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ASPECTS OF THE LIFE HISTORY OF THE LOCAL HERRING STOCK IN LINDÅSPOLLENE, WESTERN NORWAY

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ABSTRACT

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Gill net and purse seine samples were obtained during 1970–1974 for studies of the biology of the local herring stock in a landlocked fjord, Lindåspollene, in western Norway. The herring stock revealed a distinct migration pattern within the system, with a well defined spawning, feeding and overwintering area. The mean number of vertebrae was 56.70. The age, as determined from scale readings, reached 15 years, but only about 2% exceeded 10 years of age. The growth of the Lindås herring was slower than that of the Atlanto-Scandian or North Sea herring stocks, reaching L_∞ = 30.49 cm. The raw weight of the largest individuals was about 250 g. The condition factor reached its maximum in August–October and minimum in May. The mean weight loss during spawning was about 20% of the total weight. The herring spawned in late March, usually in a small fjord arm at depths ranging from 0 to 4 m. Studies of the fecundity showed large variability in number of eggs within length groups. The strength of the year classes and the growth rate of the Lindås herring is discussed in relation to biotic and abiotic conditions of the environment.

INTRODUCTION

Along the Norwegian coast there are a number of small fjords and semi enclosed bays («poll» in Norwegian) in which there are small, more or less self contained herring populations. These local herring stocks can usually be readily distinguished from the oceanic herring by the growth characteristics, and some of the populations have been subjected to scientific studies previously (AASEN 1952, 1953, RASMUSSEN 1941, 1958).

The symposium arranged by the International Council for the Exploration of the Sea (ICES) on «Herring population studies» in Copenhagen, 1961, recommended intensive studies of small, self contained populations in order to throw light upon problems such as reproduction, larval ecology, growth and tagging techniques, which only with extreme difficulties could be studied on oceanic herring populations (ANON. 1963).

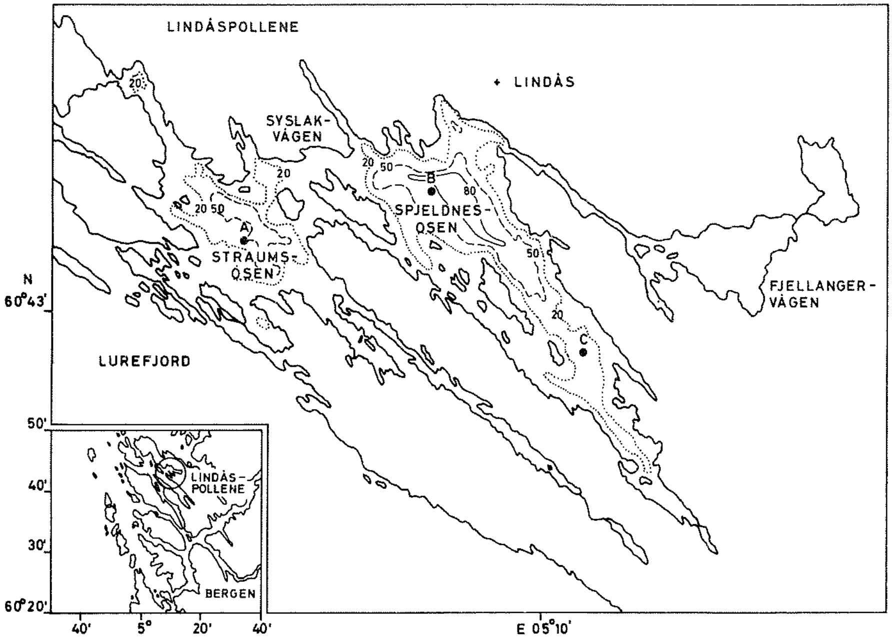

Fig. 1. Depth contour lines and hydrographical stations in Lindåspollene.

Following this recommendation, studies on a number of local herring populations in western Norway were carried out during 1962–1963 (ANON. 1969). The local stocks were as a rule rather strongly mixed with coastal herring which migrated in and out of the «polls» but the herring in Lindåspollene (Fig. 1) appeared to be less influenced by «strange» herring than the other stocks investigated. The Institute of Marine Research, Directorate of Fisheries, therfore decided to undertake intensive studies of the local herring stock in Lindåspollene. The primary emphasis should be on the description of the natural history and the population dynamics of the herring which would be a basis for studies of the relationships between stock and exploitation.

It was realized that the population parameters of the herring stock are intimately related to biotic and abiotic factors of the environment, and therefore it was decided to carry out studies of the entire ecosystem in Lindåspollene simultaneously. The Institute of Marine Biology, University of Bergen, would be responsible for the investigation on the Lindåspollene ecosystem. An outline of the research topics and the objectives of the co-operative studies between the Institute of Marine Research and the Institute of Marine Biology has been given by DAHL, ØSTVEDT and LIE (1973).

The present paper reports on the studies of the herring in Lindåspollen during the period 1970–1974, with particular emphasis on aspects of the

Table 1. Herring samples from Lindåspollene (1970–1974).

No.	Date	Number of fish	Gear	No.	Date	Number of fish	Gear
1a	23 August-70	84	Purse seine	26	4 October-72	23	Gill nets
1b	4 October-70	16	Gill nets	27	12 October-72	139	Purse seine
2	11 Nov.-70	16	»	28	9 Nov.-72	286	Gill nets
3	28 Nov.-70	100	»	29	7 Decemb.-72	4	»
4	27 January-71	76	»	30	10 January-73	24	»
5	26 Febr.-71	24	»	31	1 Febr.-73	21	»
6	18 March-71	37	»	32	23 March-73	7	»
7	28 March-71	119	»	33	28 March-73	27	»
8	22 April-71	80	»	34	29 March-73	31	»
9	5 May-71	7	»	35	11 April-73	25	»
10	10 May-71	90	»	36	25 July-73	15	»
11	8 June-71	8	»	37	15 August-73	8	»
12	10 June-71	100	»	38	23 August-73	40	»
13	29 July-71	26	»	39	12 Sept.-73	100	Purse seine
14	17 August-71	150	Purse seine	40	12 Sept.-73	124	»
15	8 Sept.-71	100	»	41	25 October-73	23	Gill nets
16	20 Sept.-71	70	Gill nets	42	16 January-74	63	»
17	19 October-71	19	»	43	20 Febr.-74	30	»
18	22 Nov.-71	150	»	44	14 March-74	83	»
19	26 January-72	275	»	45	21 March-74	147	»
20	9 March-72	57	»	46	28 March-74	8	»
21	22 March-72	37	»	47	2 April-74	100	»
22	26 April-72	14	»	48	27 July-74	9	»
23	25 May-72	7	»	49	21 August-74	36	»
24	25 May-72	15	»	50	5 Sept.-74	50	Purse seine
25	31 August-72	75	»				

life history and population dynamics of the herring. The material, which is the basis for the study, did not lend itself to estimates of stock abundance, and important topics such as recruitment, mortality, production and yield have therefore been ommitted in this report.

MATERIAL AND METHODS

The present paper is based on 44 gill net samples containing 2428 herring collected during the period October 1970–September 1974 and five purse seine samples collected during the period August–October of 1970, 1971, 1972, 1973 and 1974 (Table 1).

The gill nets (52 mm mesh size) were set on localities in Lindåspollene which are traditionally good fishing grounds (Fig. 2), and the plan was to obtain one sample per month. However, during the summer months the catches were often negative, and in February and December 1973 fishing was prevented by ice. On some occasions, particularly during the spawning

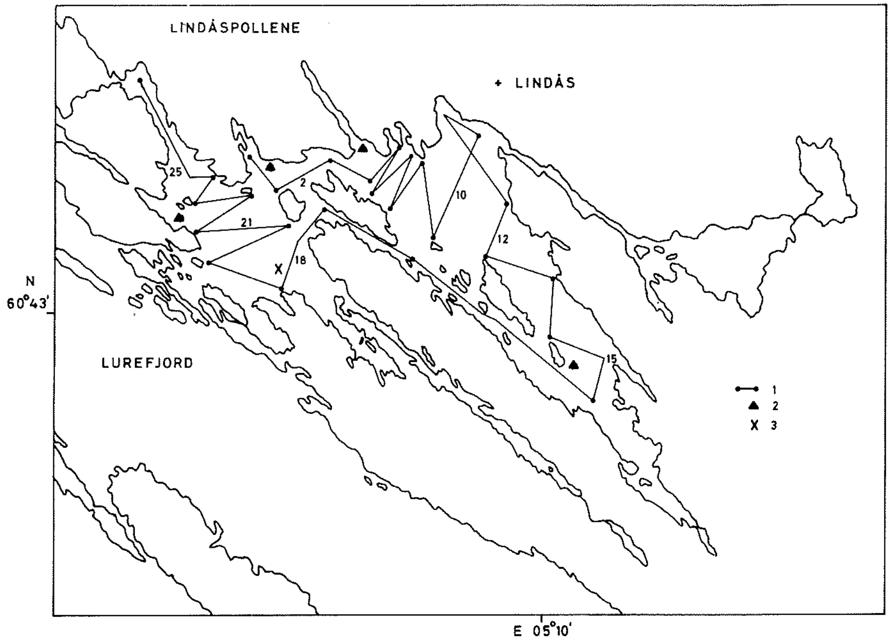

Fig. 2. Echo survey course tracks (1) gill net (2) and purse seine (3) sampling localities.

season, more than one sample was obtained in the same calender month. Data were then pooled to give monthly samples.

The purse seine catches were obtained with seines designed for commercial sprat fishing, and the sampling took place at night using artificial light. The samples contained several age groups of herring, with a preponderance of immature year classes. The purse seine catches were always made in the southern part of Straumsosen (Fig. 2).

The migrations of the herring within the Lindåspollene were determined from observations of the horizontal and vertical distribution of the herring during the investigated period. The observations were made on acoustic surveys which since March 1972 were made along fixed cruise tracks (Fig. 2). During the period August 1970–December 1973 the surveys were made with a SIMRAD EM2F (38kHz) echosounder and during 1974 with a SIMRAD EY (80kHz) echosounder.

The vertabrae were counted on 846 individuals from the gill net samples.

Length of 2421 individuals was measured from the tip of the snout to the longest caudal fin ray, with the lobes of the tail in the mid line (ANON. 1963). The lengths were measured to the nearest ½ cm below and subsequently grouped to the nearest cm below. True mean lengths have therefore been obtained by adding 0.5 cm to the calculated mean lengths.

Wet weights of 2233 herring were determined to the nearest 5 g, and grouped into 10 g intervals.

The nutritional state of the herring was expressed by the condition factor (FULTON 1911):

condition factor (K) = weight (W)/length $(L)^3$

and by the relative amount of intestinal fat classified according to AASEN (1952) into:

class 0: no fat,
class I: traces of fat,
class II: moderate fat,
class III: much fat.

The age of 2067 individuals was determined by reading the winter rings on the scales. Back calculations of lengths from measurements on the scales were performed on all the herring caught on the gill nets during 1971, using the formula of LEA (1910) and ANON. (1963)

$$l_n = \frac{s_n}{s} L$$

where s_n = radius of scale annulus at age n, s = scale radius, L = length of fish at sampling. Since length at sampling was measured to the nearest ½ cm below, 0.25 cm has been added to obtain true mean lengths.

The maturity stages of the herring were determined by the method of JOHANSEN (1919) as modified bye the ICES Working Group on Methods used in the North Sea Herring Investigations (ANON. 1963):

STAGE

I Virgin herring. Gonads very small, threadlike, 2–3 mm broad. Ovaries wine red. Testes whitish or grey brown.

II Virgin herring with small sexual organs. The height of ovaries and testes about 3–8 mm. Eggs not visible to naked eye but can be sèen with magnifying glass. Ovaries a bright red colour; testes a reddish grey colour.

III Gonads occupies about half of the ventral cavity. Breadth of sexual organs between 1 and 2 cm. Eggs small but can be distinguished with naked eye. Ovaries orange; testes reddish grey or greyish.

IV Gonads almost as long as body cavity. Eggs larger, varying in size, opaque. Ovaries orange or pale yellow, testes whitish.

V Gonads fill body cavity. Eggs large, round; some transparent.Ovaries yellowish; testes milkwhite. Eggs and sperm do not flow, but sperm can be extruded by pressure.

VI Ripe gonads. Eggs transparent; testes white; eggs and sperm flow freely.

VII Spent herring. Gonads baggy and bloodshot. Ovaries empty or containing only a few residual eggs. Testes may contain remains of sperm.

VIII Recovering spents. Ovaries and testes firm and larger than virgin herring in Stage II. Eggs not visible to naked eye. Walls of gonads striated; blood vessels prominent. Gonads wine red colour. (This stage passes into Stage III).

The number of eggs per unit weight of the gonads was determined by counting parts of gonads from 73 herring under a dissecting microscope. The gonads were preserved in Gilson's fluid and treated according to BAXTER (1959) before counting. Total number of eggs per gonad was determined by multiplication with total gonad weight. The fecundity of an additional 45 herring was determined by complete counting of eggs in the ovaries by an automatic particle counter (BERGE and PETTERSEN 1974).

RESULTS

MIGRATIONS

In a preliminary report on the acoustic surveys during 1971–1972 and the first three months of 1973, ØSTVEDT, DAHL and LIE (1973) discussed the apparent migration pattern of the herring in Lindåspollene. The major conclusions were:

a) the herring spawned in Syslakvågen in late March,
b) after spawning the herring moved into Straumsosen and remained there during the summer,
c) in September–October the herring moved into Spjeldnesosen and scattered,
d) in November–December the herring concentrated in the northern part of Spjeldnesosen and remained there until spawning in March.

This migration pattern was largely confirmed by the investigations during 1973–1974, but there were also some major discrepancies between the two periods of investigation. Thus, there was no spawning migration into Syslakvågen in 1973, and no other spawning area was located. In 1974 the herring had a normal spawning migration into Syslakvågen.

The migration pattern after spawning was also somewhat different in 1973–1974 because a part of the stock moved south into Spjeldnesosen and remained there during the summer. However, the major part of the stock moved into Straumsosen as during 1971–1972.

On the basis of all the acoustic surveys performed during 1971–1974 a migration pattern, as demonstrated in Fig. 3A, B og C, is suggested. The pattern during September–March is repeated each year, but the distribution during the rest of the year is less clear. Thus, the migration to the spawning grounds must be further studied and also the distribution during May–August.

ØSTVEDT *et al.* (1973) discussed the vertical distribution of the herring and concluded that the herring during the winter was distributed at about 50–60 m depth. The distribution during the summer was higher up in the sea. They also demonstrated vertical diurnal migrations, with a distribution near the surface at night.

The acoustic surveys during 1973–1974 were carried out during daytime, and the herring was as a rule distributed at intermediate depths (Fig. 4).

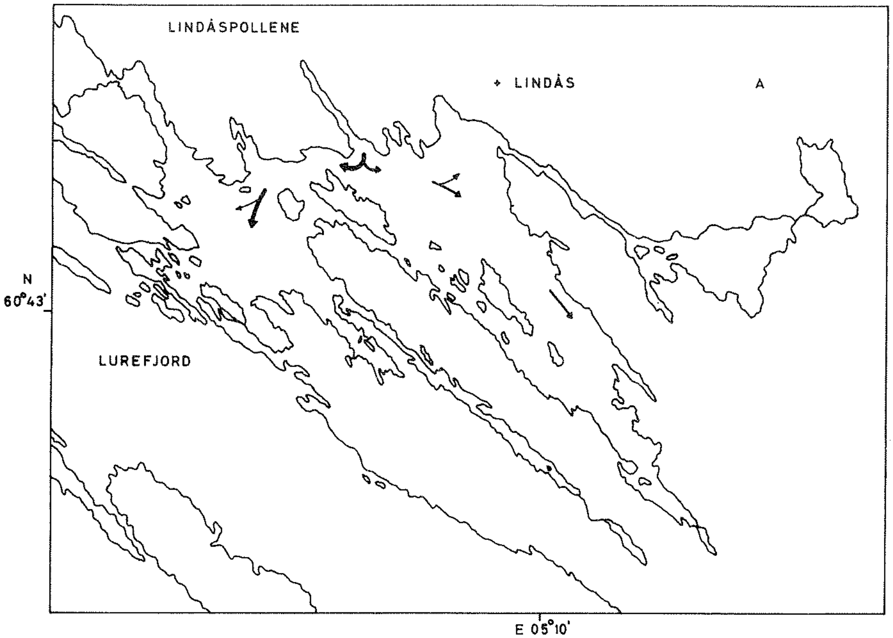

Fig. 3A. Migration pattern of the Lindås Herring during April–August.

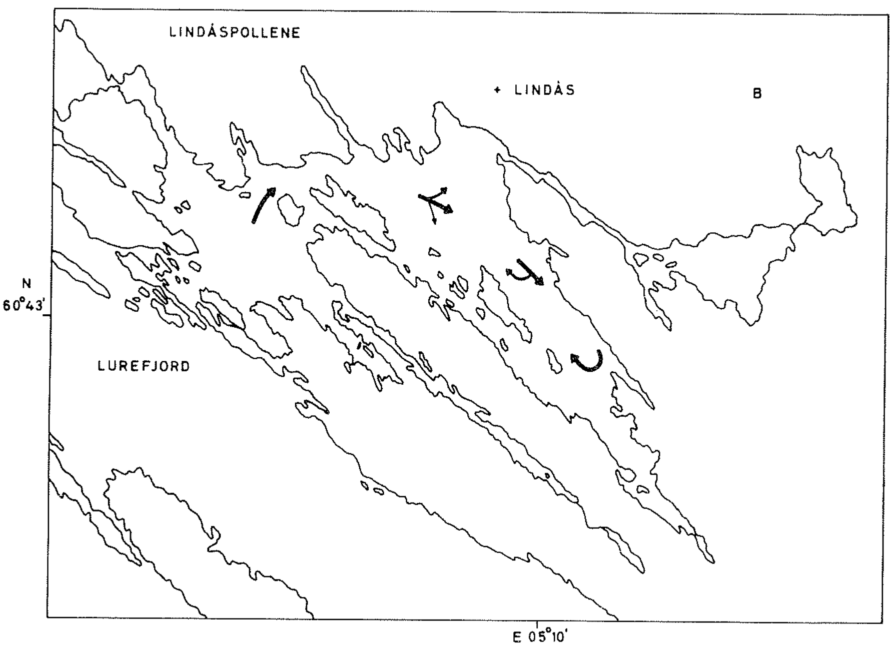

Fig. 3B. Migration pattern of the Lindås herring during September–October.

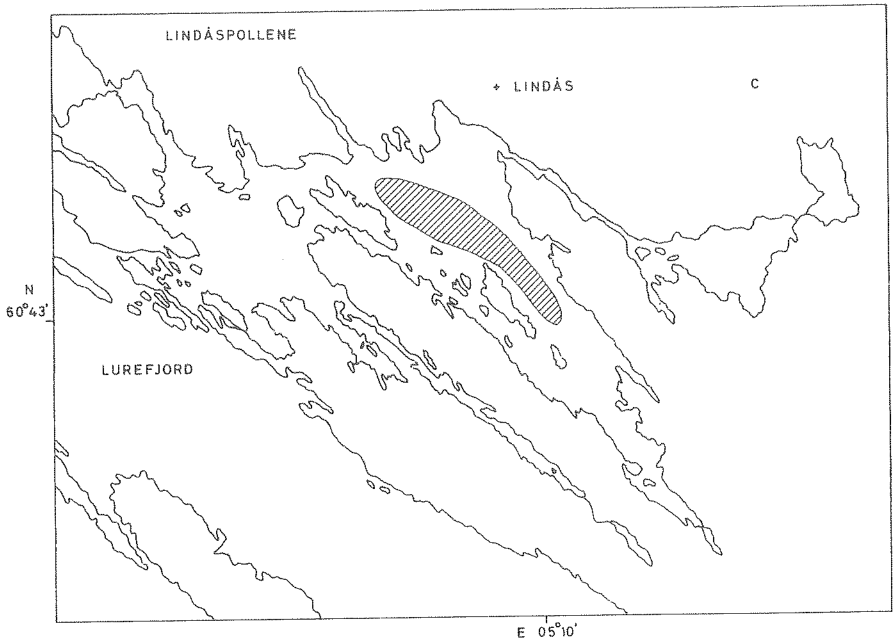

Fig. 3C. Migration pattern of the Lindås herring during November–March.

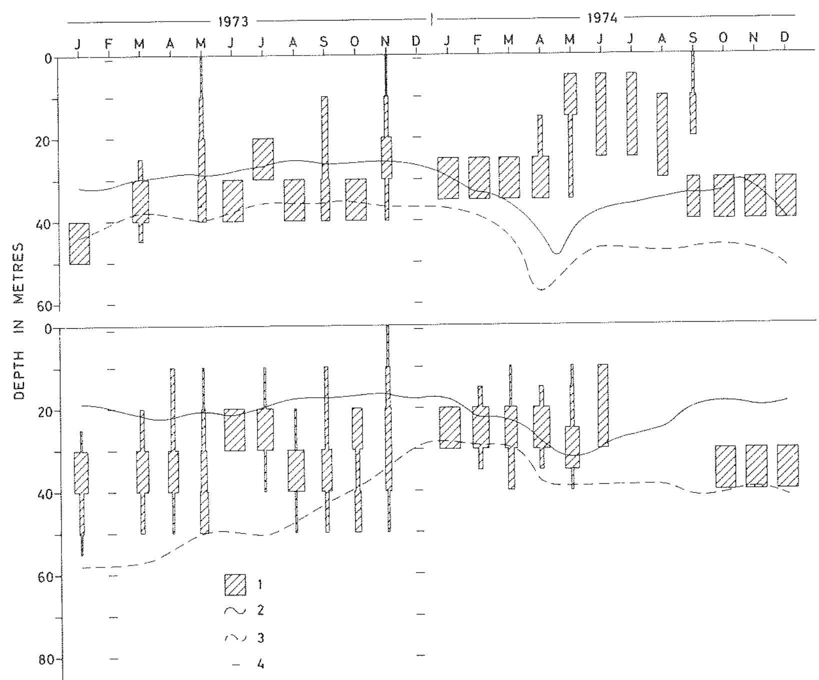

Fig. 4. Vertical distribution of the Lindås herring during 1973–1974 in relation to oxygen concentration of the water masses. 1) Herring concentration, 2) 4,0 ml $0_2/l$ $^{3)}$ *1,0 ml* $0_2/l$, 4) no observation.

Table 2. Frequency distribution of number of vertebrae of the herring in Lindåspollene during 1970–1973.

Data	Number of vertebrae						Mean	n	S^2	± C.I.
	54	55	56	57	58	59				
1970										
October	–	–	7	6	2		56.67	15	0.524	0.3738
November ...	1	1	41	56	16	1	56.76	116	0.837	0.1698
1971										
January	–	1	21	45	4	–	56.73	71	0.763	0.2073
February	–	–	7	13	4	–	56.88	24	0.535	0.2986
March	–	4	41	42	10	1	56.62	98	0.527	0.1467
April	1	2	28	33	10	–	56.66	74	0.636	0.1854
May	2	5	20	52	6	–	56.65	85	0.636	0.1730
August	–	–	10	35	5	–	56.90	50	0.296	0.1539
September ...	–	4	20	28	18	–	56.86	70	0.762	0.2087
November ...	–	7	33	46	11	–	56.63	97	0.611	0.1587
1972										
January	3	7	27	52	7	–	56.55	96	0.734	0.1748
1973										
September ...	–	2	20	22	6	–	56.64	50	0.561	0.2118
Total	7	33	275	430	99	2	56.70	846	0.589	0.0528

There was a tendency for the herring to be concentrated nearer the surface during the summer. It should be noticed that the data in the figure are percentages, and therefore the figure gives no information about the strength of the recordings between months. Thus, the data for Straumsosen during September–April and for Spjeldnesosen during May–August are based on very few and scattered recordings.

Fig. 4 shows that the majority of the recordings were made in the water layer limited by the isolines for 1 ml O_2 per litre and 4 ml O_2 per litre, and particularly during the winter the herring seems to remain in water masses characterized by very low oxygen tension. This is peculiar for a pelagic fish, and KAMSHILOV and GERASIMOV (1960) demonstrated that young Murman herring kept in aquaria died in oxygen concentrations below 2 ml per litre.

IDENTIFICATION OF THE POPULATION

The preliminary investigations in Lindåspollene during 1962–1964 showed the presence of two distinct components in the herring stock: a) a slow growing component which constitute the major part of the stock, and b) a fast growing component which was considerably less important (ANON. 1964). The latter component was referred to as the «strange» herring, in accordance with AASEN (1952).

Table 3. Analyses of variance on vertebrae counts.

Source of variation	df	SS	MS	F
Among months	11	19.30	1.75	2.97 (P 0.01)
Within months	834	489.50	0.59	
Total	845	508.80		

Vertebral counts as a means of distinguishing between populations or «races» of herring from northern European waters has been used by a number of authors (viz. RUNNSTRØM 1941, AASEN 1952, CUSHING 1958 and ZIJLSTRA 1958). In order to investigate the possible relationships between the Lindås herring and neighbouring herring stocks, vertebrae were counted in 846 individuals collected during the period October 1970– September 1973.

The monthly mean number of vertebrae in the herring from the gill net samples ranged from 56.55 to 56.90, with an overall mean of 56.70 (Table 2). An analysis of variance (Table 3) showed that there was a significant added variance component among months, but this component did not amount to more than 0,95% of the total variance, and there was no distinct seasonal or annual trend in the monthly mean number of vertebrae.

It is not unexpected that herring samples collected during a timespan of about three years would reveal differences in the mean number of vertebrae. In the first part of the investigated period the samples were strongly dominated by the 1966 year class, but from about August 1972 the 1969 year class became increasingly more important. It is conceivable that variability in the sea temperatures on the spawning grounds could cause differences in the number of vertebrae of various year classes. An inverse relationship between number of vertebra and the sea temperatures on the spawning grounds has been demonstrated by a number of authors, and considerable fluctuations in the temperatures on the shallow spawning ground in Syslakvågen must be expected.

During 1962–1964 the «strange» herring had a mean verebral count of 57.0 to 57.2 whereas the slow groving component of the Lindås herring had a mean vertebral count of from 56.4 to 56.6 (ANON. 1964). The «strange» herring during the period 1970–1973 had a mean vertebral count of 56.65 and could therefore not be distinguished significantly from the slow growing component. Thus, there seems to have been a distinct change in the number of vertebrae in the «strange» herring from 1962–1964 to 1970–1973. In 1962–1964 the number of vertebrae in the «strange» herring could not be significantly distinguished from the Atlanto Scandian herring stock (ANON 1964), and during 1970–1973 the number of vertebrae did not differ from that of the North Sea spring spawning stock (Table 4). Hence,

Table 4. Mean vertebrae numbers of the year class 1969 from different groups of spring spawning herring.

Race	V. S. Mean	Number	S^2	± C.I.
Lindås herring	56.64	462	0.591	0.0715
North S. herring	56.84	107	0.380	0.1192
Atlanto Scandian herring ...	57.02	631	0.371	0.0485

the hypothesis cannot be rejected that the «strange» herring in Lindåspollene during 1962–1964 represented specimens from the Atlanto Scandian stock, and during 1970–1973 from the North Sea spring spawning stock. It is noteworthy that the change in the apparent origin of the «strange» herring component coincided with the drastic reduction of the Atlanto Scandian herring stock (DEVOLD 1968).

The mean number of vertebrae in the slow growing component of the 1969 year class Lindås herring was quite similar to the mean number of vertebrae of the North Sea herring of the same year class (Table 4). The difference to the Atlanto Scandian stock of the same year class was more pronounced and significant beyond the 99% level of probability.

AGE

The age of the herring in Lindåspollene can easily be determined by scale readings because the winter growth rings are always well defined (Fig. 5), similar to the northern growth type of the Atlanto Scandian herring stock (LEA 1929). The age at first spawning can also often be ascertained because the growth ring during the preceding summer is distinctly reduced.

The age was determined by scale readings from 2067 individuals collected with gill nets during the period October 1970–September 1974 (Table 5). Some two year old herring were caught by the gill nets, but the population does not seem to become fully vulnerable until the fourth year.

The herring in the gill net samples ranged in age from 2 to 15 years, but only about 2% were older than 10 years. Thus, the Lindås herring is relatively short lived compared to the Atlanto Scandian herring stock where specimens reaching 24–25 years of age were frequently caught in years of high stock abundance and low fishing mortality (DEVOLD and DAHL 1964).

The 1966 year class was strong during 1971, but from the second quarter of 1972 the 1969 year class became increasingly dominant (Table 5). Subsequently, there was a reduction in the relative strength of the 1966 year class. On the basis of the relative strengths of the year classes alone, it cannot

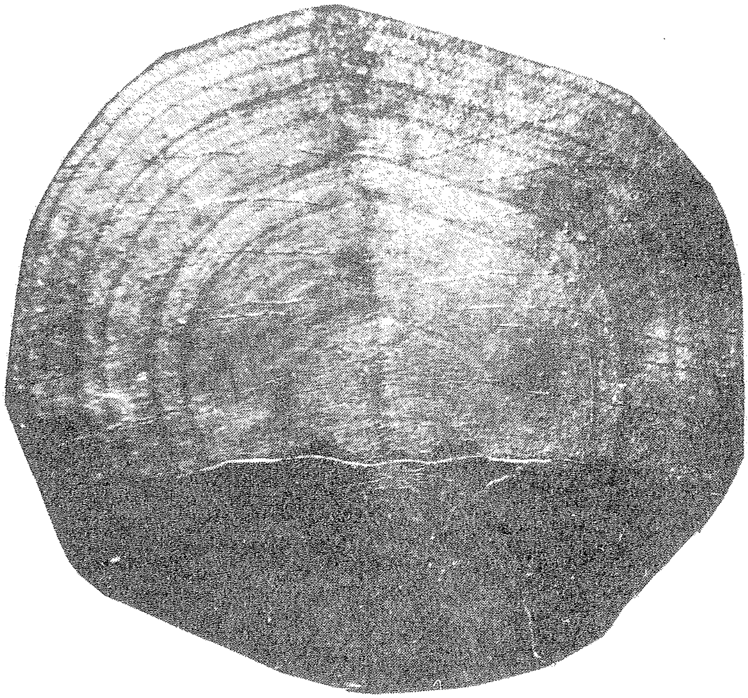

Fig. 5. Growth rings in the scale of a Lindås herring.

be determined whether the decrease in the percentages of the 1966 year class is a result of the emergence of a very strong 1969 year class, or if there was a concurrent increase in the mortality of the 1966 year class.

Table 6 shows that the 1964, 1965, 1967 and the 1968 year classes were weak whereas there is some indication that the 1962 and the 1963 year classes had been relatively strong. The preliminary investigations in Lindåspollene during 1962–1964 demonstrated that the 1959 year class was strongly dominant during that period (DAHL *et al* 1973).

LENGTH AND GROWTH

The length of the herring from the gill net samples collected during the period October 1970–September 1974 ranged from 21 to 35 cm, but about 90% of the individuals measured from 25 to 30 cm (Table 7). The majority of the individuals larger than 31 cm belonged to the «strange» herring component. The monthly mean lengths were not significantly different during 1970–1971 when the 1966 year class dominated in the samples, averaging 27.34 cm. However, there was a distinct decrease in the mean length from August 1972 when the 1969 year class became more predominant. Thus, the average of the monthly mean lengths during 1973 were only 25.57 cm.

Table 5. Seasonal composition (%) in the age structure of the Lindås herring, 1970–1974 (gill nets).

Date	Age in years														n
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1970															
October–December	0.8	2.4	75.9	7.3	0.8	4.8	5.6	0.8	0.3	0	0.8	0	0	0	124
1971															
January–March	2.2	3.9	8.7	53.4	9.1	1.3	6.5	7.8	1.7	0.4	0	0	0	0	230
April–June	0.4	5.6	6.4	76.4	6.7	0	1.9	2.2	0	0	0	0.4	0	0	267
July–September	2.2	3.3	7.8	61.1	8.9	6.7	4.4	2.2	0	2.2	0	0	0	0	90
October–December	10.1	10.7	3.8	43.4	6.9	3.8	3.8	13.2	3.1	0	0.6	0	0	0.6	159
1972															
January–March	0	5.0	4.7	1.8	48.9	10.9	2.5	4.0	11.2	3.3	1.8	1.1	0.4	0.4	276
April–June	10.3	17.0	13.8	10.3	24.1	3.4	3.4	3.4	6.8	6.8	0	0	0	0	29
July–September	8.3	44.4	5.5	5.5	30.6	0	0	2.3	1.4	1.4	0	0	0	0	72
October–December	3.2	32.5	4.5	2.5	42.7	0.6	1.3	5.7	3.3	1.3	1.9	0	0	0	157
1973															
January–March	2.8	12.1	54.3	6.5	2.8	15.0	0	2.3	2.3	0	0.9	0	0	0	107
April–June	0	8.0	88.0	0	0	4.0	0	0	0	0	0	0	0	0	25
July–September	10.4	6.2	81.3	0	0	2.1	0	0	0	0	0	0	0	0	48
October–December	5.0	10.0	75.0	0	0	5.0	5.0	0	0	0	0	0	0	0	20
1974															
January–March	7.6	10.2	10.2	64.0	3.4	0	3.4	0.6	0.3	0	0.3	0	0	0	325
April–June	0	0	3.1	75.0	9.5	2.1	8.3	0	1.0	1.0	0	0	0	0	96
July–September	33.3	40.5	4.8	21.4	0	0	0	0	0	0	0	0	0	0	42

Table 6. Annual age composition (%) of the Lindås herring samples in the years 1970–1974 (gill nets).

Years	Age										n
	2	3	4	5	6	7	8	9	10	<10	
1970	0.8	2.4	75.9	7.3	0.8	4.8	5.6	0.8	0.8	0.8	124
1971	3.2	5.9	6.7	62.1	7.8	2.0	4.0	6.3	1.2	0.8	746
1972	2.6	19.6	5.5	3.1	45.8	6.5	2.2	4.3	7.5	5.9	534
1973	4.5	8.5	67.0	3.5	1.5	10.5	0.5	1.5	1.5	1.0	200
1974	5.9	7.8	8.6	66.4	4.8	0.5	4.5	0.5	0.5	0.5	463

Table 7 indicates that the herring in Lindåspollene did not b ecome fully vulnerable to the gill nets before they had reached a length of about 24 cm.

The length distribution of the herring caught in the purse seine in the autumn of each of the years 1970–1974 indicates the relative strengths of the year classes that were not vulnerable to the gill nets at the time of sampling (Table 8). The samples from 1970 and 1971 were strongly dominated by the 1969 year class, and the absence of the 1970 and 1971 year classes as 0- or 1-group indicates that the latter year classes were weak. The 1972 year class, however, was very abundant in the 1972 sample as 0-group, in the 1973 sample as 1-group and in the 1974 sample as II-group which indicates that the 1972 year class is relatively strong.

The length-at-age was determined by back calculations from scale readings for 626 herring caught during 1971. Considerable and statistically significant differences among the year classes regarding growth during the first four years of life were clearly discernable (Table 9). The 1965, 1967 and 1968 year classes had significantly higher l_1, l_2, and l_3 than the year classes 1962, 1963 and 1966. The l_1 and l_2 for the 1969 year class indicate that it belongs to the latter group. In the comparison of lengths-at-age for different year classes it should be kept in mind that the results will be biased by presence of Lee's phenomenon (LEE 1920), and this would particularly apply to the 1962 and 1963 year classes in the present study. However, since the lengths-at-age are determined from the individuals caught in 1971 only, the importance of the Lee's phenomenon cannot be estimated.

It is an interesting fact that the year classes which were classified as relatively strong on the basis of the age frequencies (Table 6) were precisely the year classes characterized by low l_1 and l_2. This indicates that the growth rates during the first years of life may be density dependent. It seems also that slow growth during the first year of life is not compensated by more rapid growth during the following 2–3 years.

The length-at-age as determined for the entire 1971 material is shown in

Table 7. Length frequency distributions, true mean lengths (L), and 95% confidence intervals (C.I.) of the means, of herring from gill-net samples in Lindåspollene, 1970–1974.

	Length, cm										n	Mean L(cm)	± C.I.
	<24	24	25	26	27	28	29	30	31	>31			
1970													
October ...			2	4	8	1		1			16	27.25	0.59
November .		1	3	28	36	17	12	13	5	1	116	28.09	0.28
1971													
January ...			1	8	34	10	11	8	4		76	28.32	0.33
February ..		2	1	6	6	3	2	1		1	22	27.55	0.79
March.....	1	1	12	25	48	26	23	9	6	5	156	28.13	0.30
April		1	9	20	31	14	3	2			80	27.31	0.26
May		1		12	50	23	5	3	2		96	27.86	0.22
June			3	18	49	24	8	4	2		108	27.83	0.27
July	1	2	1	5	9	7			1		26	27.27	0.63
September .			4	8	19	17	10	9	3		70	28.36	0.36
October ...	1	1	1	1	3	2	2	4	4		19	28.76	1.13
November .	1	13	8	20	24	32	23	25	4		150	28.10	0.31
1972													
January ...			12	16	71	74	60	36	5	1	275	28.54	0.16
March		2	1	8	23	29	12	12	6	1	94	28.60	0.33
April	1	3		2		2	3	1	1	1	14	27.86	1.67
May				1	5	1	9	5	1		22	29.18	0.56
August	1	12	12	11	13	16	4	3	3		75	27.10	0.45
October ...	2	7	5	4	2	1	1	1			23	25.89	0.76
November .	2	6	26	32	25	68	66	43	14	4	286	23.53	0.22
1973													
January ...	1	4	5	2	3	2	6	1			24	27.04	0.87
February ..	5	2	5	3	2	3	1				21	25.88	0.80
March.....		8	23	8	8	4	6	6	2		65	26.95	0.46
April	1	14	4	4		1	1				25	25.30	0.55
July	9	1	4		1						15	24.03	0.80
August	4	9	19	12	2	1	1				48	25.50	0.43
October ...			6	5	3	1	5	1	1	1	23	27.76	0.88
1974													
January ...	1	8	16	13	13	7	2	2		1	63	26.71	0.45
February ..			5	5	4	5	3	2	1	5	30	28.53	0.88
March		9	52	80	58	22	11	5		1	238	26.89	0.17
April			9	34	22	23	7	3	1	1	100	27.55	0.26
July	1		2	5	1						9	25.94	0.47
August	24	8	3	–	–	1					36	23.25	0.26
Total	56	115	254	400	573	437	297	200	66	22	2 421		

Table 8. Length distribution of herring (in per cent) from purse seine catches in Lindåspollene, 1970–74.

Year	Length, cm																						n
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
1970						1.2	35.7	42.9	15.5	4.7													84
1971							6.4	6.8	4.3	1.7	11.5	26.7	22.2	12.4	4.3	2.1	0.4	0.4	0.4	–	–	0.4	234
1972	1.4	47.5	46.2	1.4	0.7	–	–	–	0.7	0.7	–	0.7	–	–	0.7	–							139
1973					64.0	25.0	1.0	1.0	–	–	–	1.0	–	–	–	–	1.0	4.0	2.0	1.0	–	–	100
1974									6.0	32.0	38.0	6.0	–	–	1.0	3.0	2.0	1.0	1.0	6.0	3.0	1.0	100

Table 9. Growth estimates (true mean) for the Lindås herring during the first four years of life (L_1 - L_4), with 95% confidence intervals of the means (C.I.).

Year-class	Length, cm							
	L_1	± C.I.	L_2	± C.I.	L_3	± C.I.	L_4	± C.I.
1970	9.5	0.4						
1969	9.1	0.2	16.2	0.4				
1968	11.2	0.7	19.5	0.8	24.3	0.6		
1967	10.9	0.6	19.0	0.7	23.8	0.6	25.2	0.5
1966	10.0	0.1	16.5	0.2	21.9	0.1	25.4	0.1
1965	11.0	0.3	19.3	0.5	22.5	0.4	24.8	0.3
1963	10.1	0.4	17.3	0.7	21.0	0.9	23.8	0.5
1962	10.0	0.3	16.3	0.4	20.3	0.5	23.2	0.4

Table 10. It should be noticed that the data for the 1961 and 1964 year classes were very scarce, and the estimated length-at-age for these year classes may therefore not be precise. The entries in the table along the diagonal, i.e. length at capture fòr the various year classes, refers to individuals caught during the last quarter of the year only, when annual growth is terminated. The table shows that the length increments for individuals older than 4 years in 1971 were small, indicating unfavourable growth conditions.

The data in Table 10 were plotted in a Walford diagram (Fig. 6) of L_t+_1 versus L_t, and the regression line:

$$L_{t+1} = 10.38 + 0.66L_t$$

Table 10. Growth estimates (true mean) for the Lindås herring from the 1971 material.

Year-class	Length, cm											n
	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	
1970	9.5	15.6										19
1969	9.1	16.2	20.3									96
1968	11.2	19.5	24.3	26.0								25
1967	10.9	19.0	23.8	25.2	26.8							27
1966	10.0	16.5	21.9	25.4	27.5	27.5						331
1965	11.0	19.3	22.5	24.8	27.0	28.6	28.9					55
1964	10.1	17.8	22.0	23.8	25.8	27.6	29.0	29.8				3
1963	10.1	17.3	21.0	23.8	25.5	27.2	28.9	30.0	30.4			22
1962	10.0	16.3	20.3	23.2	23.8	26.0	27.4	28.9	30.2	30.2		39
1961	9.8	15.9	20.6	24.8	25.0	26.2	27.0	28.6	29.7	30.5	30.5	9

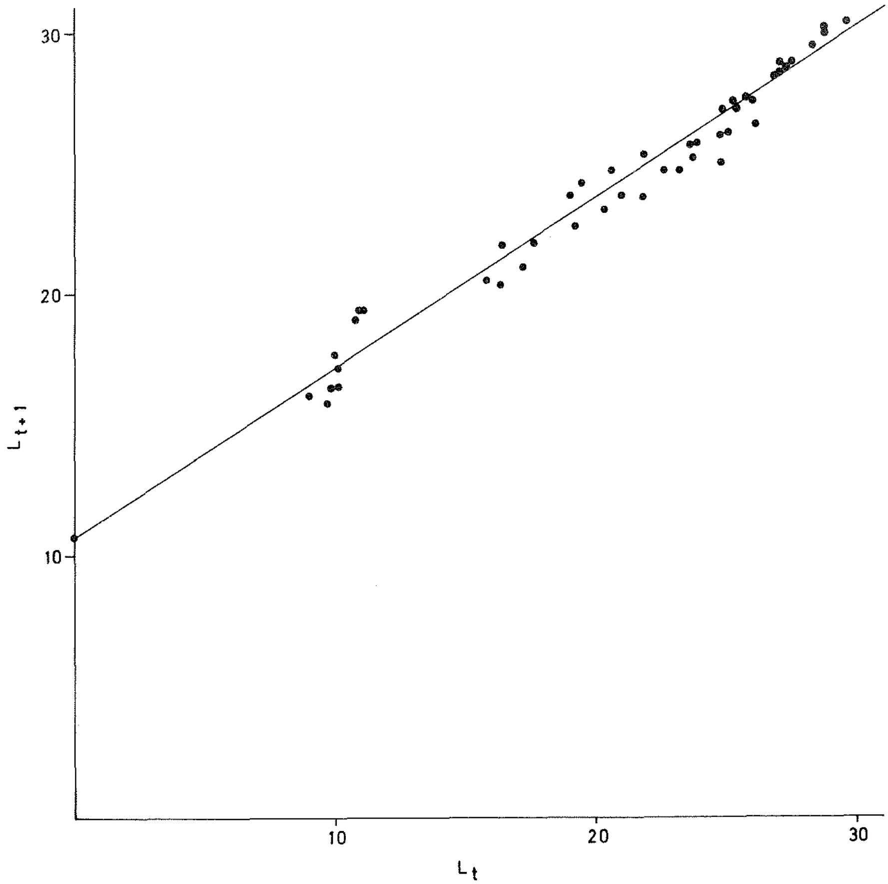

Fig. 6. Walford plot of back calculated lengths from scale readings.

could be fitted by the method of least squares. The regression line was used to determine $L\ \infty = 30.49$ and $t_0 = 0.035$, and the von Bertalanffy growth equation for the Lindås herring was determined as:

$$L_t = 30,49\ (1 - {}_e\ ^{0.416\ (t - 0.035)}\ ).$$

The growth curve represents the mean growth of the Lindås herring well during the first four years of life (Fig. 7), but from the fifth year on the calculated growth was too high. The «strange» herring had a considerably higher growth rate during the first four years of life than the Lindås herring, whereas the Lusterfjord herring (AASEN 1952) had a slower growth (Fig. 7).

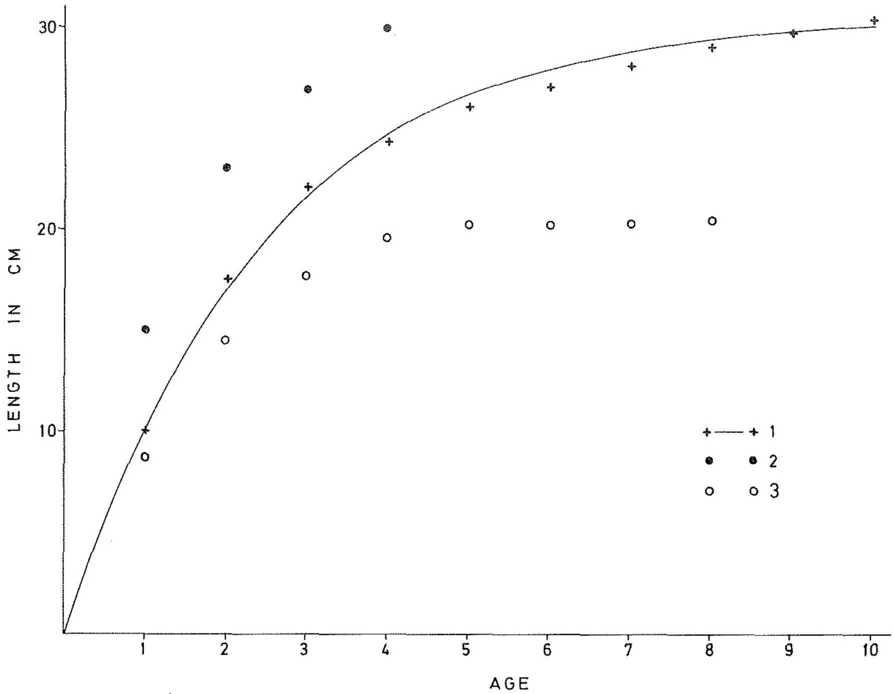

Fig. 7. Von Bertalanffy growth curve for the Lindås herring (1), and length/age plots for the «strange» herring (2) and the Lusterfjord herring (3) from Aasen (1952).

WEIGHT, CONDITION FACTOR AND INTESTINAL FAT CONTENT

The weight of the herring from the gill net samples ranged from 70 to 300 g (Table 11), and about 60% of the individuals weighed from 150 to 200 g. The monthly mean weights during 1973, when the 1969 year class dominated in the samples, were considerably lower than during the preceding years.

The 1966 year class, which dominated during 1970, 1971 and 1972, showed distinct seasonal variability in weight, with minima during the first and maxima during the last quarters of the years (Table 12).

In 1971 the herring did not attain the same weight as in 1970 whereas a pronounced increase in weight took place during 1972. This is an indication that the conditions for the herring in Lindåspollene during 1971 were poor which explains the slow growth during 1971.

The weight/age curve was typically sigmoid (Fig. 8), and the natural logarithms therefore yielded two reasonably straight lines, intersecting at the fourth year of age. This is the age of maturity for the majority of the Lindås herring, and the change in weight increase may therefore be related to the ripening of the gonads.

Table 11. Weight frequency distribution of Lindås herring, 1970–1974.

Month	Weight in g																n	Mean
	<100	100	110	120	130	140	150	160	170	180	190	200	210	220	230	>230		
1970																		
October								5	2	4	1	1	—	—	1	1	15	181
November			1	1	1	1	9	7	13	16	11	15	6	2	3	21	107	196
1971																		
January					1	8	12	12	14	4	6	3	3	3	4	1	71	173
February	2	—	—	2	—	1	3	1	5	1	2	2	1	2	2		24	170
March	1	1	3	3	11	10	23	26	18	9	11	13	3	9			141	165
April				1	6	6	12	15	22	9	3	1	1	2	—	1	79	164
May				1	3	14	22	18	23	9	1	2	1	1			95	160
June				1	5	7	24	30	10	8	10	3	6	—	—	3	107	166
July			3	—	3	1	4	5	4	3	1	1	—	1	—	1	27	160
September			2	1	1	2	6	10	12	7	2	9	8	2	5	4	71	183
October			2	—	2	2	2	—	—	3	—	1	3	—	—	4	19	185
November	1	7	7	5	10	11	16	13	17	17	10	18	7	8	—	4	151	173
1972																		
January			4	7	5	15	34	29	31	25	22	13	12	2	1		200	168
March			1	1	1	4	10	4	5	5	2	1	2	—	1		37	163
April		2	3	—	1	1	1	—	—	3	—	—	—	2	—	1	14	157
May					1	3	1	5	3	3	2	—	2	—	2		22	173
August			3	6	9	2	2	6	5	8	6	7	6	8	2	8	78	182
October			1	9	2	3	—	—	1	2	—	2	1	1	—	1	23	151
November	2	5	5	10	5	8	6	11	6	14	11	13	13	8	12	13	142	176
1973																		
January		4	3	2	2	3	1	3	1	—	1	1	1	1	—	1	24	146
February		3	2	3	—	3	3	2	1	1	—	—	1	1	—	2	22	153
March			7	12	12	2	8	2	5	3	3	1	2	1			58	144
April	2	8	9	2	1	—	2	—	—	1							25	113
July			6	3	1	1	2	1	—	—	—	—	1				15	131
August	6	1	3	5	12	9	5	3	1	1	—	1	—	—	1		48	132
September	7	7	12	23	21	17	16	6	6	3	—	1	—	2			121	132
October			1	1	3	1	3	1	3	2	2	1	1	1		3	23	176
1974																		
January	4	6	11	12	6	5	7	6	1	—	3	1	1				63	131
February		1	3	3	2	4	4	2	2	2	—	1	1	3	2		30	159
March	4	14	24	42	44	35	23	26	9	3	4	4	3	1	—		236	136
April			2	5	21	11	23	12	4	6	7	2	5	1	1		100	155
July			1				2	1	—	3	2						9	166
August	25	7	2	—	2												36	87
Total	54	66	120	161	194	190	287	262	224	175	123	118	91	62	37	69	2 233	

Table 12. Mean weight of the 1966 year class in the Lindås herring, 1970–1974.

Month	Mean weight	n
1970 *		
October	175	13
November	185	78
1971		
January	160	41
February	168	13
March	160	76
April	160	55
May	161	63
June	163	87
July	164	16
September	177	36
October	173	4
November	165	59
1972		
January	161	88
March	156	28
May	155	7
August	210	21
November	194	62
1973		
January	202	9
March	182	7
1974		
March	158	9
April	194	9

A regression line for weight and length data for 2233 herring (Table 13) in logarithmic transformation was determined as:

$$W = 0.011\ L^{2.9025}$$

The regression line is plotted in Fig. 9. The 95% confidence interval for the slope of the regression line (2.9025) was ± 0.1392, and the hypothesis of isometric growth, i.e. the slope was not significantly different from 3, could no be rejected.

The condition factor (FULTON 1911):

$K = W/L^3$ (W in g L in cm)

is a measure of weight per unit volume under the assumption of isometric growth, and the larger the K, the better is the «condition» of the fish.

The condition factor was determined for all the individuals collected during 1970–1974 (Fig. 10). The highest values usually occured during

Table 13. Length-weight relationship of Lindås-herring, 1970–1974.

g	Length, cm																			
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
10	5	2																		
20	8	7	14	3																
30			1	15	9	1														
40					1	3	4	1												
50							11	8	1											
60							6	29	7		1									
70								10	16	2	1									
80									14	9	1	2								
90									3	11	3	7	5							
100										1	5	3	29	20	1					
10											3	6	33	36	10					
20											2	6	20	72	45	8				
30												2	9	76	77	21	2			
40													3	36	86	59	9	2		
50														15	72	120	22	4		
60														5	42	134	36	10	3	
70														1	25	77	78	34	4	
80														1	11	35	60	38	11	
90															3	23	38	47	19	
200															2	18	26	32	27	4
10																3	17	35	24	5
20																	10	19	16	7
30																	4	10	19	7
40																	3	8	7	11
50																		5	8	3
60																		—	3	4
70																		—	2	3
80																		1	4	4
90																			1	2

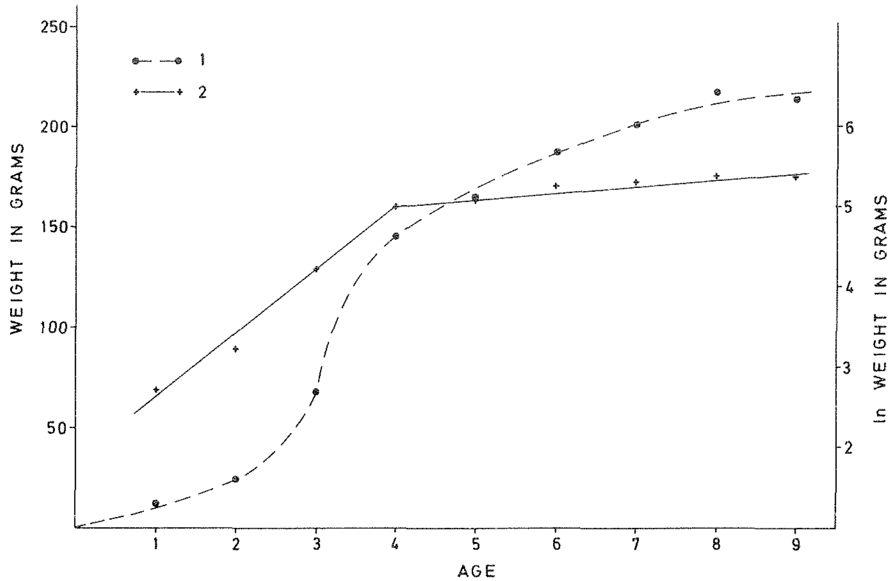

Fig. 8. Weight/age curves for the Lindås herring.

August–October, but there were distinct differences from year to year. Thus, it appears that 1970 and 1972 were particularly «good» years, whereas 1971 and 1973 had considerably lower condition factors during early autumn. A decrease in the condition factor could be observed already in October, and the minimum was usually reached in January. Then there was a rapid increase, culminating in March, and subsequently a decrease until the annual minimum was observed in May. On the average there was a decrease in the condition factor of about 15% from the autumn maximum to the May minimum, but from autumn 1970 to May 1971 the decrease was more than 20%. This decrease in weight reflects changes in body fat and sexual products, and therefore the annual variability in calorific content must be considerably higher than the variability in weight.

The rapid changes in the condition factor during the first quarter of the year coincides with the change from maturity stage IV to stage V and VI, i.e. the period of the most rapid growth of the gonads (AASEN 1952).

The amount of fat deposited on the intestines is commonly used as an indicator of quality in the marketing of herring, and the intestinal fat is thus another measure of the condition of the fish. In the present investigation the amount of intestinal fat was classified in accordance with AASEN (1952). The intestinal fat content was highest in July–August, when about 80–90% of the individuals had moderate fat content (Fig. 11). Through the autumn and winter there was a rapid decrease in the intestinal fat, and less than 10% of the individuals showed traces of fat during spawning in late March. After

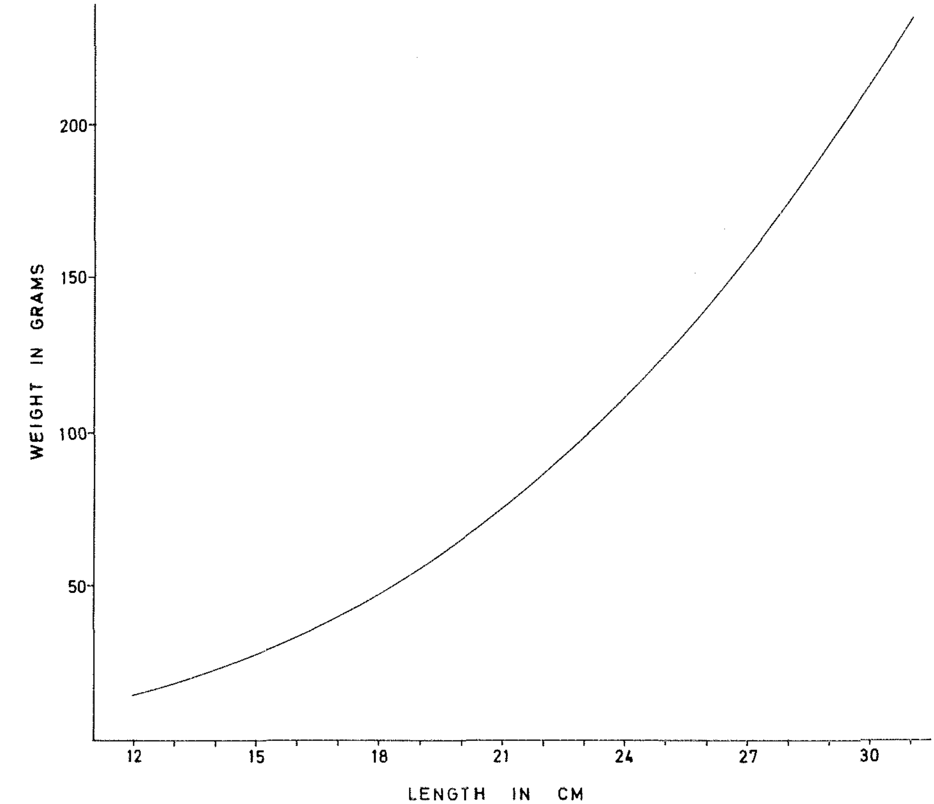

Fig. 9. Weight/length curve for the Lindås herring.

the spawning the herring very quickly startet to deposit intestinal fat again, and already in May had 45% of the individuals a moderate amount of fat.

It is interesting to note that the amount of intestinal fat started to decrease from August–September which indicates that the herring already then could not find sufficient food for maintenance metabolism, but had to utilize deposited fat as a source of energy.

There were some differences among the years in amount of intestinal fat; thus, it appeared that the decrease in autumn started one month earlier in 1971 than i 1972 and 1973. However, the inaccuracy of the classification method for intestinal fat prevents more stringent testing of annual differences.

MATURITY, FECUNDITY AND SPAWNING

The maturity stages were determined by the method of JOHANSEN (1919) which has been slightly modified and adopted for the Atlanto Scandian and

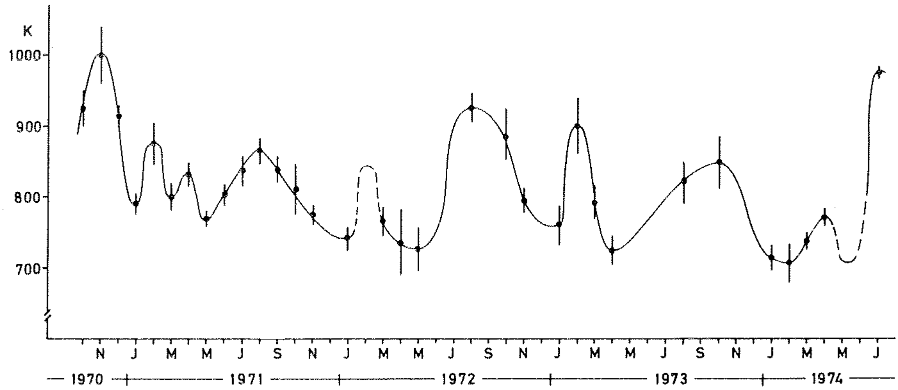

Fig. 10. Variation in the condition factor of the Lindås herring during 1970–1974.
Vertical lines: 95% confidence intervals.

for the North Sea herring stocks (ANON. 1963). In a qualitative classification scheme there is always an element of subjectivity on the part of the investigator, which introduces an added variance component in the data. In the present study this component has been minimized because all the maturity stage determinations have been made by one of the authors (O.D.) who has considerable experience with the method.

The overwhelming majority of the herring caught with gill nets were mature or maturing (Table 14), only 3.6% were in stage II and none in stage I. The size selectivity of the nets is the principal reason for this, but there are also indications that the migration pattern of the immature herring may be different from that of the mature stock (ØSTVEDT *et al.* 1974). Mature and immature herring will therefore not be caught together in the nets.

Maturity stage III appears in May–June and dominates from July–August until October (Table 14), and stage IV dominates from October until February. During February–March the herring pass through stage V, and the majority of the specimens were in stage VI, i.e. with fully ripe gonads, at the end of March. High percentages of spent herring (Stage VII) were rarely encountered, but recovering spent herring (stage VIII) dominated the samples during the period May–July. The scarcity of samples during the period May–August prevents accurate determinations of maturity stage distribution during this period.

Maturity stage IV was observed for about four months, stages III and VIII about three months, whereas the stages V–VII lasted only about two to four weeks (Fig. 12 A). This maturity cycle is very similar to that of the Atlanto Scandian herring (Fig. 12 B), but each maturity stage was reached about one month later in the year.

Thus, spawning in Lindåspollene occurred in late March, which coincides with the spawning time for other local west Norwegian herring stocks,

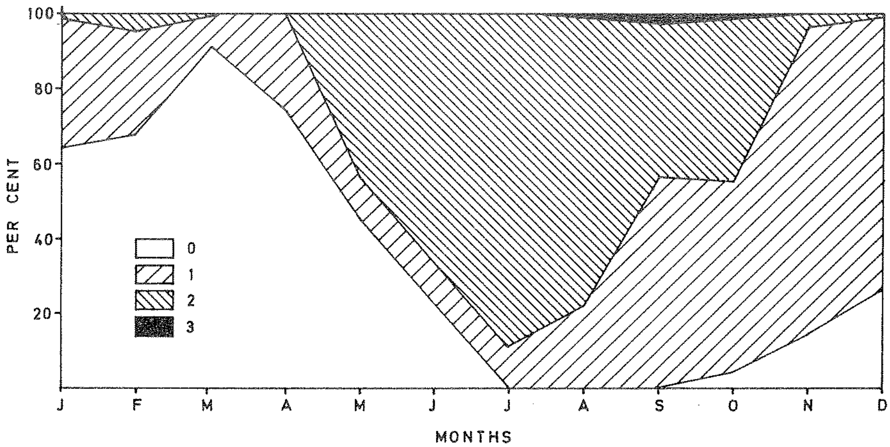

Fig. 11. Mean percent distribution in amount of intestinal fat through the year in the Lindås herring. 0: no fat, 1: traces of fat, 2: moderate fat, 3: much fat.

e.g. Heiamarkspollen and Fjellspollen (ANON. 1964) and Lusterfjorden (AASEN 1952).

Although there was a general seasonal trend in the maturity cycle of the herring in Lindåspollene as outlined above, there were also distinct differences among the years, particularly concerning maturity stages V and VII. It is noteworthy also, that a few specimens in stage VI were found in October–November 1971. Autumn spawning herring have also been observed in other polls in the Bergen area (ANON. 1964).

There were 53,2% males and 46.8% females in the total gill net catch during 1970–1974, and the males dominated in the majority of the samples. However, a t-test for the paired samples showed that the difference in sex composition was not statistically significant ($t = 1.49$, $0.10 < p < 0.20$).

Fecundity was determined on 117 herring ranging in length from 24 to 31 cm. The mean number of eggs per ovary ranged from 35459 at 24 cm to 51615 at 31 cm, but there were large variabilities in fecundity within length groups. An analysis of variance on log transformed data (Table 15) showed that the variance component among length groups was significant on the 95% level of probability, and a regression line was therefore fitted. The regression equation was:

$$N = 363.33\ L^{1.42}$$

where N = fecundity, L = length in cm. The correlation coefficient was low ($r = 0.4390$) but statistically significant at the 99% level of probability.

The slope of the regression line differed quite distinctly from the results of previous investigations on the fecundity of herring. Thus, BAXTER (1959) found slope values ranging from 3.8417 to 4.3290 in three different North Sea stocks and Atlanto Scandian herring, and KÄNDLER and DUTT (1958)

Table 14. Maturity stages (%) of Lindås-herring 1970–74, per month, gill nets.

Month		Stages								n
		I	II	III	IV	V	VI	VII	VIII	
Oct.	1970			60.0	33.3	6.7				15
Nov.	»			1.8	98.2					116
Jan.	1971				95.7	4.3				71
Feb.	»			4.2	58.3	37.5				24
Mar.	»		1.3	–	5.1	17.3	75.0	1.3		156
Apr.	»						7.5	58.7	33.8	80
May	»			9.0	–	–	3.3	–	87.7	90
June	»			10.0	–	–	–	–	90.0	107
July	»		3.8	88.5	–	–	–	–	7.7	26
Sept.	»		1.5	77.1	21.4					70
Oct.	»			15.8	73.6	5.3	5.3			19
Nov.	»		1.2	4.0	92.0	0.7	0.7	0.7	0.7	150
Jan.	1972		0.5	0.5	98.0	0.5	–	0.5		200
Mar.	»				17.0	55.3	26.6	1.1		94
Apr.	»						85.7	14.3		14
May	»			13.6	–	4.5	–	4.5	77.4	22
Aug.	»		24.0	24.0	52.0					75
Oct.	»			65.2	34.8					23
Nov.	»		0.7	5.0	92.9	1.4				141
Jan.	1973		12.0	32.0	52.0	–		–	4.0	25
Feb.	»		4.8	4.8	85.6			–	4.8	21
Mar.	»					7.5	84.6	7.8		65
Apr.	»					24.0	72.0	4.0		25
July	»		40.0	13.3	–	–		–	46.7	15
Aug.	»		27.5	45.0	27.5					40
Oct.	»			87.0	13.0					23
Jan.	1974		28.6	1.6	50.8	14.2	–	1.6	3.2	63
Feb.	»		3.3	6.7	73.4	13.3	–	3.3		30
Mar.	»		5.1	3.4	7.2	65.7	16.5	1.7	0.4	236
Apr.	»					5.0	95.0			100

found slope values ranging from 3.465 to 5.063 in three Baltic and two North Sea stocks. The size of the gonads in fishes is generally an isometric function of length, i.e. the fecundity is proportional to the cube of the length (BAGENAL and BRAUM 1968), and a formula of the form:

$$F = a + b\,L^3$$

would therefore be a more realistic representation of the relationship between length and fecundity. Applying this formula to the data on the Lindås herring by the method of least squares, the regression equation:

$$F = 20843 + 0.97\,L^3$$

was estimated.

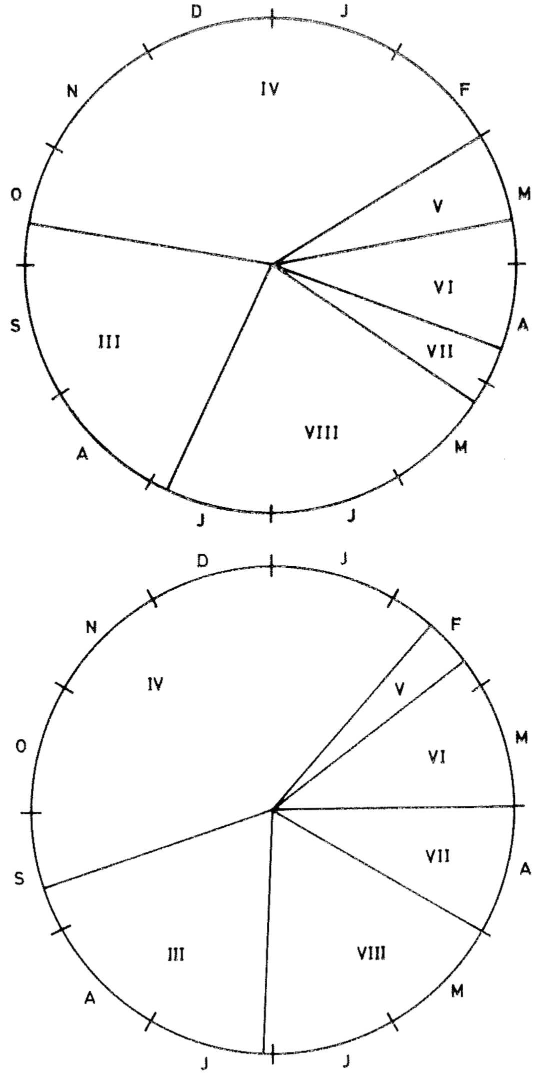

Fig. 12. Annual maturation cycle in the Lindås herring (above) and in the Atlanto-Scandian herring (belowe).

The two regression lines were not distinctly different (Fig. 13), but the line based on the cube of lengths is probably preferable.

The mean weights of the gonads collected during January, February and March of 1971 represented 12.9% ± 1.2%, 16.3% ± 1.3% and 19.3% ± 1.4% of the total body weight, respectively. A mean weight loss of about 20% during spawning must therefore be expected, and this compares favourably with other investigations on herring (Aasen 1952).

Table 15. Analysis of variance on fecundity. Herring ranging in length from 24 to 31 cm (8 length groups).
Data in log-transformation.

Source of variation	df	SS	MS	F
Among length classes	7	0.2576	0.0368	4.9066
Linear regression	1	0.1860	0.1860	15.6303
Deviations from regression	6	0.0716	0.0119	1.5866
Within length classes	99	0.7076	0.0075	

Syslakvågen (Fig. 1) has long been recognized as a spawning area for the Lindås herring (DAHL *et al.* 1973), but the investigations during 1970–1974 revealed considerable annual variability in the success of the spawning. Massive spawning was observed in Syslakvågen on 23 March 1971 and 27 March 1972 in depths from 0 to about 4m (Fig. 14). The eggs, which were clearly visible from the surface, were attached to algae, pebbles and rocks, distributed over an area of about 2 500 m^2. No eggs were observed on the spawning ground in 1973 and only a small number in 1974.

In 1971 herring larvae were collected with a Clarke-Bumpus plankton sampler in the surface waters on the spawning ground, and the maximum number of larvae, 43.5 individuals/m^3, was observed on 20 April. In 1972 larvae were observed from 16 April, reaching a maximum of 140.8 individuals/m^3 on 25 April. In 1973 no herring larvae were observed in Lindåspollene on larval surveys carried out until the month of July. Thus, there are indications that the spawning was a failure in 1973, and this hypothesis is supported by the fact that no 0-group herring were found in a purse seine catch from September 1973, nor I-group in a sample from September 1974 (Table 8).

In a detailed study of spawning and larval ecology of the Lindås herring FUREVIK (1976) observed spawning in Syslakvågen in 1974, but not in 1975. The highest number of larvae on the spawning ground in 1974, 151.27 individuals/m^3, was observed on 17 April, i.e. 20 days after spawning.

DISCUSSION AND CONCLUSIONS

The herring in Lindåspollene can be distinguished from neighbouring stocks by vertebral counts or growth pattern. However, both of these parameters are subject to phenotypic variation, and genetic studies must therefore be performed in order to further describe the racial identity of the stock. The component of fast growing herring occurs mainly as young

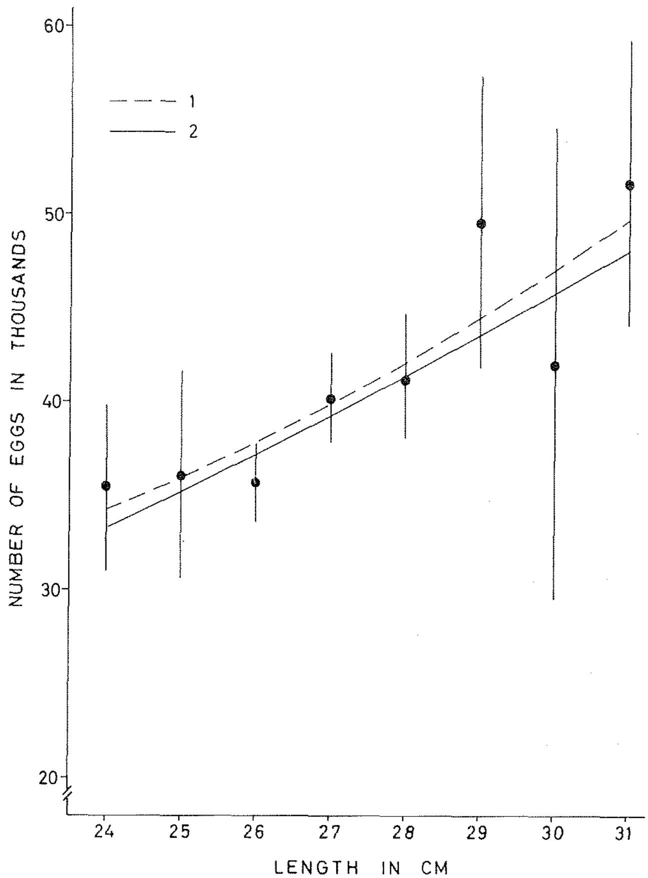

Fig. 13. Fecundity/length curves of the Lindås herring. 1: $N = 20843 + 0.97 L^3$, 2: $N = 363.33 L^{1.42}$

mature individuals. It seems reasonable, therefore, to conclude that the «strange» herring spends only shorter periods of their lives within Lindåspollene.

The migration of the herring stock within Lindåspollene seems to follow a standard pattern which could be compared with seasonal migration found in herring stocks in the open ocean as described by HARDEN JONES (1968). The feeding migration in spring is particularly directed towards Straumsosen, but a part of the stock moves also to the southern shallow part of Spjeldnesosen. On the basis of the hydrographical data alone it is difficult to explain this seasonal migration. A study of zooplankton during 1971–1972 revealed, however, that the spring migration coincided with a maximum of zooplankton biomass in Straumsosen and in the southern part of Spjeldnesosen in April (HAUG 1972). In the sentral parts of Spjeldnesosen a spring

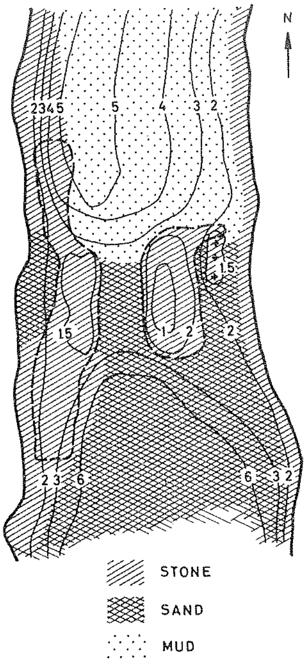

Fig. 14. Depth contour lines and bottom types at the spawning ground in Syslakvågen.

zooplankton maximum was not observed. There were also local differences in the composition of the zooplankton, *Calanus finmarchicus* being more abundant in Straumsosen (ELLINGSEN 1973). Thus, the feeding migration seems to be related to differences in quantity and composition of zooplankton within Lindåspollene.

The majority of the zooplankton during late autumn and winter was concentrated in the deeper layers of Spjeldnesosen (HAUG 1972), i.e. in the overwintering area for the herring. Attempts to catch herring at daytime during the overwintering period have not been successful, and therefore one cannot conclude whether feeding takes place or not.

Emigration of part of the Lindås herring stock to the neighbouring fjords might be expected (ANON. 1964). The differences in the environmental and feeding conditions between the outside fjord system and Lindåspollene would probable be reflected in the growth pattern as determined from scale readings, but such changes in the growth were never observed. It seems likely, therefore, that the emigrated herring do not return to Lindåspollene.

The local herring stock in Lindåspollene is characterized by large fluctuations in the relative strengths of the year classes, with a rich year class emerging every 3–4 years. The present investigation has shown that there were parallel fluctuations in the success of the spawning as determined from observations on the spawning grounds in Syslakvågen and from larval surveys (FUREVIK 1976). The prespawning aggregation of the herring in the northern part of Spjeldnesosen was observed each year, but in both 1973 and 1975 (FUREVIK 1976) the herring did not spawn in Syslakvågen. Estimates of spawning stock size are not available, but age composition data of the prespawning stock in 1973 revealed that the strong 1969 year class dominated, and one would therefore expect a relatively large spawning stock. Thus, the spawning failure in 1973 indicates that success of spawning is not directly related to the spawning stock size. Environmental conditions on the spawning grounds may, however, have a major effect on the success of spawning. In late March 1973, when the spawning failed, i.e. the mature herring did not enter the spawning grounds in Syslakvågen, the salinity at 80 cm depth was only 15.0–17.0‰. (ELLERTSEN 1975). Also RUNNSTRØM (1941) demonstrated for the Atlanto Scandian herring that environmental conditons are important during spawning, and that the herring only deposit their eggs at certain hydrographic conditions. The spawning area in Syslakvågen is shallow, and therefore it is conceivable that the environmental conditions are affected by short term variability in meteorological parameters such as temperatures and precipitation. However, there was no relationship between the strength of the year classes during the period 1959–1974 and the temperature and the precipitation during the first three months of the respective years.

The success of spawning seems to be one of the major factors determining the strength of the year classes, but there are indications that factors affecting eggs and larvae may be equally important. Thus, the number of eggs deposited on the spawning grounds in 1971 was at least as high as in 1972, but the highest density of larvae on the spawning ground at the time of hatching in 1971 was 43.5 individuals/m^3 compared to 140.8 individuals/m^3 in 1972. Observations from purse seine samples during 1971–1974 (Table 8) indicated that the strength of the 1971 year class was insignificant compared to the 1972 year class.

The spawning in 1974 was less successful than in 1971 and 1972, but the number of larvae on the spawning ground at the time of hatching was about the same as in 1972 (151.3 individuals/m^3). Thus, the effect of a successful spawning may be reduced by high egg mortality. FUREVIK (1976) observed predation on the herring eggs by cod, pollack and haddock, and he found that egg mortality was correlated with egg density.

The investigations during 1971–1974 indicate that the very considerable variability in the strength of the year classes in the Lindås herring stock is primarily related to success of spawning in Syslakvågen and to the biotic and abiotic conditions on the spawning grounds. These relationships will be the object of detailed studies in the future research programme in Lindåspollene. The time when the yolk sac has been resorbed has long been considered a critical period in the life of fish larvae (HJORT 1914, 1926) because the absence of suitable and sufficient food organisms may lead to mass starvation. SOLEIM (1942) reported on observations of large numbers of dead herring larvae in samples from the spawning grounds of the Atlanto Scandian herring.

Abundance of larvae at the egg yolk stage has often been used as an index of spawning stock size (SAVILLE 1964). The observation made in Lindåspollene both on the success of spawning and the larval abundance, shows that further studies on the relationship between spawning stock size and larval abundance are greatly needed.

The herring larvae in Lindåspollene may be subjected to considerable fluctuations in the amount of food organisms from year to year. HAUG (1972) found that the zooplankton biomass during the months of March and April was about twice as high in 1972 as in 1971, and ELLINGSEN (1973) found the same difference in the number of zooplankton organisms. Thus, the 1971 year class experienced very poor food conditions at the larval stage, which may be an additional source of reduction of the year class. The poor plankton conditions in 1971 are also reflected in slow growth of all year classes, and in that there was no increase in the mean weight during 1971. Similarly, the condition factor and the amount of intestinal fat during 1971 indicated poor feeding conditions.

The zooplankton community in Lindåspollene is strongly dominated by small copepods. The mean biomass (ashfree dry weight) during the period April–September 1971 for *Pseudocalanus elongatus, Temora longicornis,* and *Oithona similis* was 87.5, 43.7 and 43.7 mg/m^2, respectively, whereas the dominant larger zooplankton organism, *Calanus finmarchicus,* had a mean biomass of 19.7 mg/m^2 (ELLINGSEN 1973). Assuming that the composition of the zooplankton in the watermasses reflects the diet of the herring (SAVAGE 1931), the food of the Lindås herring would consist mainly of small organisms. The energy expenditure related to feeding on the small prey may reduce their relative importance as food organisms, which might explain the slow growth of the Lindås herring compared to the North Sea herring stocks and Atlanto Scandian herring. In these herring stocks *Calanus finmarchicus* constitutes the most important food organisms (RUDAKOVA 1956, CUSHING 1962).

Lindåspollene is characterized by low temperatures (5–3°C) in the water masses deeper than 25–30 m, and the hydrographic investigations during 1971–1974 revealed only small seasonal fluctuations in the temperatures at these depths (AURE 1972, WESTERGAARD 1975). During most of the year the major part of the herring stock was at day time distributed at depths exceeding 30 m, i.e. in water masses 3–4°C colder than the deep water of the

Norwegian coast and fjords (EGGVIN 1940, SÆLEN 1962). Thus, the herring are most of the year exposed to low temperatures and one might expect reduce growth rate even during good feeding conditions. The part of the Atlanto Scandian herring, which are living under the most extreme temperature conditions, e.g. the northern growth type, had reduced growth rate as compared with the more southern component of the stock (ØSTVEDT 1965).

Studies on local Norwegian herring stocks indicate, however, that food conditions play an important part in the growth of the herring. The Lusterfjord herring (AASEN 1952) lives in water masses 2–3°C warmer than the water in Lindåspollene, but it has a very slow growth rate. The zooplankton conditions in the two areas are, however, quite similar, thus *Calanus finmarchicus* comprised about 2% of the total number of organisms in Lindåspollene (ELLINGSEN 1973) and about 3% in Lusterfjorden (AASEN 1952).

The zooplankton of both areas was dominated by small copepods, e.g. *Pseudocalanus elongatus, Acartia spp., Temora longicornis, Oithona spp,* and *Paracalanus parvus.* It seems, therefore, that the slow growth of the herring in Lusterfjorden and in Lindåspollene is related to the composition of the zooplankton community rather than to the temperature of the water masses. This conclusion agrees well with CUSHING (1962) who demonstrated increased growth of the North Sea herring after 1950 as *Calanus* became more predominant in the zooplankton.

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