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HAVFORSKNINGSINSTITUTTETS EGG-OG LARVEPROGRAM (HELP)

The condition of the herring larvae off Western Norway in the period 1985-87.

by

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ABSTRACT

A herring larval sampling program has been carried out off Western Norway in the period 1985-1988. This paper deals with results from 1985-1987. Larval growth and condition have been studied both with living and formaldehyd preserved material. A comparativ study of the gut content has been carried out between the three years. The larvae have been staged according to morphometric criteria, and the duration of the different stages has also been investigated. High abundance of larvae beyond the "critical stage" were found both in 1985 and 1987. The growth and gut analyses show that there had been good larval feeding conditions both these years. In1986 , however, there were found few larvae without yolksac. Both the study of growth and the examination of gut content show that the larvae were in worse condition. At the same time of development the larval population in 1985 was dominated by growing larvae with resorbed yolksac, and more than 50% of the larvae had started to develop the dorsal fin. In 1986, however, the larval population was dominated by newly hatched larvae, while the population in 1987 was dominated by larvae at the stage of yolksac resorbtion.

INTRODUCTION

The size of the Norwegian Spring-Spawning herring stock has been at a very low level the last 20 years. Strong regulations and three years with good reproduction success in 1973,76 and 79 have slowly rebuilt the spawning stock to about 500 million metric tons in the mid eighties. This was enough to produce a large year-class in 1983. Expecting a large increase of the spawning stock with the recruitment of the numerous 1983-year-class in 1987-1989 a program to study the recruitment mechanisms was launched in 1985 for the period 1985-1990 (BJØRKE, FOSSUM & SÆTRE 1986, FOSSUM, BJØRKE & SÆTRE 1987 and SÆTRE, BJØRKE & FOSSUM 1988). The program was later on included in a national program to study the possible consequences on fish eggs and larvae of oil exploration on the Norwegian continental shelf north of 62 N (HELP). Historical tradition in the sampling of herring larvae of Norwegian Spring - Spawners (e. g. WIBORG 1960, DRAGESUND 1970, SELIVERSTOV 1974 and BJØRKE 1981) and acknowledgement of the herring as the most economically important species in the Norwegian Sea, Barents Sea and the Norwegian shelf ecosystems, were other factors contributing in selecting recruitment mechanisms in herring as the main basic research program in HELP.

In the present study, indications of the year-class strength from the larval investigations, such as growth coefficient and number of larvae that had survived through the critical stage, were compared to the year-class strength estimated from the 0-group surveys.

MATERIALS AND METHODS

The investigations in 1985 were carried out in the period 10 -16 April. Survey grids and larval distribution are shown in BJØRKE, FOSSUM and SÆTRE (1986). In 1986 the study was carried out in two different surveys 29 March - 7 April and 9 - 18 April. The first one in the central area of larval distribution , the second one in the whole area of larval distribution. Survey grids and larval distribution are shown in FOSSUM, BJØRKE and SÆTRE (1987) . The study in 1987 was carried out in the period 28 March - 8 April and 10 - 20 April in two different surveys. The first one in the main area of the herring larvae distribution. The second one in the whole area of distribution, but this was incomplete because of bad weather conditions. For survey grids and larval distribution see SÆTRE, BJØRKE and FOSSUM (1988).

On each station herring larvae were sampled with conical dip-nets with 0.5m2 opening and 375µm mesh size. The nets were hauled from 150-0m (or 5 m above the bottom to the surface in shallower waters) with a hauling speed of 0.5 m/s. The larvae were sampled in non-filtering cod ends, and could still be alive during the sorting process, to secure the best possible larvae for staging and morphometric measurements. The larvae were sorted out from the sampling buckets, counted and up to 50 larvae (if present) were measured to nearest mm below.

The herring larvae were preserved in 2% formaldehyd, and 20 larvae (if present) were selected from each station for stageing (according to DOYLE 1977), and for dry weight and gut content analysis. Because of gut content voidance in herring larvae (HAY 1981, BLAXTER and HOLLIDAY 1963, ROSENTHAL 1969), only a qualitativ analysis with the gut content was performed between years. Because of weight loss during preservation in formaldehyd (THEILAKER and DORSAY 1980), samples of larvae were also staged and length measured on board, dried to constant weight and weighed in the laboratory on a Cahn electrobalance to nearest µg.

If food organisms could be recognized through the epithelium of the gut of the preserved larvae,they were dissected out and classified into one of the following three groups, copepod eggs, copepod nauplii and copepodites. No other food items were found. The larvae were rinsed in fresh water, dried to constant weight and weighed.

The vertical hydrografic distribution was observed by CTD casts.

RESULTS

The present material consists of 3445 herring larvae of standard length 8-18 mm and dry weight 50-1265 µg. 1138,695 and 1612 larvae were sampled in the three years 1985, 86 and 1987, respectively. In 1986, 48 larvae were staged, measured and dried on board, while 74 were staged and measured on board in 1987. The mean standard length and dry weight of the larvae in different developmental stages are given in Table 1 and 2.

Table 1. Standard length and dry weight in the different developmental stages (preserved material).

Stage	Mean standard length (mm)			Mean dry weight (µg)			Nos. of larvae		
	1985	1986	1987	1985	1986	1987	1985	1986	1987
1a	8.2±0.9	8.1±0.8	8.3±0.8	144±35	144±30	147±33	62	60	86
1b	9.0±0.7	9.1±0.9	8.4±0.9	120±27	127±25	120±26	118	193	331
1c	10.2±1.1	10.0±0.8	9.4±0.9	135±34	133±26	123±28	87	186	281
1d	10.3±1.2	10.6±0.8	10.1±0.8	142±38	151±28	147±30	193	121	338
2a	13.0±1.2	11.8±0.8	12.2±1.5	248±71	199±36	258±104	632	87	487
2b	16.4±0.9	-	16.4±1.1	486±91	-	636±109	45	-	9
2c	17.0	-	17.2±1.0	700	-	836±60	1	-	5
3a	-	-	18.8	-	-	1265	-	-	1

Table 2. Standard length and dry weight of larvae staged and measured on board.

Stage	Mean standard length (mm)		Mean dry weight (µg)		Nos of larvae	
	1986	1987	1986	1987	1986	1987
1b	9.7±0.5	-	213±40	-	7	-
1c	10.7±0.7	11.2±0.4	244±39	219±32	18	5
1d	11.2±0.6	11.0±0.6	273±46	227±32	12	22
2a	12.2±1.1	13.6±1.8	324±69	440±193	11	46
2b	-	17.7	-	1118	-	1

The larval material sampled was composed of both yolksac-larvae and post-larvae. The percentage distribution of the different stages for the three years are shown in Table 3. The development of the the larval population in 1987 was somewhat delayed compared to what was found in 1985 when the population was composed of post-larvae in stage 2a. Compared to 1986, however, when most of the larvae were in the yolksac stage, the larvae had reached a more developed stage in the 1987 material.

It can be seen from Tables 1 and 2 that the larvae shrink during fixation, and tests of the means of length and weights before and after fixation all show a highly significant length and weight loss ($4.7<t<11.6$) . The percent shrinkage is given in table 3. The larval sample in 1987 is from the second coverage. The material sampled in 1986 only had half the length-shrinkage compared to the 1987 material, while the weight loss was slightly higher in 1986 .

Table 3. Shrinkage due to fixation

Stage	Length (%)		Weight (%)	
	1986	1987	1986	1987
1b	6.2		40.0	
1c	6.5		45.5	
1d	5.4	10.0	44.7	36.5
2a	3.3	10.2	38.6	38.2

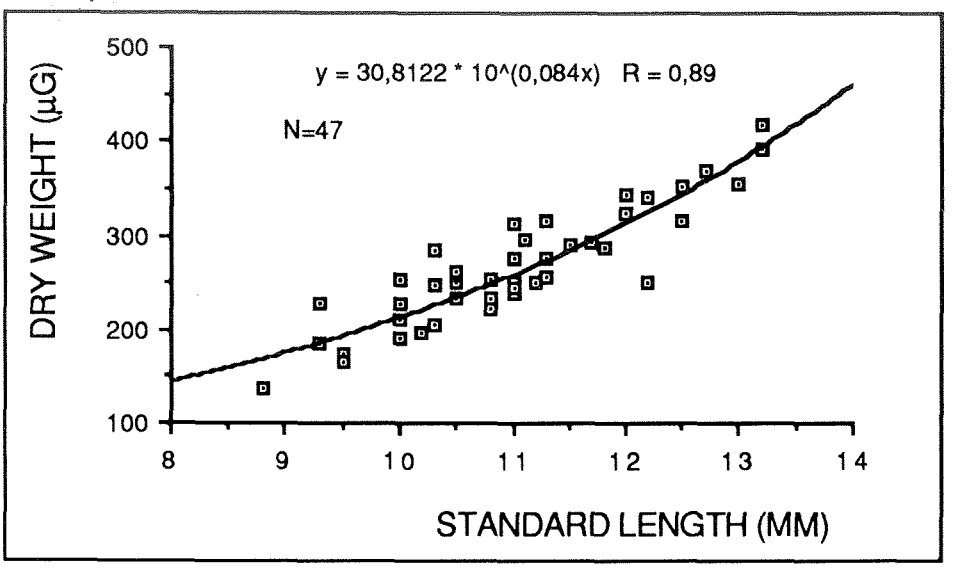
The larval material sampled was composed of both yolksac-larvae and post-larvae. The percentage distribution of the different stages for the three years are shown in Table 4. The development of the the larval population in 1987 was somewhat delayed compared to what was found in 1985 when the population was composed of post-larvae in stage 2a. Compared to 1986, however, when most of the larvae were in the yolksac stage, the larvae had reached a more developed stage in the 1987 material.

Table 4. The perscentage distribution of the larvae in the different developmental stages in 1985, 1986 and 1987.

Stage	1a	1b	1c	1d	2a	2b	2c	3a
1985	5.4	10.4	7.6	17.0	55.5	4.0	0.1	-
1986	9.3	29.9	28.7	18.7	13.4	-	-	-
1987	5.7	21.8	18.5	22.3	30.7	0.6	0.3	0.1

The hatching started abouth 10 March both in 1986 and 1987 , with the main hatching in the last week of March both years (BJØRKE 1988). Little is known abouth the hatching in 1985. The age of a small sample of larvae (N=10) caught west of the Sklinna bank in late May, was estimated from daily increment counting. These few larvae were hatched during the last fifteen days of March.

In fig.1 the length/ weight plot of the larvae not exposed to formalin in 1986 and 1987 is shown. There is a strong length/weight relationship indicated by correlation coefficients r=0.89 and 0.97. Both the steeper slope for the data sampled in 1987, 0.095 compared to 0.084, and the more variable data in 1986 indicate faster growth and better conditions in 1987 than in 1986.



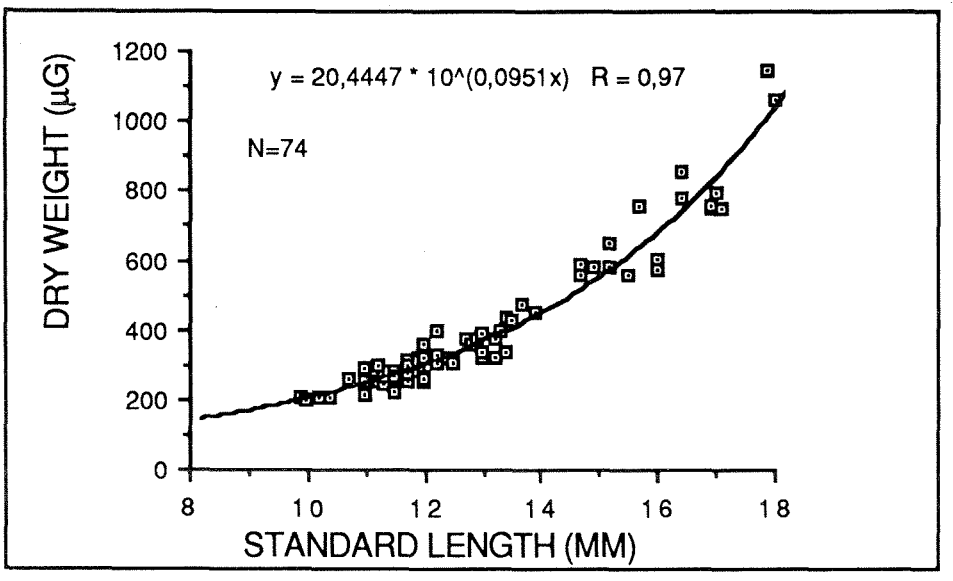


Fig.1. The length/dry weight plot of the larvae not exposed to formalin. Upper plot from the 1986 survey. Lower plot from the survey in 1987.

The plots of the preserved material in the three years 1985-87 are shown in figs. 2-4. Length/ weight plots of preserved material have weaker length/weight relationships because of variable weight loss during fixation. The growth parameter in 1987 (the slope=0.08) is higher than in 1986 (0.04) and equal to the parameter found in 1985 (0.08), indicating reduced growth in 1986.

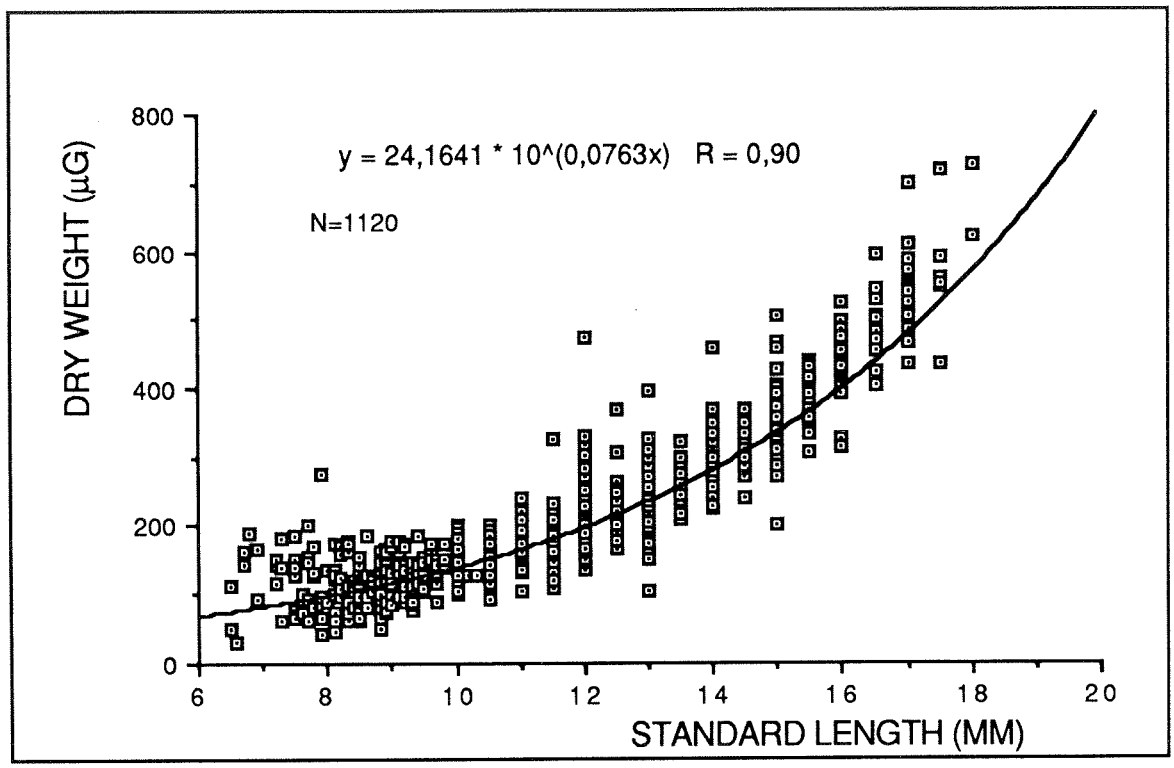


Fig.2. Length/dry weight plot of the material sampled in 1985.

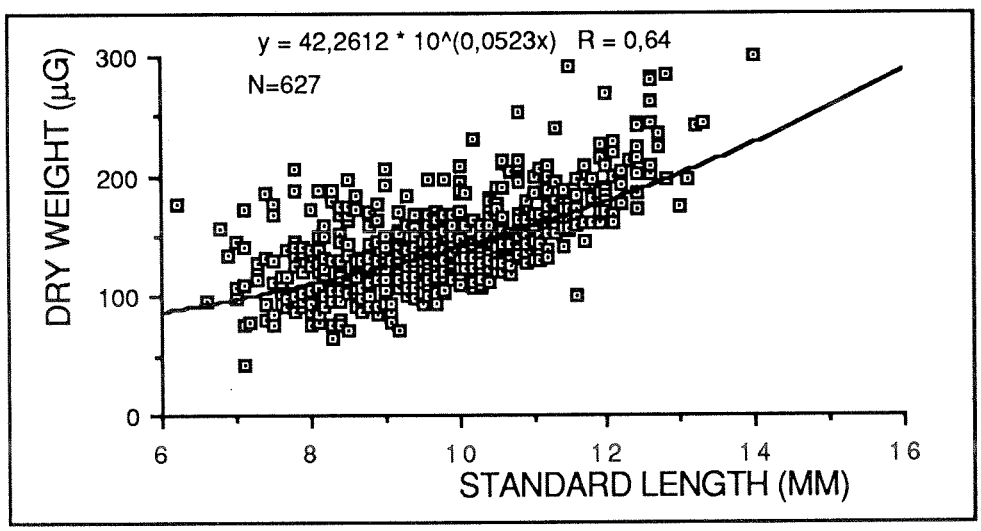


Fig.3. Length/dry weight plot of the material sampled in 1986.

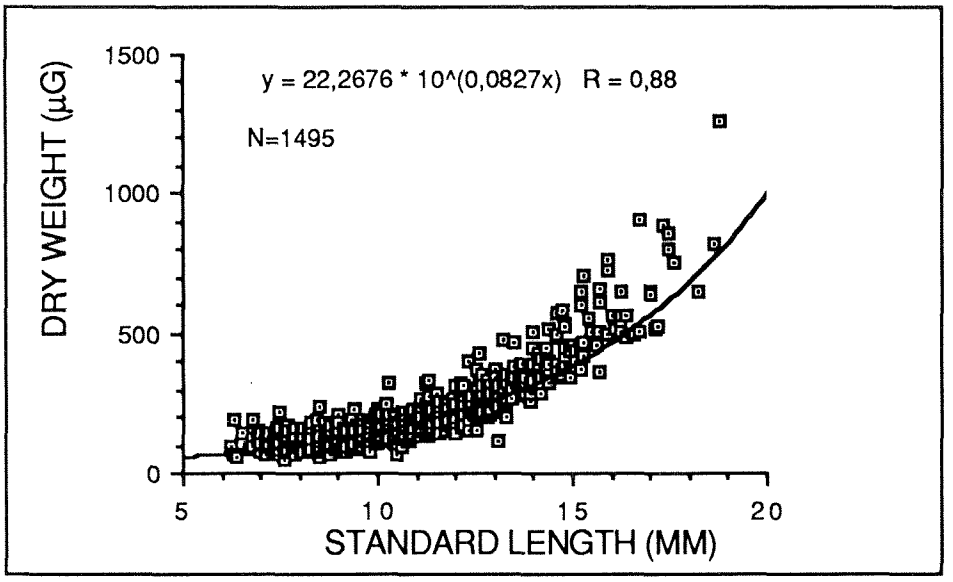


Fig.4. Length/dry weight plot of the material sampled in 1987.

Plots of the condition factor versus standard length of the material sampled the three years 1985-1987 are shown in figs.5-7.

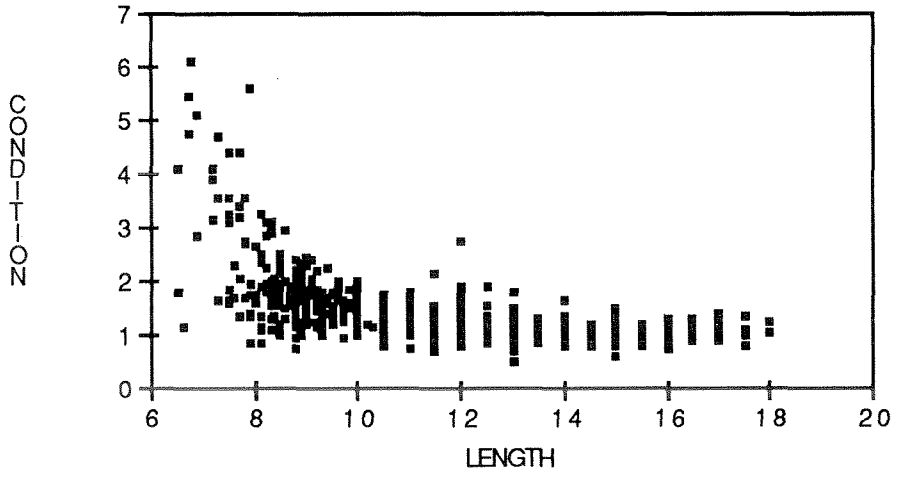


Fig. 5. Length versus condition of the material sampled in 1985.

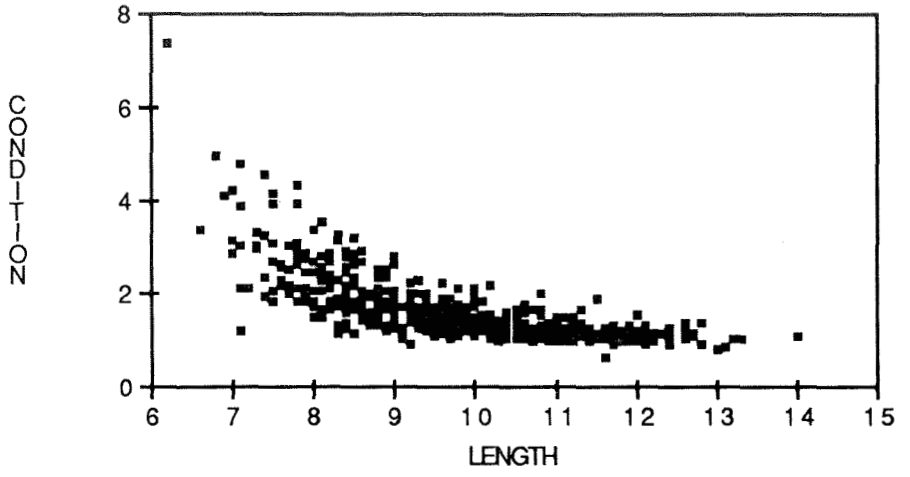


Fig. 6. Length versus condition of the material sampled in 1986.

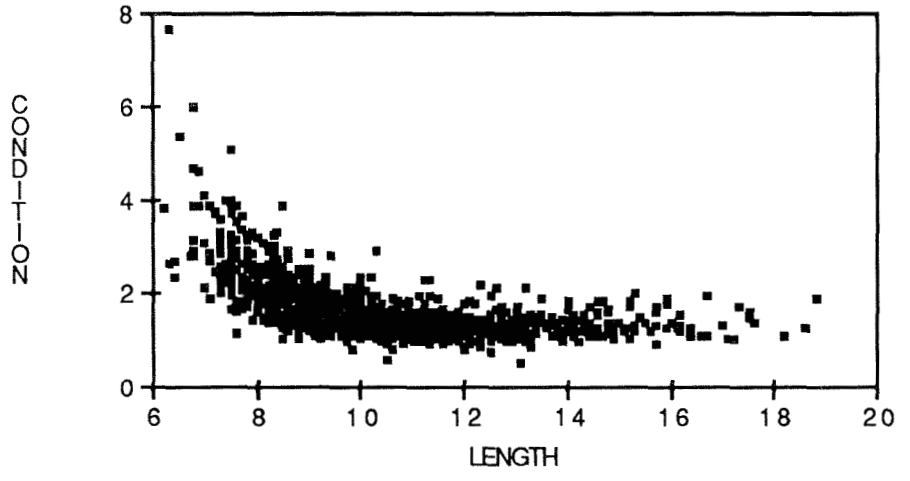


Fig. 7. Length versus condition of the material sampled in 1987.

In all three years the condition factor (k=10w(µg)/l(mm)3) decreases during the yolksac period. After the yolk-sac is resorbed the condition stabilises and a test of the difference in the condition factor between the larvae in stage 2b and 2a in 1985, shows no significant difference, although the mean condition coefficient is 1.11±0.21 in the larvae in stage 2a and 1.08±0.12 in the 2b larvae. There were too few larvae in stage 2b in 1987 to do such a test. To study the condition factor between the three years, the 2a larvae were selected . These are postlarvae which develop dorsal fin rays. Tabel 5. shows the mean condition factors, the number of larvae in each sample , the significance levels and the sizes of t.

Table 5. T 'tests between the condition factors of the 2a larvae in 1985, 1986 and 1987.

Year	1985	1986	1987
Mean	1.11±0.21	1.22±0.25	1.34± 0.27
Number of larvae	623	79	480
1985	-	t=4.17	t=15.6
1986	s=0.0000	-	t=3.65
1987	s=0.0000	s=0.0000	-

This table shows that the condition of the larvae sampled in 1987 was best followed by the 1986 larvae. The larvae sampled in 1985 had the lowest condition factor. The mean condition factor of the 46,2a larvae, sampled and worked up in situ was 1.67±0.19 in 1987, another indication of the large weight loss due to formalin fixation.

The growth rate (mm/day) and specific growth rate (SGR%) of the larvae can be calculated in larvae of known age. The specific growth rate where dry weight is fitted to the exponential growth equation can be calculated after the following formula (WARREN 1971):

$$w2 = w1\, e^{k(t2-t1)}$$

w2= dry weight at time 2.
w1= dry weight at time 1.
t1= time 1 (days)
t2= time 2 (days)

If the morphological stages are growth independent, and the sample is a representative sample of the whole stage (in stages of long duration), the stages can be used as age criteria. Different experiments in addition to DOYLE (1977) have been carried out to estimate the stage duration both in the laboratory and in mesoscala e.g. ØIESTAD (1983), MAC LACHLAN et al. 1981 and MOKSNESS (in prep.). Table 6 shows the mean duration of the different substages after these authors.

Table 6. The duration of the different substages in days.

Stage	1a	1b	1c	1d	2a	2b
	3	4	3	2	11	5

To be sure there is a representative sample of the long 2a stage, the 2b stage must be present. This was fulfilled both in 1985 and 1987, but not in 1986. The growth rate and the specific growth rate were calculated for the yolk-sac stage for all three years and for the period 1-25 days in 1985 and 1987 the results are shown in table 7. The growth rate was about 0.20 mm/day in the yolksac period. After the yolksac was resorbed the growth rate was estimated to be 0.42 mm/day both in 1985 and 1987. The specific growth rate was almost equal to 0 in the yolksac period for all three years. The reason for this is that the larvae have their lowest weight in the 1b stage, 3-7 days post hatching when they start to feed. Thereafter they experience a continous weight increase. The post larvae had a specific growth rate of 8.2 and 9.8% in 1985 and 1987 respectively. The specific growth rate is very sensitive to weight loss during fixation, so this is only very uncertain estimates.

Table 7. The specific growth rate (SGR%) and the growth rate (GR mm/ day) of herring larvae in 1985-87.

	1985			1986			1987		
Age	0-10	10-25	1-25	0-10	10-25	1-25	0-10	10-25	1-25
SGR	-0.1	8.2	4.9	0.5	-	-	0.0	9.8	5.9
GR	0.23	0.42	0.36	0.25	-	-	0.18	0.42	0.32

The length distribution of the larvae in the different stages are shown in Fig. 8. There are so small differences from year to year during the yolksac period, so the result with the unpreserved larvae, staged in situ are used for all three years. The 2a larvae are adjusted for 7.5% length shrinkages.
The 2a stage is well presented both in 1985 and 1987, while the 1986 material contains just the smallest larvae in this stage.

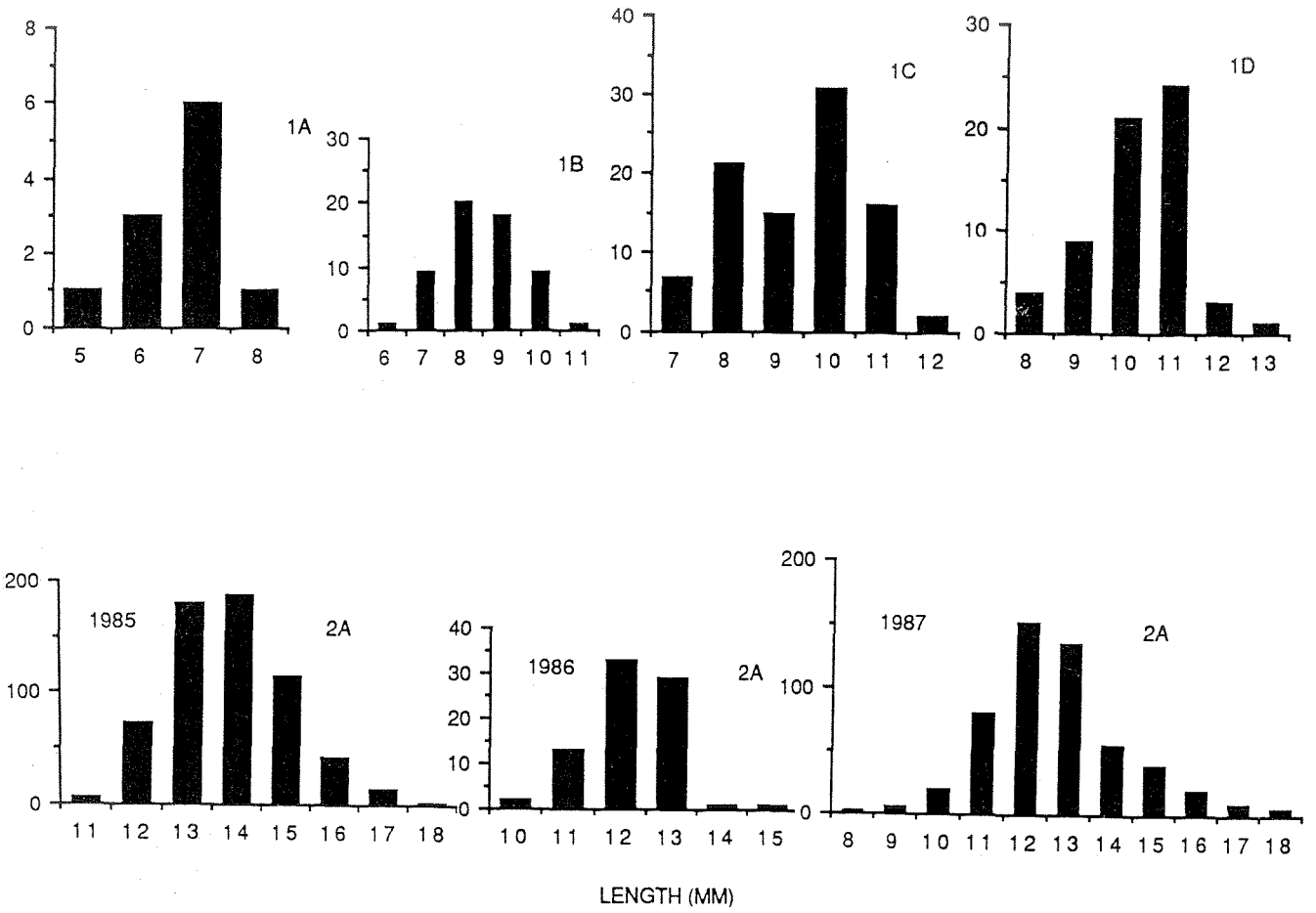


Fig. 8. The length distribution of larvae sampled in 1985-87.

The diet of the larvae during stages 1a-2b a time span estimated to be 28 days , is shown in Fig.9. There were found 8 copepodites, 934 cop. nauplii and 207 cop. eggs in the larval guts. No other food items were found. The low feeding ratio in the larger larvae comes from the emptying of the gut during catching and preservation. The peristaltic movements of the gut is much stronger in the more developed larvae. There is a stronger impact of cop. eggs in 1987 than the previous two years. The number of cop. nauplii is on the same level in 1985 and 1987 and higher than in 1986, another indication of good larval conditions both in 1985 and1987. First feeding was seen in stage 1b larvae (3-6 days old). Cop. eggs seem to be an important first feeding item. Later on the importance of this food item is reduced.

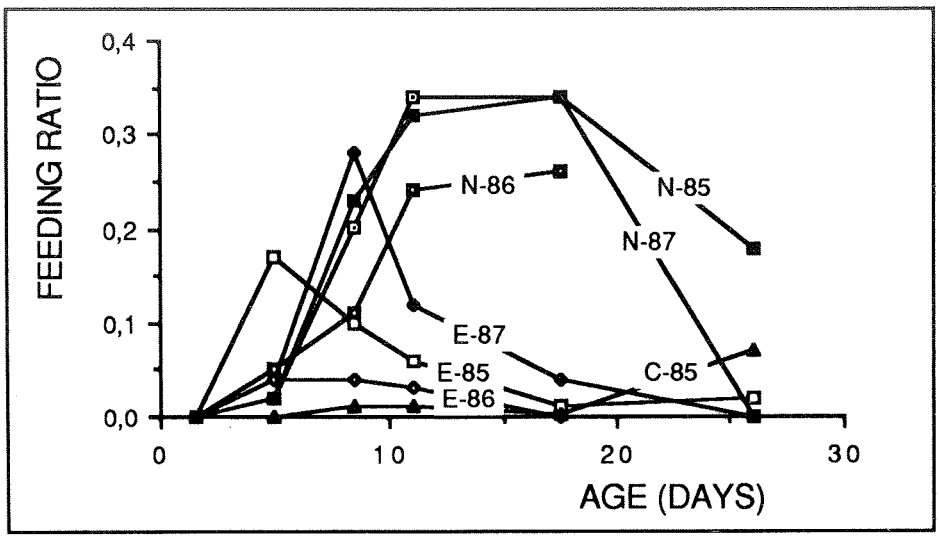


Fig.9. The diet of the herring larvae in the period 0-28 days post hatching. E-Eggs,N-Nauplii and C-Copepodites.

DISCUSSION

The mortality of larvae of fast growing species like mackerel and anchovy is larger than slower growing ones like cod and herring. There is also a tendency of reduced mortality of the progeny when the dry weight of each spawning product is increased (Mc GURK1986). Therefore one can expect increasing year-class/ spawning-stock relationships in e.g. cod, herring, salmon and spiny dogfish. If one only looks at the large year-classes of herring like the 1904,1950, 1959 and 1983 there is a linear relationship between the spawning stock and the year-class size (HAMRE pers. comm.)

However, there is large year-to-year variation caused by different parameters. The year-class size of Norwegian Spring Spawning Herring and other species using the Norwegian Coastal Current for nursery and transportation, is to the last extent controlled by the physical environment in the current. In SÆTERSDAL and LOENG (1984), good year-classes of both cod and herring typically occur in the front of a warm period. But it is very difficult to see the link between the environment and recruitment as the year-class strength may not be established before the herring is 2 group.

The herring pass through several difficult stages on the way to reduced and stable natural mortality. Spawning success and egg predation may be of importance, but good correlations between larval production and spawning stock excists (SAVILLE and

RANKINE1985, LOUGH et al. 1985). Many different authors report about variable egg-mortalities. This is e.g. discussed in JOHANNESSEN (1986). The mortalities are variable, but very often ignorable. Herring eggs spawned in the littoral-zone are exposed to a higher density of predators than eggs spawned in 50-100m dept.

Newly hatched larvae are exposed to mortality from predation and environmental stress. Blooms of predators will make a heavy reduction on the yolksac-larvae, while the larvae seem to have wide tolerance limits for environmental parameters (BLAXTER 1960, BISHAI 1961, BLAXTER and HOLLIDAY 1963, De SILVA and TYTLER 1973 and SERIGSTAD pers. comm.) In the post-yolksacstage, mortality due to starvation and transportation into areas with low survival possibilities are highly significant. Very few proofs of starved larvae in the period of transitional feeding exist except SOLEIM (1942), but many report about the sensivity of larvae to suboptimal feeding conditions (SHELBOURNE 1957, BAKUN and NELSON 1977, NIELSON et al. 1977, PARRISH and MacCALL 1978, WALSH et al. 1980, FRANK and LEGGETT 1982, YODER 1983 and CRECCO and SAVOY 1983). After metamorphosis the 0-group herring are mainly vulnerable to predation from fish, sea birds and mammals.

The herring is very sensitive to predation up to this age 2+ and when SISSENWINE (1984) compared the mortality in the egg and larval stage(0-5 months) to the mortality in the postlarval stage (5 months-2 year) the latter was the largest. In the last few years it is seen that relatively large year-classes have been eaten up as 0 and 1 group by young cod in the Barents Sea. But it is also believed that very large year-classes (1950,1959) are so large that they can withstand a large predator pressure.

This paper focuses at the period of first feeding, and use criteria like feeding ratio, condition or number of 2a-stage larvae to postpone the size of the year-class. The material is from the three years 1985-87 and we know the fate of these year-classes from postlarval surveys, 0-group surveys and later acoustic surveys. The fate of the three year-classes differed widely. The 1985 year-class was large as 0-group, the other two were very small. Therefore everything can be related to the 1985 year-class as a good one. Later on the 1985 year-class was eaten up by a huge amount of small cod and haddock in the Barents Sea, which doubled their biomass that year.

The larval index built on the 2a larvae is largest in 1985, followed by 1987 and 1986. The development in 1986 may be a little late

caused by a slightly lower temperature (0.5 C). From this we can se that the year-class in 1986 never really was a year-class. More larvae hatched than in 1987 (according to the hatching investigations) but the conditions must have been so bad that very few larvae survived through the yolksac period and started to grow. In 1987, however, more larvae started to grow, but at the postlarval survey and later the 0-group survey very few larvae were found. On the coastal banks 1 million metric tons of immature herring were found just in the period when the larvae were drifting through this area, and there is possibile that the larvae were eaten by its elder "brothers and sisters".

The feeding condition was good both in 1985 and 1987, and reduced in 1986. If the feeding results are compared to BJØRKES (1978) it is evident that the feeding ratio was much lower in the present investigations. He found a feeding ratio of 2.5, mainly cop. eggs, while the present feeding ratio was 0.5. The reason for this may be that the present larvae were collected by vertical nets, hauled at a low speed. BJØRKES (1978) larvae were collected by fastgoing equipment which must have killed the larvae almost immediately and little gut content was defecated. In the present investigations the larvae can have emptied their guts during the catching , sorting and fixation process and a comparison of the results is impossible.

Length weight plots of the larvae also indicate that the conditions were best in 1985 and 1987 and poorer in 1986. But the results of condition of 2a larvae are somewhat contradictory to this. Here the 1985 results were ranked lowest , and the larvae in best condition were found in 1987. The only explanation that can be given to this is that the 1986 sample was too small to give any reliable results.

The estimates of growth-rates given are in accordance with the results based on the same herring stock (DRAGESUND and NAKKEN 1973) and with results from other stocks (LOUGH et al. 1982, WOOD and BURD 1976). CHRISTENSEN (1985) reviewed information about field studies on growth rate of North Sea herring. These ranged from 0.16 mm/day to 0.35 mm / day.

The investigations was carried on in 1988, and we hope to get additional information in the future about these difficult problems.

CONCLUSIONS

The temperature conditions were somewhat better during the cruises in 1985 and1987 compared to 1986.

The larval population was dominated by larvae with resorbed yolksac which developed the fin rays in the dorsal fin in 1985 (Stage 2A).

The larval population was dominated by young-yolksac larvae in 1986.

The larval population was dominated by late yolksac stages and by larvae with resorbed yolksac which had started to develop the dorsal fin in 1987 (Stage 2A).

In 1987, the growth and feeding conditions were almost identical to what was found in 1985.

The indexes of growth and feeding were lower in 1986 compared to the two other years.

The larvae started to feed during the 1b stage when the larvae were 3-7 days old.

Copepod eggs seem to be an important food item for first feeding yolksac larvae, later on cop. nauplii is the most important food item until the larvae start to take copepodites after three weeks of age.

A growth rate of 0.22 mm/day in the yolksac stage and 0.42mm/day in the post yolksac stage was found.

The specific growth rate was 8.2 and 9.8% in the post yolksac period in 1985 and 1987 respectively.

The shrinkage due to formalin fixation was found to be 7.5% in length and 40% in weight.

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