring fry can be observed already in August. Rabinerson (1925) has regarded these fish as young herring of the Norwegian herring stock.

Makuschok (1932) tries, however, to show that there exists a special herring race in the Barents Sea which also spawns on hitherto unknown spawning places situated in this area. Makuschok means that the about one year old herring which are found at the Murman coast cannot have drifted the long way from the spawning grounds at the southwest coast of Norway during this time. My investigation (1934 II) on the distribution of the herring larvae makes it, however, very probable that the fry can drift from the newly discovered spawning places in northern Norway to the Murman coast in the course of the first summer. While newly hatched larvae are found at Vesterålen in March and April, older pelagic larvae are observed in the eastern part of Finnmarken (outside Varangerfjord) already in June and July. It is therefore not unreasonable to suppose that the herring fry which according to Awerinzew occur at the Murman coast in August originate from the spawning places in northern Norway.

Awerinzew (1935) is also of the same opinion and mentions that there are no facts that indicate the presence of an individual herring race at the Murman coast. He writes further: »Beim Vergleich der hier aufgezählten Tatsachen mit dem, was über die Laichgebiete, die Art und Zeit der Verteilung der Jungfische an der Küste Norwegens, sowie über andere charakteristische Besonderheiten der norwegischen *Cl. harengus*-Rasse aus den vorzüglichen Arbeiten Einar Leas und,

in den letzten Jahren, aus den Arbeiten Runnströms bekannt geworden ist, muss meines Erachtens unumwunden der Schluss gezogen werden, dass die Murman-Heringe als Jungfische der norwegischen Rasse zu deuten sind, die vom Strom weit nordostwärts getrieben worden sind und die dann während ihrer ersten 4—6 Lebensjahre sich an der Murman-Küste aufhalten. Als Laichgebiet kann für diese *Cl. harengus* nicht bloss die Stadt—Kristiansund Region (Møre-Küste) sein, sondern hauptsächlich die Lofoten—Vesterålen Region.«

Table 21. Year-class 1930.

	Locality	Year of capture	Nr.	Growth increments				
				t 1	t 2	t 3	t 4	t 5
Fat herring	Skolpenbank	7. I 1933	202	9.51	5 30	4.00	—	—
	Landegofjord Bodø	22. VIII 1932	83	10.50	6.40	4.90	—	—
Spring herring	Kasfjord North. Norw.	8. IV 1935	109	9.65	5.07	4 21	4.14	2.79
	Bokn. West coast	8. III 1935	132	10.09	5.39	4.59	5.03	4.09
	Lindesnes	12. III 1935	86	10.30	5.50	4.80	5.30	4.00

Awerinzew remarks about the appearance of the winter rings on the scale of the Murman herring: »Es ist zu vermerken, dass bei der Untersuchung der Schuppen solche von Nord — wie auch vom Südtypus (nach Leas Terminologie) also solche mit scharf ausgeprägten und umgekehrt mit verschwommenen Winterringen vorgefunden sind. Schuppen des letzten Typus machen 15—20 % oder noch weniger aus.« This proportion of »northern« and »southern« types is very similar to that found among the northern Norwegian spawning herring (table 20).

It is thus resonable to suppose that the herring of northern origin which join the spawning shoals appearing in northern and southern Norway originate from different areas of the northern waters.

The spawning herring in northern Norway may be recruited mainly from young herring grown up at the Murman coast while the young herring from the common fat herring districts in northern Norway may migrate to more southern spawning grounds.

As the young herring apparently live under less favourable temperature conditions at the Murman coast than at the Atlantic coast of the northern Norway one ought to expect a growth difference between the young herring groups inhabiting these areas.

I have at my disposal a representative sample of young herring from the Skolpen bank in the Barents Sea caught by Mr. Iversen's fishery expedition in January 1933.

This sample contained mainly fish of the yearclass 1930 the same year class which appeared as spawning herring on the northern as well as southern spawning places in the year 1935. A comparison of these young herrings with fish of the same year class caught at Bodø in Nordland August 1932 shows a rather dissimilar growth.

The herring from Skolpen bank had an average length of only 18,81 cm while the younger herring from Bodø had reached an average length of 21,60 cm. In figure 10 and table 21 the different growth rates are clearly demonstrated. It is apparent that the herring from the Barents Sea have a slower growth rate then that of the young herring from northern Norway.

If the northern elements of the spawning herring in northern and southern Norway originate from different northern areas, viz. northern Norway and the Murman coast, a similar growth difference ought to be expected as that found between the young herring from the two areas.

The material of spring herring from the year 1935 gives a good opportunity to compare the growth of herring from different spawning places along the Norwegian coast. As previously mentioned the year class 1930 appeared as recruit spawners along the whole coast from the southern part of Troms district in the north to the Oslo fjord in the south. Almost all the recruit spawners represented fish of the same scale type namely N_{3+1+0} and which thus had lived their first three winters in northern coastal waters and their fourth winter in the ocean while they appeared on the different spawning grounds in their fifth winter. The whole material is not yet worked up but I have in the lower section of fig. 10 given the growth curves for spawning herring from three different spawning localities: I. Kasfjord in northern Norway; II. Bokn at the southwest coast north of Stavanger and; III. Lindesnes in southern Norway. The average length of the spring herring from the three areas was 25,86, 29,19 and 29,80 cm. These figures show that it is a considerable difference in growth between the spawning herring from northern Norway and the herring of the same year class and the same scale type from southern Norway. The diagrams in fig. 10 demonstrate that this growth difference is present already in the first years of life (t_1— t_3) when all the fish yet lived as young herring in northern

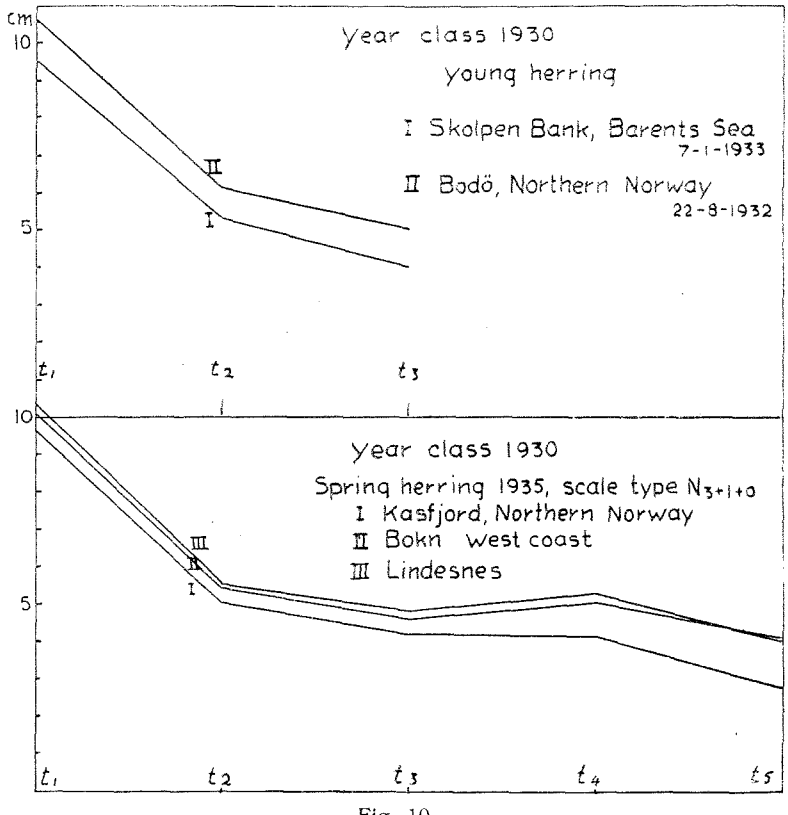

Fig. 10.

coastal waters. One sees also that the values for t_1— t_3 of the spawning herring from northern Norway correspond very well to the growth dimensions of the young herring from Skolpen bank, while the spawning herring from southern Norway has higher values more corresponding to those of the young herring from Bodø.

It is thus very probable that the herrings which spawned in northern Norway in 1935 were identical with the fish which were found as young herring in the Barents Sea in January 1933, while the young herrings from northern Norway (Bodø) apparently have joined more southern spawning shoals.

In the further course of the life history of the spawning herring, when they adopt an oceanic mode of life in the fourth and fifth year, the growth difference (t_4, t_5 fig. 10) is still more pronounced. This is apparently caused by the migration southwards to more favourable growth conditions of the young herring spawning in southern Norway while the herring spawning in northern Norway remain in a more unfavourable environment.

It is probable to suppose that the northern spawning herring in the oceanic intermediate stage live in the open waters of the Barents Sea and this is in accordance with the opinion of A w e r i n z e w (1935) who writes: »Die Arbeiten mit Treibnetzen, die im Anschluss an die Angaben dieser Karte im Barentsmeer ausgeführt worden sind, gestatteten mir, die Richtigkeit der Ansicht E. L e a s bezüglich des Bestehens eines ozeanischen Stadiums im Leben der norwegischen *Cl. harengus*-Rasse zu bestätigen. In einer 100 Meilen und darüber von der Küste entfernten Region habe ich in einer gewissen Jahreszeit grössere Schwärme fetter, unreifer, vierjähriger und älterer Heringe getroffen«.

In discussing the life history of the Norwegian herring O t t e s t a d (1934) assumes a southern Norwegian herring stock spawning along the west coast northwards to Møre and a northern Norwegian herring stock spawning on the banks outside Vesterålen and Lofoten according to my investigations. The fry from the last mentioned spawning places form according to O t t e s t a d an essential part of the northern fat-herring shoals, and the main part of these fish returns to the northern spawning grounds as mature herring.

According to my experience I find that such a distinct separation in two Norwegian herring stocks do not exactly answer to the real facts. In 1935 I observed a rather continuous spawning along the coast from the southern part of Troms to Møre and from the Haugesund district along the southwest and southern coast to the Oslofjord. A sharp limit between the spawning places in northern Norway and those at the Møre coast did not exist. Also in respect to the racial characters such as the mean number of vertebrae there is a greater similarity between the spawning herring from northern Norway and the Møre coast than between the herring from the Møre and the southwest coast which probably is caused by the circumstance that the spawning grounds north of Stadt are more influenced by Atlantic water than the coast south of Stadt (compare fig. 11).

The young herring fry drift with the coastal current northwards from the spawning places although a part of them undoubtly can remain in the fjords of the area were they are hatched. In the course of the summer the herring fry are distributed along the whole region from southern Norway to the Murman coast. It is difficult to decide from which spawning grounds the fry in the different regions originate, but a marked graduation in the mean number of vertebrae from south to north indicates that there is no complete mixing of the fry from the different hatching places (R u n n s t r ö m 1933). From the experience of the conditions in the Barents Sea one must assume that the young herring in this area mainly originate from the spawning places in

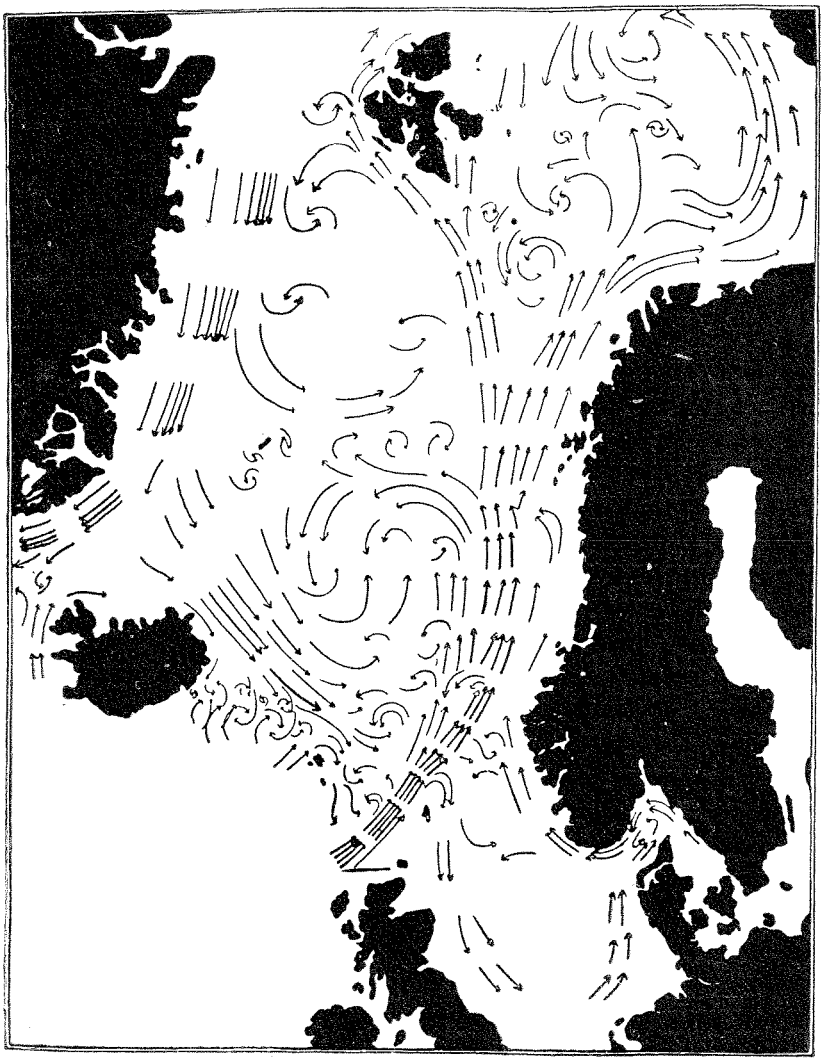

Fig. 11. The circulation of the Norwegian Sea according to Helland-Hansen and Nansen (1909).

northern Norway and that the young herring in northern Norway to a great extent are hatched in more southern areas.

As I have shown in the present paper the fat herring from northern Norway in contrary to the assumption of Ottestad plays a great part in the formation of the southern spawning shoals.

When the young herring leave the coast in order to adopt an oceanic mode of life Lea (1929 II) assumes that the fish from the different coastal regions meet in a central area probably situated in the

southern part of the Norwegian Sea where they then develop to mature fish and form shoals of recruit spawners. With the knowledge of the precense of different spawning groups along the coast with different mean numbers of vertebrae and different composition as regards the northern and southern origin of the fish it is, however, difficult to assume one common meeting place. One must rather assume that the young herrings in the intermediate stage frequent different areas of the ocean, and it is probable that the system of currents in the Norwegian Sea has a great influence on the grouping of the oceanic herring. As seen in the figure 11 (from Helland-Hansen and Nansen 1909) there exist in the ocean different cyclonic systems. Such vortex movements occur in the North Sea, in the southern and northern parts of the Norwegian Sea and in the Barents Sea. It is reasonable to suppose that the migration of the herring to a great extent is directed by the current system and that the young herring emigrating from the different coastal regions to the ocean will be »caught« by the different cyclonic systems. The current system will thus support the formation of more or less separated groups of oceanic herring which originate from different coastal regions. According to the current system it is to be expected that herring emigrating from the west coast and the southern part of northern Norway to a great extent will be mixed in the cyclonic system of the southern Norwegian Sea while herring of more northern origin will dominate in the northern cyclonic systems. In this way one can understand the different composition of the shoals of recruit spawners immigrating to the different parts of the coast as regards southern and northern origin as demonstrated in table 20. Thus in my opinion one cannot assume two strictly separated herring stocks, but the Norwegian herring stock is composed of different groups of spawners with more or less separated areas of migration which are influenced by the current system. Influenced by the different external conditions on the spawning grounds along the coast the various groups of spawners can show a difference in the mean number of vertebrae, but they are not to be regarded as different races (Runnström 1933) and an interchange between the offspring from the different hatching centres along the coast occurs undoubted.

On the fact that 20—30 years ago one did not know of such great masses of young herring at the Murman coast as have been observed in recent years Awerinzew (1935) raises the question if the biology of the Norwegian herring have changed in the last period in the manner that the spawning places have been displaced northwards.

That certain changes really occur we know through the existence of good periods in the history of the herring fisheries interrupted by a disappearance of the herring from the common spawning grounds. In

the latter half of the last century the herring disappeared almost entirely from the common fishing places at the southwest coast during a shorter period while at the same time great masses of large herring immigrated to the coastal region of northern Norway. Many observations indicate, however, that herring were present also in southern Norway but that they spawned on more outer banks in the open sea. It is then a question if the occurrence of spawning herring in northern Norway as observed in the last years represents a new phenomenon. My study on the occurrence of newly hatched herring larvae indicates, however, that spawning must have taken place in this area during a rather long period. Already in the year 1909 larvae were observed but regular observations are lacking. Nor the yield of the spring herring fishery on the west coast has shown a decreasing tendency which should indicate a displacement of the spawning groups. It is, however, of importance to study this problem thoroughly and it is reasonable to suppose that variations in the current system is of great consequence for this phenomenon. In order to study to which degree displacements of the spawning occur along the coast I have in the last years made regular observations on the quantitative distribution of the herring roe in various spawning areas combined with observations on the variation in the hydrographical conditions.

Chapter 5.

The recruitment of the Norwegian spawning stock.

Lea (1930) has in his important paper »Mortality in the Tribe of Norwegian Herring« calculated the coefficient of remanence for the group of mature spawning fish. This calculation is based on the relative age-distribution of the Norwegian spring herring established for a long series of years (1907—1928). Lea comes to the result that 0,81 represents the best value for the calculable coefficient of remanence. That means that 81 per cent of the spawning stock will survive after the lapse of one year or expressed in another manner that the mortality is 19 per cent. It was then possible to construct a part of what Lea terms »an approximate ideal age distribution for the group of spawners in the Norwegian tribe of herring, that is an age-distribution, where the effect of the fluctuations in the numerical strength of the different year-classes are eliminated«. As the group of spawners every year receives an addition of young herring spawning for the first time at an age from 3—7 years (recruit spawners) it was in the study of the effect of mortality necessary to exclude these age groups which may be affected by immigration. In fig. 12 I have reproduced the »mortality curve« given by Lea (1930) in his fig. 3. The curve is based on the study of individuals more than 6 years of age and is extrapolated backwards to the age of nil. The empirical values for average age distribution of the spawning stock (1907—1928) are represented by black dots. One finds that the part of the curve which represents fish older then 7 years corresponds well with the corresponding empirical values, while the distribution of the age groups where immigration takes place must be determined empirically. From an age of 7 years the spawning stock is thus reduced according to a mortality rate of 19 per cent. The younger year groups of the spawning herring are affected by the immigration

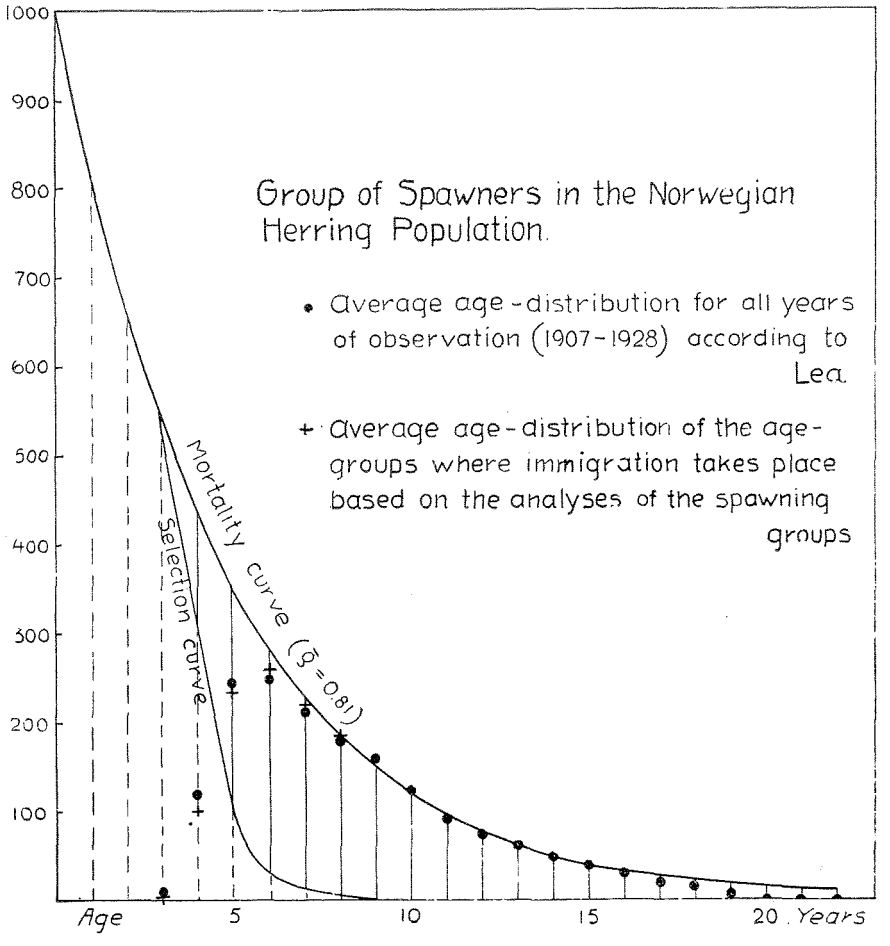

Fig. 12.

of the recruit spawners from the stock of young herring as well as by the rate of mortality.

It will of course be of importance to study the renewal of the spawning stock as well as the mortality, and L e a has also treated this problem on the basis of the calculated mortality curve and the empirical values for the average age distribution. L e a writes: »If the curve may be assumed to hold for the younger individuals (3 to 6 years) actually incorporated in the group of spawners, then some idea can be formed concerning the transfer of the individuals from the stock of immature fish to the group of spawners during the critical ages 3 to 6 years. By comparing the height of the ordinates to the dots (empirical frequency) with the height of the ordinates to the mortality curve (expressing the

supposed total number of individuals of the age groups) it will be seen that of the age-group 3 evidently only a very small fraction is transferred to the group of spawners, while the rest of the age-group is still immature. At the age of 4 years about 28 per cent of the supposed total number have been included in the group of spawners, at the age of 5 years about 70 per cent and at the age of 6 years about 88 per cent«.

In this manner it is posible to find the difference between the supposed total number of individuals and the number present in the group of spawners for each of the age-groups and L e a has drawn a »selection curve« which separates the immature portion of the individuals in the age-groups from the portion which is included in the group of spawners.

As demonstrated in the present paper one can determine the number of spawning rings on the scale of each single fish and one has here a new method to study the recruiting of the spawning stock.

Instead of separating the spring herring in different year classes (fish born in the same year) one can separate the old spawners in different spawning-classes (fish spawning for the first time in the same year). In table 6 the spawning stock at the west coast in the year 1932 was treated in this manner and separated in fish spawning for the first time in the years 1917—1932. Each spawning-class is also separated in different spawning-groups (3—8) according to the age at first spawning. Each vertical column shows then the real composition of the recruit spawners in the years 1917—1932. In the column farthest to the right one gets the average composition of the different spawning classes as regards the spawning-groups.

In the upper section of table 22 I have given this average composition of the total number of spring herring analysed in the year 1932. One finds that the herring immigrated to the spawning shoals at an age of 3 to 8 years, and the relative values show how great part of the total stock immigrated at an age of 3 to 8 years. It is then supposed that the different spawning-groups have the same rate of mortality. One finds in accordance with L e a that the influx of 3, 7 and 8 years old recruit spawners is rather insignificant and that the main influx takes place at an age of 4, 5 and 6 years. I find that at the age of 4 years about 22 per cent of the total number have been included in the group of spawners, at the age of 5 years about 69 per cent, and at the age of 6 years about 94 per cent, which agrees rather well with the corresponding values given by L e a namely 28, 70 and 88 per cent.

I have in fig. 12 marked off with a cross the relative number of fish present in the group of spawners for each of the age groups 3—8 on the respective ordinates of the mortality curve according to my estimations. One find that my estimations (crosses) based on the

determination of the spawning rings on material from a single season show a very good agreement with the average age distribution (black dots) given by L e a for a long series of observations (1907—1928). This good agreement must be regarded as a further proof on the correctnes of the determinations of the spawning rings on the scale.

Table 22. Average age-composition of the group of Recruit-spawners.

			Age at 1st spawning							
			3	4	5	6	7	8	9	Total
West coast	S	nr.	6	376	514	46	—	—	—	942
		%	0.6	39.9	54.6	4.9				
	N	nr.	—	44	393	453	100	6	—	996
		%		4.4	39.5	45 5	10.0	0.6		
	Total	abs.	6	420	907	499	100	6	—	1938
		%	0.3	21.7	46.8	25 7	5.2	0.3		
Møre— Trønde-lag	S	nr.	3	84	103	2	—	—	—	192
		%	1.6	43.7	53.6	1.0				
	N	nr.	—	11	150	199	41	3	—	404
		%		2.7	37.1	49.3	10.1	0 7		
	Total	nr.	3	95	253	201	41	3		596
		%	0.5	15.9	42.5	33.7	6.9	0.5		
Northern Norway	S	nr.	—	22	34	5	—	—	—	61
		%		40.0	60.0	0.1				
	N	nr.	—	7	76	122	46	3	1	255
		%		2.7	29.8	47.8	18 0	1.2	0.4	
	Total	nr.	—	29	110	127	46	3	1	316
		%		9.2	34.8	40.2	14 6	0.9	0.3	

It is apparent that the average age distribution indicated by the black dots in figure 12 gives a mean to approximately estimate the increase and decrease of a certain year class among the stock of spawning herring. At an age of 3 to 6 years the number of spawning herring of a certain year class will increase according to the immigration from the stock of immature herring. The increase from one year to the next can be determined according to the ratio between the height of the ordinates to the black dots. From an age of 8 years when all the herring have been transferred from the stock of young herring to the spawning group the number will decrease according to the rate of mor-

tality. One has thus here a method to calculate the relative value of a certain year class from one year to the next year, and this method may be utilized practically in order to give a prognosis of the age distribution of the Norwegian spring herring stock calculated from that of the last year. Such a prognosis has been given with good results by Rollefsen (1935) for the Norwegian cod. Rollefsen has in two preliminary reports (1933, 1934) made the assumption that the narrow outer zones on the otoliths of the cod are spawning zones. Working up the otolith material on this hypothesis Rollefsen finds »that definite numerical regularities may be formulated regarding the recruitment of the skrei stock with new spawners and also regarding the mortality of the stock. These rules might be numerical expressed by a system of factors, and we should therefore be able, given an observed stock, with aid of these factors to follow it theoretically exactly to its next stage of development.....« The good agreement between the age distribution calculated and the actually observed demonstrated by Rollefsen (1935) gives a convincing proof of the validity of his supposition that the peculiar zones in the otoliths are spawning zones.

The statement of spawning rings by the analysis of the rings on the scale of the Norwegian herring given in the present paper also supports the assumption by Rollefsen.

As regards the herring the analysis of the spawning rings has given a clue to the study of the rules for the recruitment of the spawning stock as previously shown. In figure 12 was demonstrated the close agreement between my results and the distribution for the age groups where immigration takes place as determined empirically by Lea. In this respect the analysis of the spawning groups of the Norwegian herring has not given any new results above that which Lea already has demonstrated but the agreement confirms the right interpretation of the spawning rings.

The possibility to separate the herring of different origin according to the different appearance of the »northern« and »southern« coastal winter rings gives, however, a method to study the rules for the immigration of the different components of the spring herring. As already mentioned in a previous chapter the herring of southern origin develop to mature fish earlier than the herring of northern origin. The diagrams in the upper section of figure 13 demonstrate the average age composition of the first time spawners (compare table 22) from the west coast when the whole spawning group is considered and when the spawners are separated in fish of southern (S) and northern (N) origin. It can be seen that the main influx of recruit spawners of southern origin takes place at an age of 4 and 5 years while the recruit spawners of northern

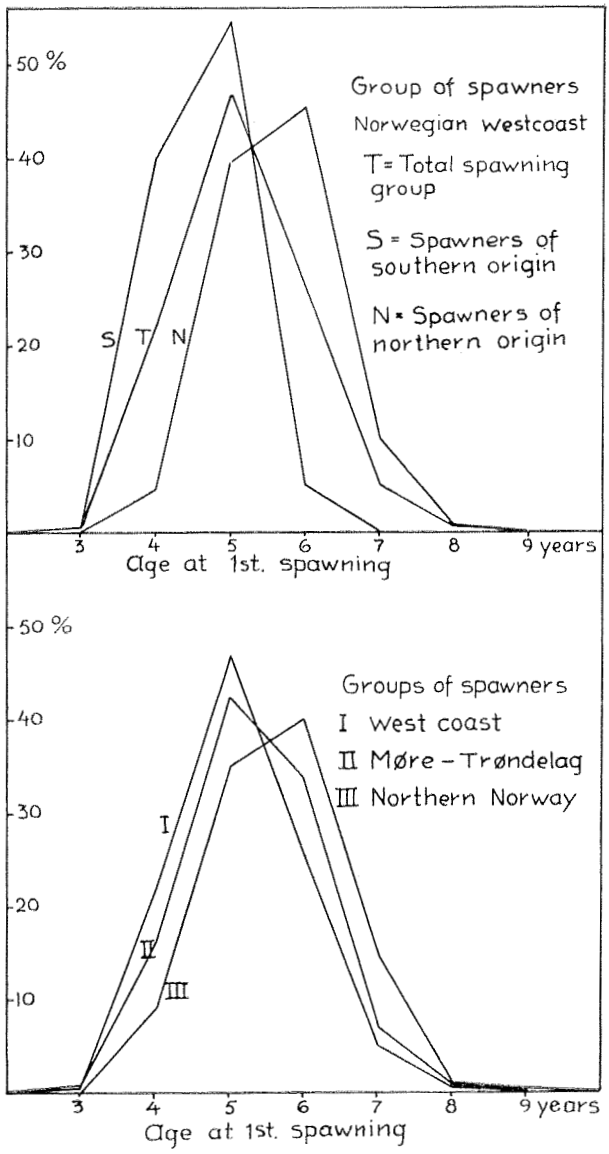

Fig. 13.

origin mainly immigrate at an age of 5 and 6 years. The 4 years old recruit spawners are thus mainly of southern and those 6 years old mainly of northern origin while there is a great influx of southern as well as northern fish at an age of 5 years.

If one uses the average age composition given by L e a (figure 12) in order to calculate the increase from one year to the following one of

the younger year classes of the spawning stock where immigration takes place one must assume a constant composition of the various year classes as regards southern and northern components. However, this supposition does not always holds good and the method can therefore in some cases give great errors in the prognosis as will be demonstrated.

In figure 14 I have given the age distribution of the Norwegian spring herring from the west coast in the years 1934 and 1935. The 4 years old fish in 1934 represent the year class 1930 which appeared on the spawning grounds for the first time in this season. From the relative strength of the year class 1930 in the spawning season 1934 one ought not expect that this year class would play any great part in the renewal of the spawning stock in the following years. It was therefore unexpected that a very great influx of this year class took place in the year 1935 and the now 5 years old fish of this year class were quite dominating in the spawning stock with a relative value of about 40 per cent.

If one had tried to calculate the age distribution in 1935 from that in 1934 according to the average age distribution given by L e a or from the curve for the total group of spawners in the upper section of fig. 13 one had got a much smaller relative value for the year class 1930 than actually observed in the season 1935. According to this calculation the number of spawning fish of this year class would have increased some more then two times from 1934 to 1935 but the increase was much greater.

An analysis of the origin of the spawners of the year class 1930 according to the scale type gives, however, an explanation of the phenomenon. From our experience as regards the general composition of the recruit spawners illustrated in the upper section of figure 13 one ought to expect that the 5 years old spawners consist of a greater portion of fish of southern than of northern origin. However, this was not the case in the year 1935. The spawners of the year class 1930 consisted almost exclusively of herring of northern origin and the immigration of the southern contingent seems to have completely failed. The fish of this year class present among the spawners in 1934 represented thus the first contingent of recruit spawners of northern origin immigrating at an age of 4 years. Looking on the curve for the age distribution of the recruit spawners of northern origin in fig. 13 one finds that the increase from 4 to 5 years is much greater for the northern than for the southern contingent. Instead of calculating the increase of the year class 1930 from the year 1934 to the next year according to the average age composition of the total group of spawners one must in

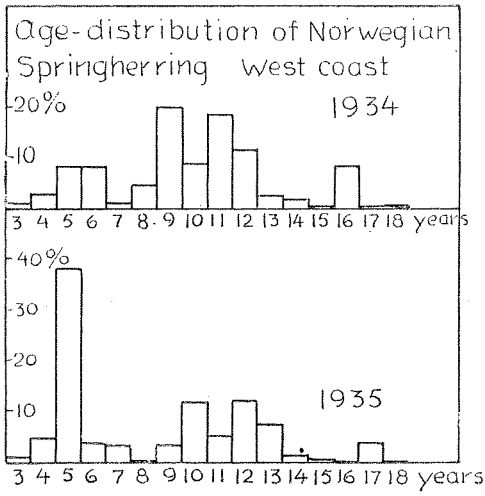
Age-distribution of Norwegian
Springherring West coast
20%
10
1934
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 years
40%
30
20
10
1935
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 years

Fig. 14.

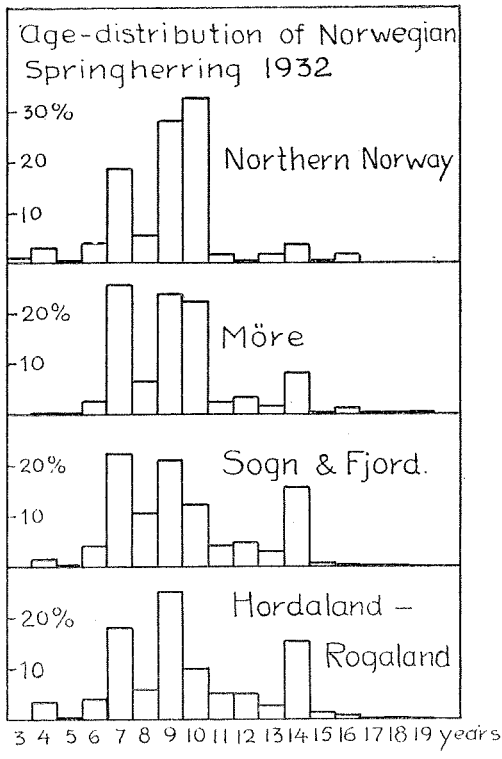
Age-distribution of Norwegian
Springherring 1932
30%
20
10
Northern Norway
20%
10
Möre
20%
10
Sogn & Fjord.
20%
10
Hordaland –
Rogaland
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 years

Fig. 15.

this case base the calculation on the average age composition of the northern component. The increase will then be about 8 times instead of about 2 times and this corresponds better to what really happened. It is thus necessary to analyse the proportion of fish of southern and northern origin among the age groups where an immigration takes place and to treat the two groups separately.

Somewhat the same conditions as found for the year class 1930 was met with for the year class 1922. The recruit spawners of this year class immigrating to the Norwegian west coast consisted mainly of fish of northern origin.

It is an interesting biological phenomenon that the southern young herring stock of certain year broods can fail almost completely. It is not probable to suppose that this may be due to a failure of the spawning or hatching on the southern spawning grounds. It is more reasonable to assume that the herring fry hatched on the southern spawning grounds to a great extent disappear from the southern coastal waters in certain years due to a stronger drift northwards than what usually occurs. In this manner a displacement northwards in the distribution of the young herring can take place. It is likely that such a displacement of the young herring to more northern waters will favour the immigration to more northern spawning places and this can really be demonstrated as regards the year class 1922. In figure 15 I have given the age distribution of the different groups of spawners along the Norwegian coast in the year 1932 arranged from north to south. One sees that the year class 1922 (10 years old fish) who was mainly of northern origin plays a rather insignificant part in the composition of the group of spawners at the south west coast. The relative value for this year class increases, however, northwards and in northern Norway the 10 years old fish are dominating. This peculiar distribution of the year class 1922 has not only been met with in the year 1932 but for a serie of years.

It is thus probable that the drift of the herring fry can play a part in the fluctuations in the strength of the year classes within a certain group of spawners.

As has been seen in the previous chapter the various groups spawning along the Norwegian coast have a different composition as regards the relative number of fish of southern and northern origin. One can not therefore expect that the different groups follow the same rule for the recruitment of the spawning stock. In the lower section of figure 13 I have given the average age composition of the recruit spawners in the different areas of the Norwegian coast. One finds that the mean value for the age at first spawning increases from south to north. This

is in accordance with the fact that the more northern spawning groups to a greater extent are recruited by herring of northern origin. One can not therefore apply the average age composition based on the group of spawners at the west coast on the northern groups. One finds, however, a good agreement between the age composition of the recruit spawners from northern Norway which mainly are of northern origin and that of the northern component of the recruit spawners from the west coast (fig. 13). Table 22 shows also that respectively the southern (S) and northern (N) components of the different groups, treated separately, agree rather well in the different areas as regards the age at first spawning.

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Explanation of the Plates.

PLATE I.

Fig. 1. Scale from an 1½ years old young herring from northern Norway with one »northern« winter ring. Scale type N_1.

Fig. 2. Scale from an 1½ years old young herring from the west coast of Norway with one »southern« winter ring. Scale type S_1.

PLATE II.

Fig. 1. Scale from an 4½ years old herring in the oceanic intermediate stage from the west coast of Norway with two »southern« coastal rings and two »oceanic« rings. Scale type S_{2+2}.

Fig. 2. Scale from an 7 years old spawning herring from the west coast of Norway with two »southern« coastal rings, two »oceanic« rings and two »spawning« rings. Scale type S_{2+2+2}.

PLATE III.

Fig. 1. Scale from an 4½ years old herring in the oceanic intermediate stage from the west coast of Norway with three »northern« coastal rings and one »oceanic« ring. Scale type N_{3+1}.

Fig. 2. Scale from an 7 years old spawning herring from the west coast of Norway with three »northern« coastal rings, one »oceanic« ring and two »spawning« rings. Scale type N_{3+1+2}.

Fig. 1 and 2 Plate I from Lea (1929 II).
Plates II and III original photos.

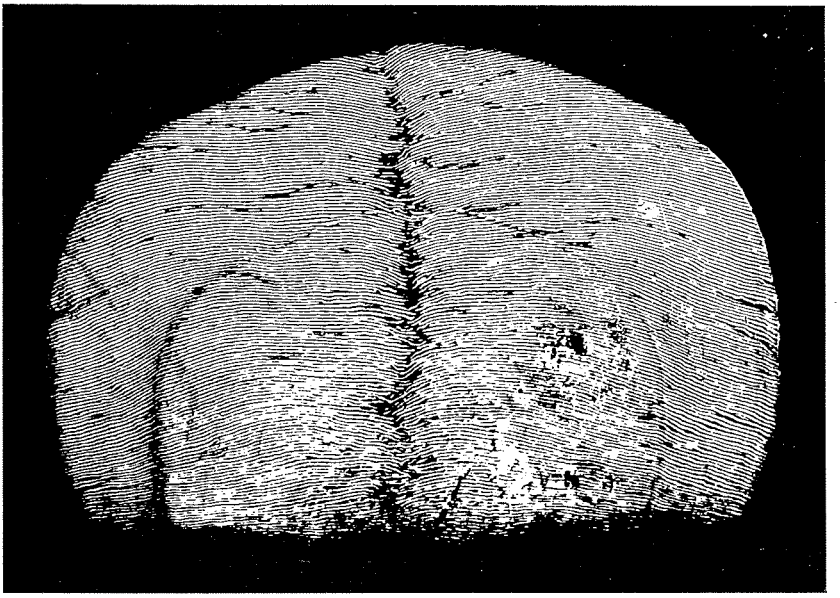

Fig. 1.

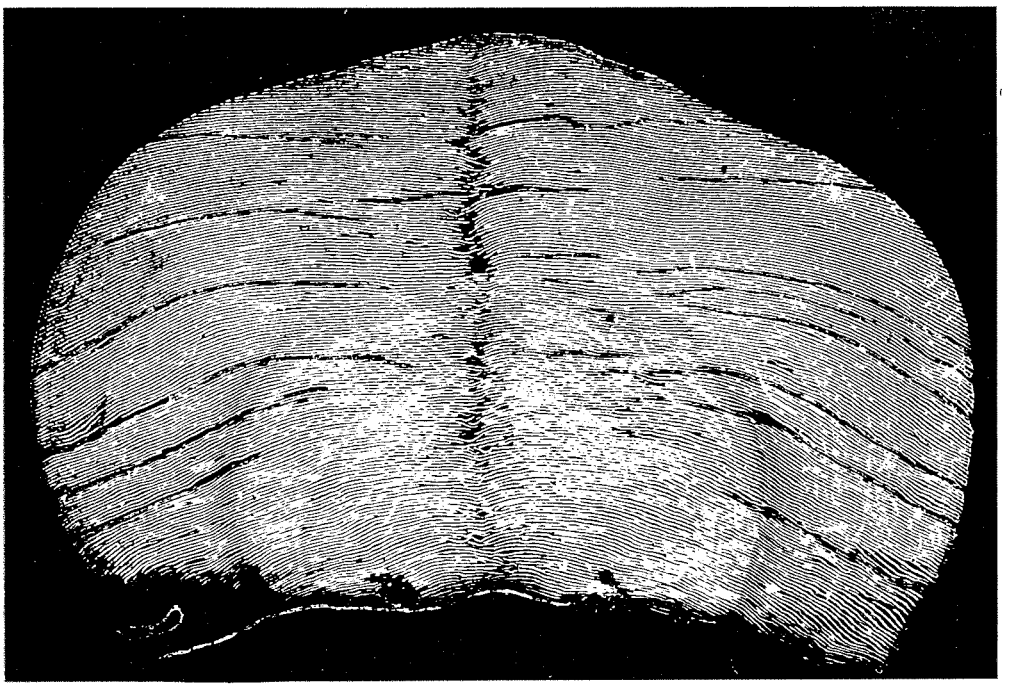

Fig. 2.

Plate II

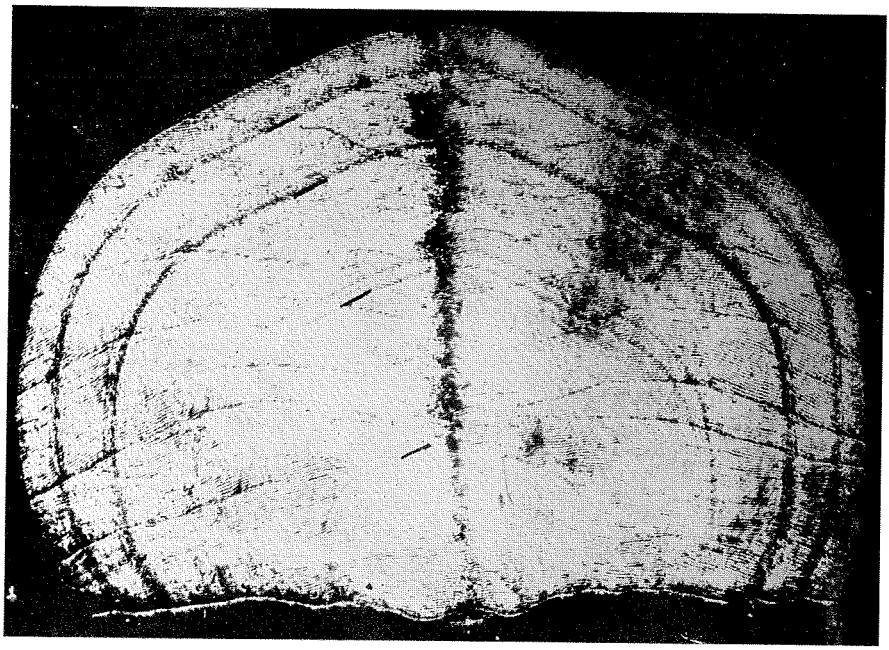

Fig. 1.

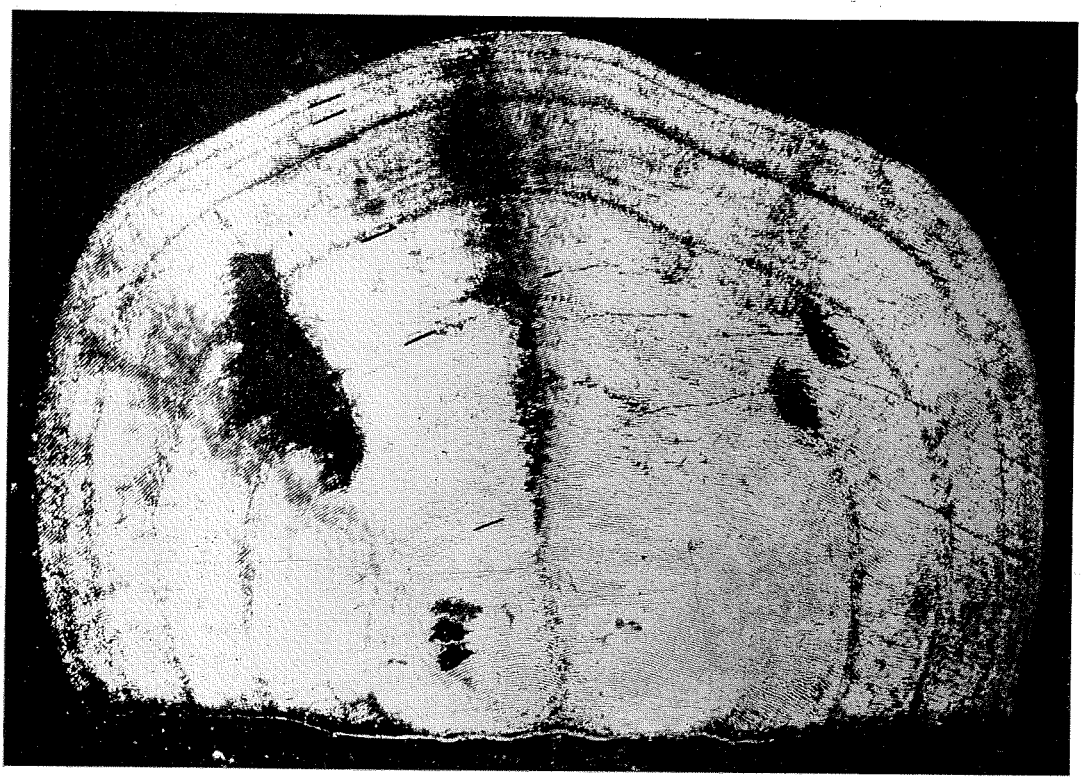

Fig. 2.

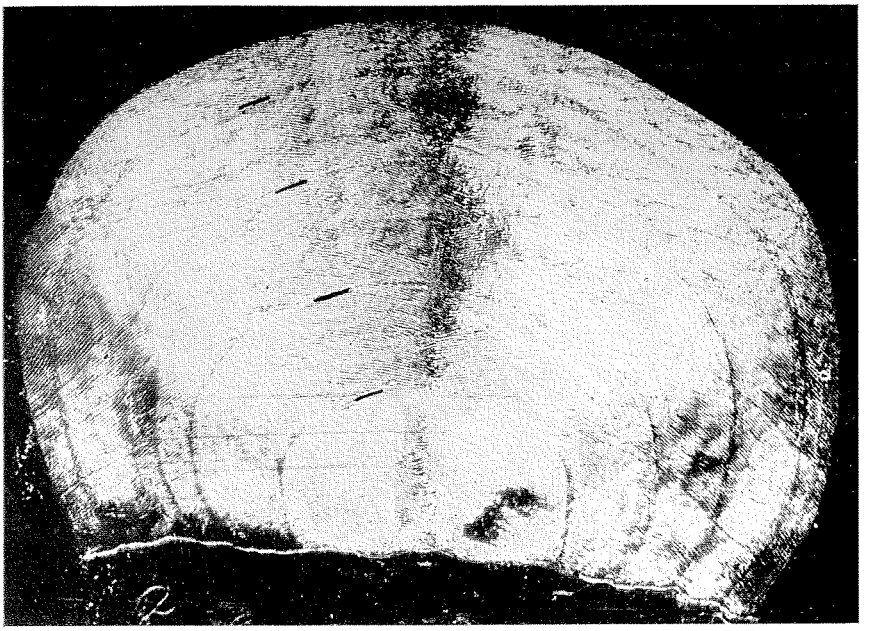

Fig. 1.

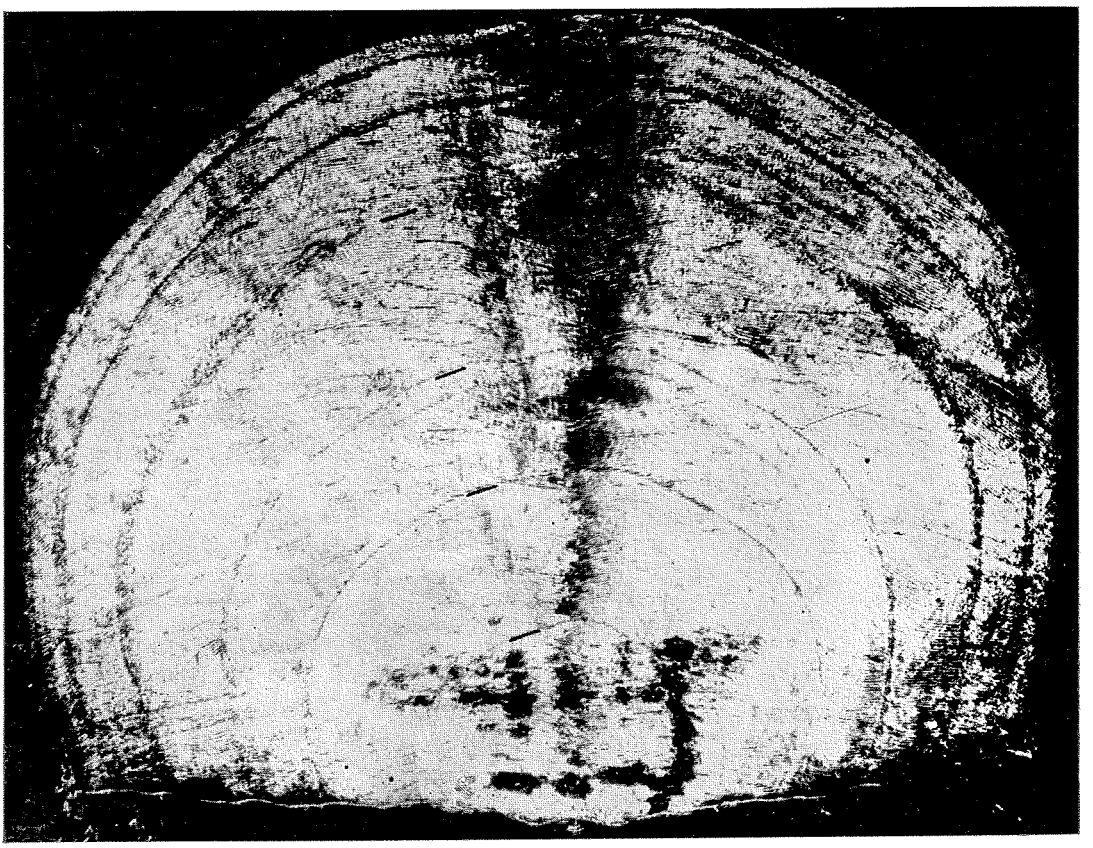

Fig. 2.