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# ESTIMATED HATCHING DATE AND GROWTH HISTORY OF NORWEGIAN SPRING SPAWNING HERRING (*CLUPEA HARENGUS* L.) FROM OTOLITH DATA OF LARVAE OF THE 1990 YEARCLASS.

by

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## ABSTRACT

This study was performed on herring larvae of the 1990 yearclass of Norwegian spring spawners. The larvae were caught in May on the Norwegian shelf in the area from 64 $^0$ N - 69 $^0$ N. There was one size group of larvae with standard length 20-30 mm and another with standard length 30-40 mm. The distribution of data for hatching date and growth history were back-calculated from otolith data. These data were compared with the hatching that actually took place over the spawning grounds in March/April the same year. Differences in growth rate and distribution of birth date between the larvae within the investigated area were studied.

## INTRODUCTION

The Norwegian spring spawning herring is historically the largest population of herring in the world and the most important species in the Norwegian Sea and the Barents Sea ecosystems. From almost extinction in the early 70's the spawning stock has increased to 1.5 mill. metric tonns in 1989, because of heavy restriction on fishing. There is a tradition of field studies of the recruitment processes of this stock with the works of e,g.

Dragesund (1970), Dragesund and Nakken (1973) and Bjørke (1978).

In this period of recovery of herring stocks, it has been and is of great interest to study the recruitment processes of the stock, and in the period 1985-90 this has been carried out under the HELP-program (The Egg- and Larval Program of the Institute of Marine Research, Bergen Norway).

Studies of otolith microstructure have shown to be a useful tool for back-calculating growth and hatching date of the individual larvae. The verification of the 1:1 nature of increments and age (in days) of Campana and Moksness (in press) improves the use of this technique in spring spawned herring .

In the present study otoliths were taken from larvae with standard length of 20-40 mm sampled on the Norwegian Shelf in May 1990. The daily increments were read and the width of the individual zone was measured. On the basis of these data the hatching curve and growth history of the herring larvae were calculated. The back-calculated hatching curve of the spring spawned herring larvae were compared with the hatching that actually took place on the spawning grounds in March-April of the same year. These results are discussed with respect to the abundance of microzooplankton during the first feeding period of the herring larvae of the 1990 yearclass.

## MATERIALS AND METHODS

### Sampling of yolksac larvae

The sampling program for yolksac herring larvae and microzooplankton was carried out with the small research vessel "Opal". Samples were collected (if possible) over the spawning grounds of the spring spawning herring twice a week during March and April (see Figure 1; H. Bjørke and L. Rey, pers. comm., Institute of Marine Research, Bergen). The larvae were sampled with conical dip nets with 0.5 $m^2$ opening and 375 µm mesh size. The nets were hauled from 150-0 m with a speed of 0.5 ms $^{-1}$. 50 larvae were staged according to Doyle (1977) and measured to the nearest mm. For further information on the sampling program, see Bjørke (1988).

The hatching curve was calculated on the basis of the 1b, larvae. These were more uniformly distributed both horizontally and vertically than were the 1a larvae, but still relatively concentrated over the spawning grounds. The original number of 5 days old 1b larvae (stage-duration, see Bjørke et. al 1986) were back-calculated with 10% daily mortality rate (Christensen 1985).

The older larvae of Norwegian spring spawners of the 1990 yearclass were sampled on the Norwegian shelf during May in the area 64 $^0$ - 69 $^0$N. The sampling locations are indicated in Figure 1. The gear used was a mid-water capelin trawl with a 10 m fine (8 mm) mesh-sized net inside the cod end. The larvae were preserved in 80% buffered ethanol shortly after capture.

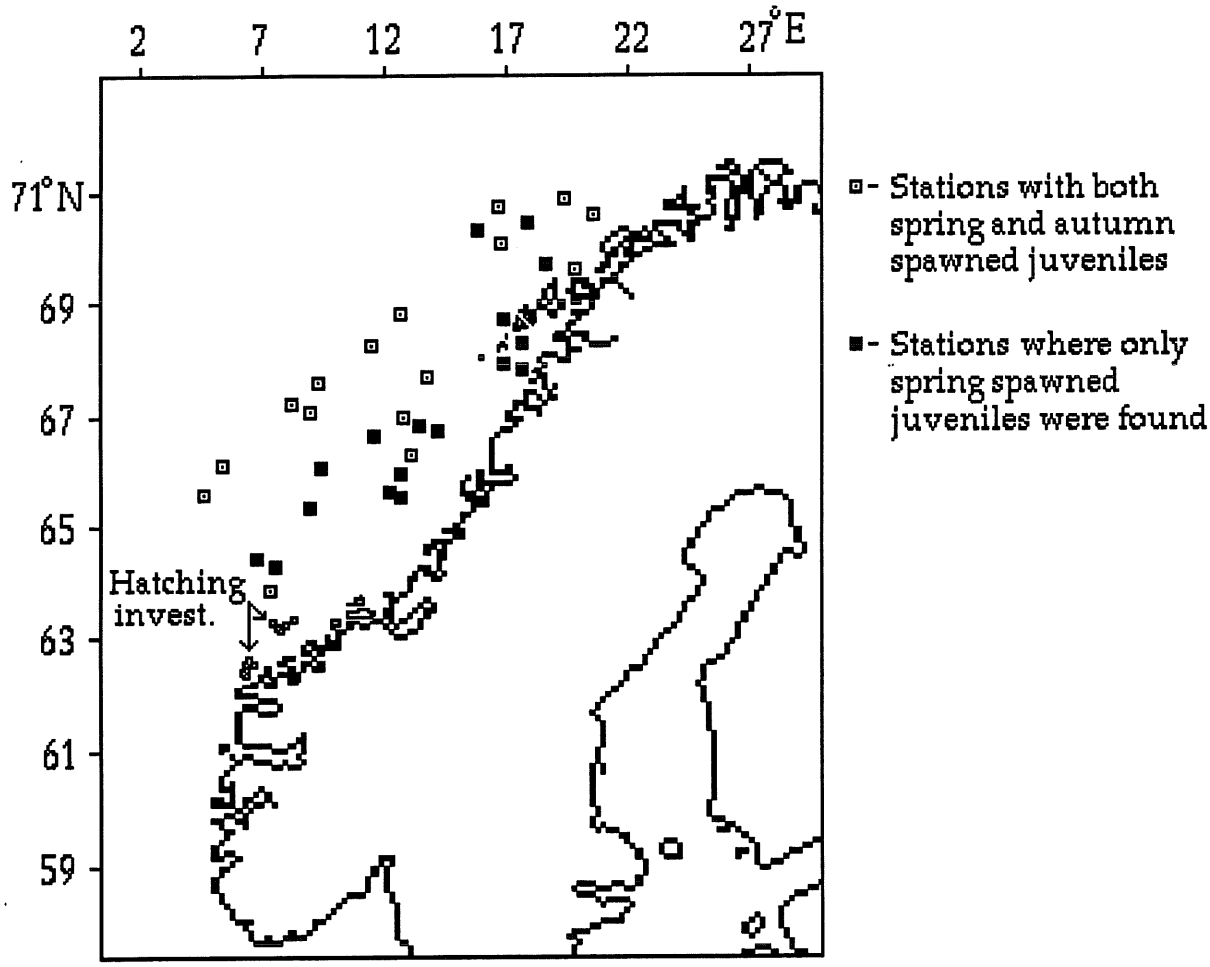


Figure 1. Sampling locations of larvae caught during May (▫, ▪ ), and for the hatching investigations ( ∘ ) carried out during March-April 1990.

<u>Laboratory work</u>

The sagittae from each herring larvae were removed and mounted on glass slides for later examination in light microscopy. The examination and measurements of the microstructure in the sagittae were conducted using the same techniques as described by Moksness and Wespestad (1989). To get the real age of the larvae nine days were added to the number counted to compensate for the yolk-sac stage (Campana and Moksness in press).

Correction for shrinkage due to conservation in 80% ethanol is 40% for dry weight and 4% for standard length (Moksness, own unpubl. data).The condition factor, CF, was calculated according to the formula:
$CF = (DW/SL^3)*1000$, where DW and SL are dry weight (mg) and standard length (mm) respectively.

## RESULTS

### The samples of larvae

257 larvae were examined and a summary of the statistics is given in Table 1. The larvae belonged to two different groups. Most of the larvae were spring spawned $N_{spring}=228$, while the rest of the larvae were autumn spawned $N_{autumn}=29$. In Figure 1 the stations where the autumn spawned larvae were caught are indicated, they are mainly found on the outer part of the shelf.

Table 1. The average standard length (SL) with standard deviation (SD). Minimum (Min) and maximum (Max) standard length, average dry weight (DW) and condition factor with standard deviation (SD). The number of spring spawned and autumn spawned herring larvae (N) sampled on the Norwegian Shelf in May 1990. The length and weight data are corrected for shrinkage.

| Hatching period | SL+SD (mm) | Min (mm) | Max (mm) | DW+SD (mg) | CF+SD | N |
|---|---|---|---|---|---|---|
| Spring | 24.0±2.2 | 18.2 | 31.5 | 4.0±1.5 | 0.29±0.08 | 228 |
| Autumn | 35.4±3.3 | 29.1 | 42.8 | 38.8±17.1 | 0.84±0.19 | 29 |

The standard length of the spring-spawned larvae ranged from 18.2 to 31.5 mm, while the autumn-spawned ranged from 29.1 to 42.8 mm. Figure 2 shows the length distribution of the two different groups; there is very little overlap between them. On the 33 stations where samples of herring were taken, 169 larvae had a standard length of 30 mm or above, while 2455 larvae were less than 30 mm.

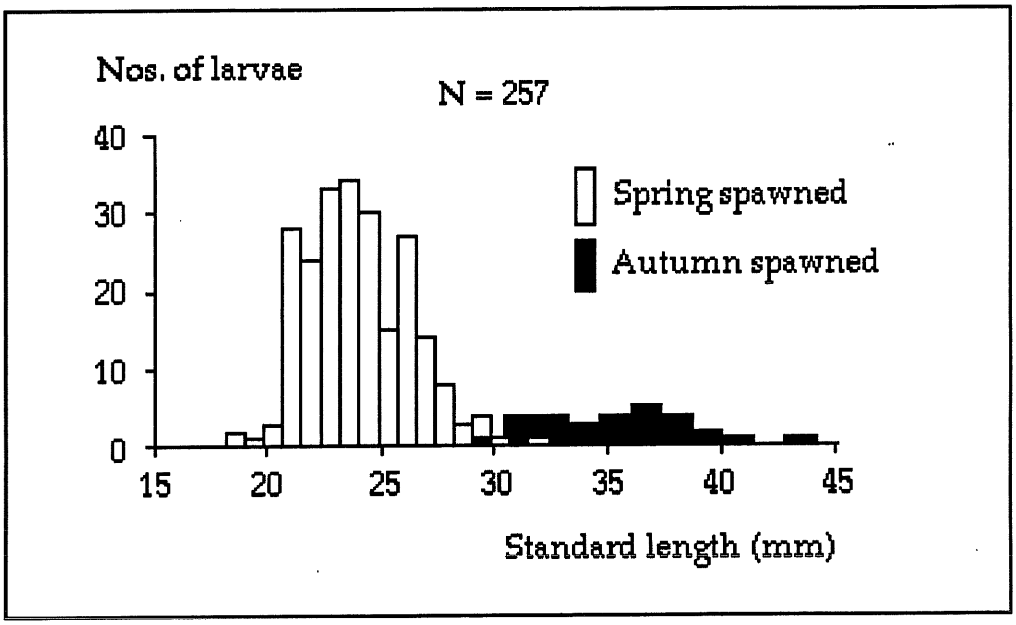


Figure 2. Distribution of length of the spring- and autumn- spawned herring larvae.

Microstructure

The average number of zones in the otoliths and the distance from the nucleus of the otolith to the hatching ring -the hatch chec -, are given in Table 2.

Table 2. The average number of increments and distance from the nucleus to the hatching ring (hatch check), both with standard deviation.

| Hatching period | Hatch check, µm ± SD | Increments ± SD | N |
|---|---|---|---|
| Spring | 12.7±1.0 | 36.4±7.1 | 228 |
| Autumn | 10.4±1.1 | 199.2±27.0 | 29 |

The average increment width during life span is given both for the autumn-spawned and spring- spawned larvae in Figure 3.

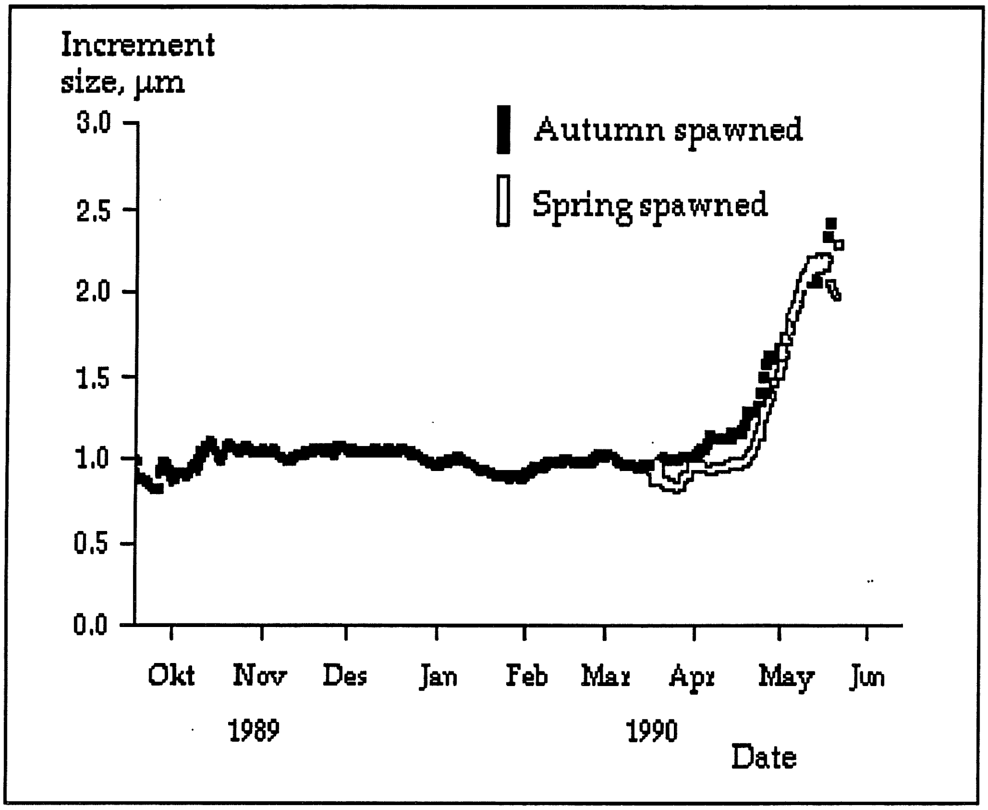


Figure 3. The average increment size (µm) measured in the autumn- and spring spawned larvae.

The figure shows the formation of very thin increments in autumn spawners during winter. The increments are slightly above 1 µm in November and December. In January and February the increment width is below 1 µm. The formation of larger increments starts in April and towards the middle of May the width is above 2.0 µm. The spring spawners deposit small increments during the first month. After that there is a fast increase in the width which also is above 2.0 µm in the middle of May. However, the response to the improved food conditions in spring is somewhat faster in the larger autumn spawners.

The mean growth rate of the autumn spawners is 0.13 mm/day in the whole period from October 1989 to May 1990. The back-calculated growth rate of the spring spawners is shown in Figure 4. The growth rate was calculated from one week after the yolksac is resorbed (when the relationship between ring deposition and somatic growth is well established) until the herring were caught as well developed larvae 1-2 months later. Initially the growth rate was close to 0.40 mm/day. The rate decreased in the period from 20 to 40 days after hatching to 0.25 mm/ day. After this period and until the larvae were collected there was a slow increase in the growth rate to 0.30 mm/day .

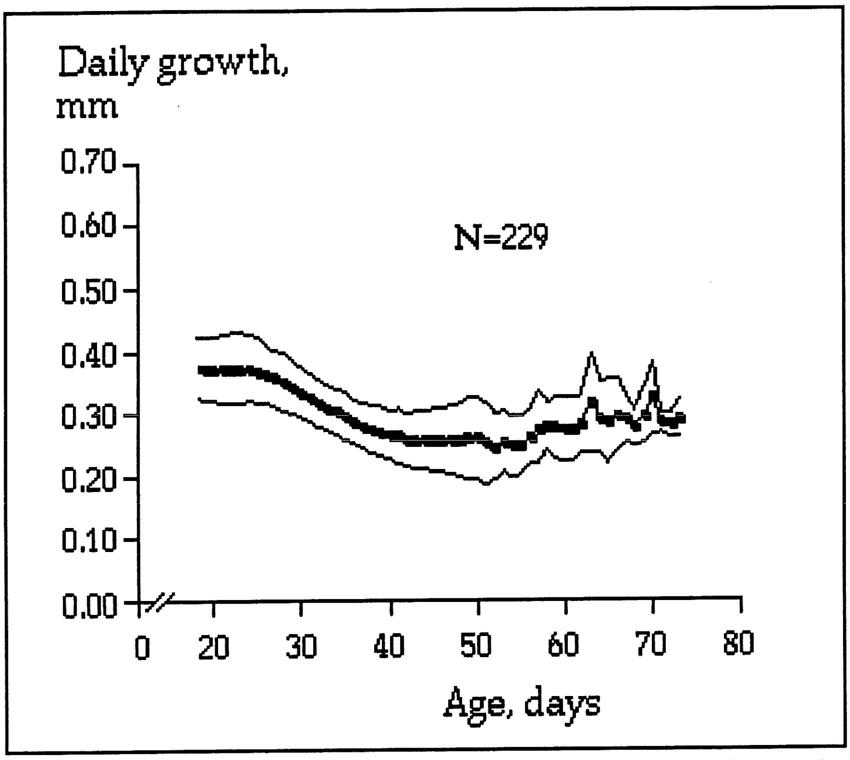


Figure 4. Back-calculated daily growth rate from the spring spawned larvae caught in May 1990.

<u>Back-calculated hatching</u>

The hatching of spring-spawned herring larvae occurred at the main spawning grounds from 10 March and terminated towards 10 April. 50% hatching occurred by calender day 85 ( 26 March). The hatching curve is shown in Figure 5.

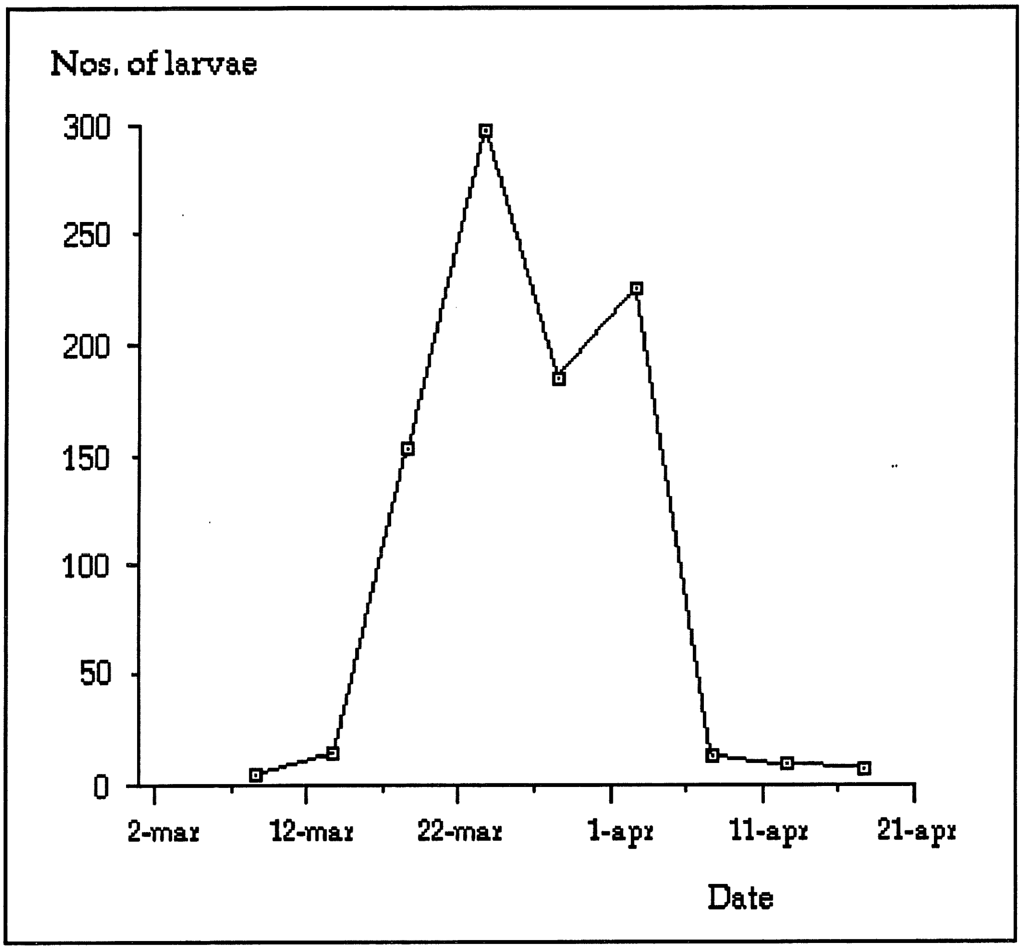


Figure 5. The hatching curve of spring-spawning herring in 1990. Number of larvae examined was 1550.

Another hatching curve was back-calculated from the otolith data. This is the hatching curve of the herring larvae that survived the first feeding period. This hatching curve is shown in Figure 6 together with the hatching curve that was measured in March/April. The back-calculated hatching took place in the same time period from 10 March to 10 April, but 50% hatching occurred later on calender day 91 (1. April) (t-test; $t=12.03$, $p<0.01$, $DF=666$).

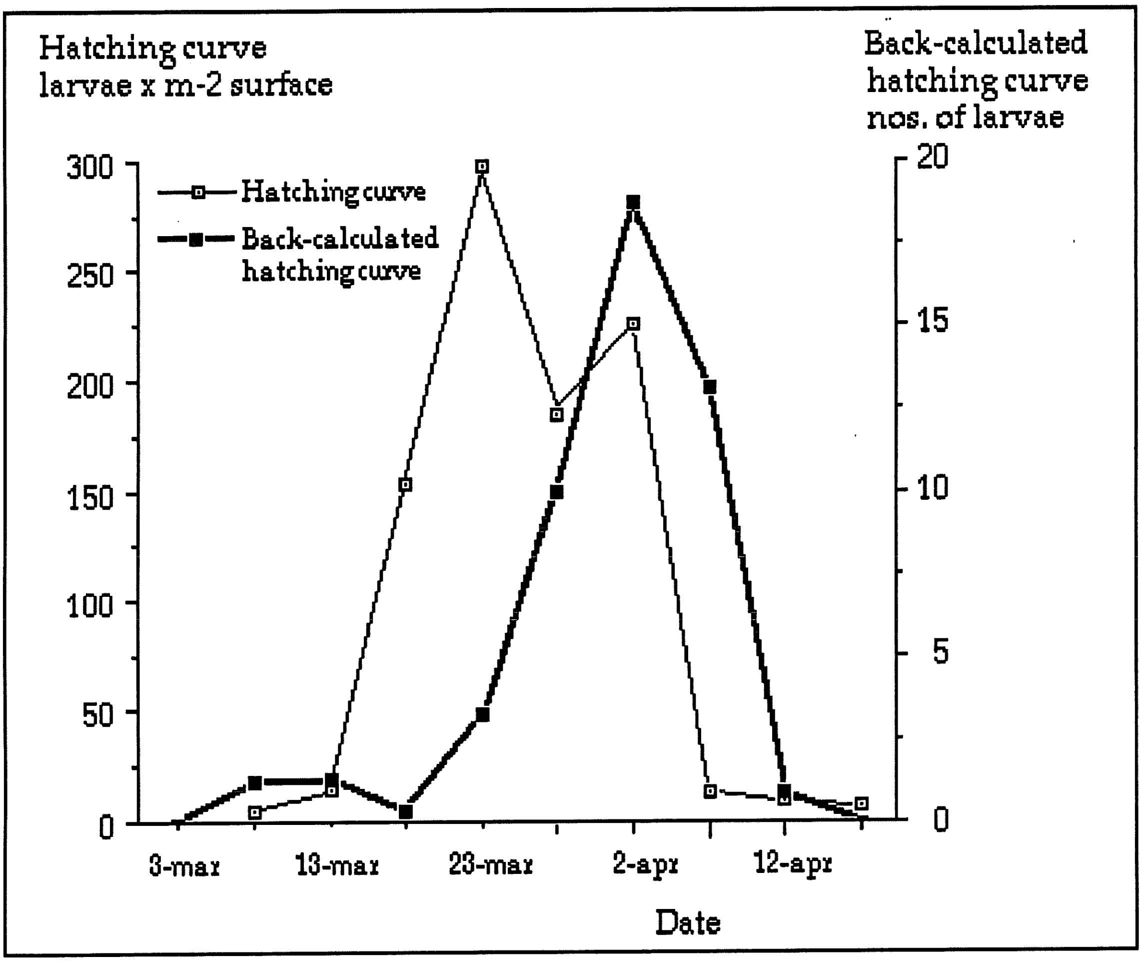


Figure 6. Hatching curves of spring spawning herring in 1990. Number of larvae examined was 229.

The material sampled in May was divided into three categories depending on the location of the sampling site. One group between 64 and 66 $^{o}$N, another between 66 and 68 $^{o}$N and a last one between 68 and 70 $^{o}$N. The back-calculated hatching curves in the three different areas are shown in Figure 7. 50% hatching took place on calender day 90, 92 and 90 in the three areas respectively and were not significantly different (Kruskal-Wallis; statistic 3.044, p=0.218,DF=2). No growth differences between the three areas were found (Figure 8).

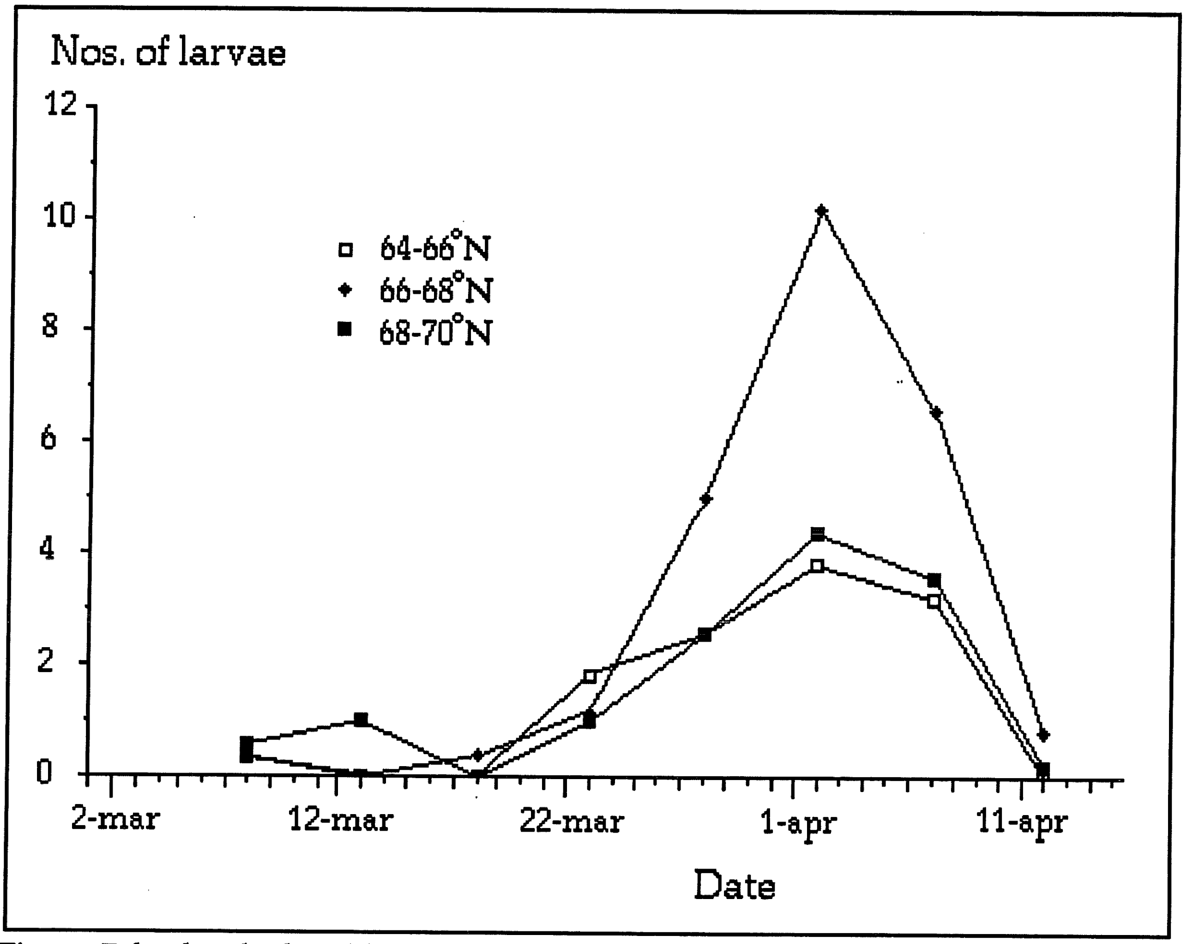


Figure 7. back-calculated hatching curves for three different areas, 64-66N, 66-68 N and 68-70 N.

Both the back-calculated hatching and growth curves indicate that the sample of 1990 herring larvae was a rather uniform one .

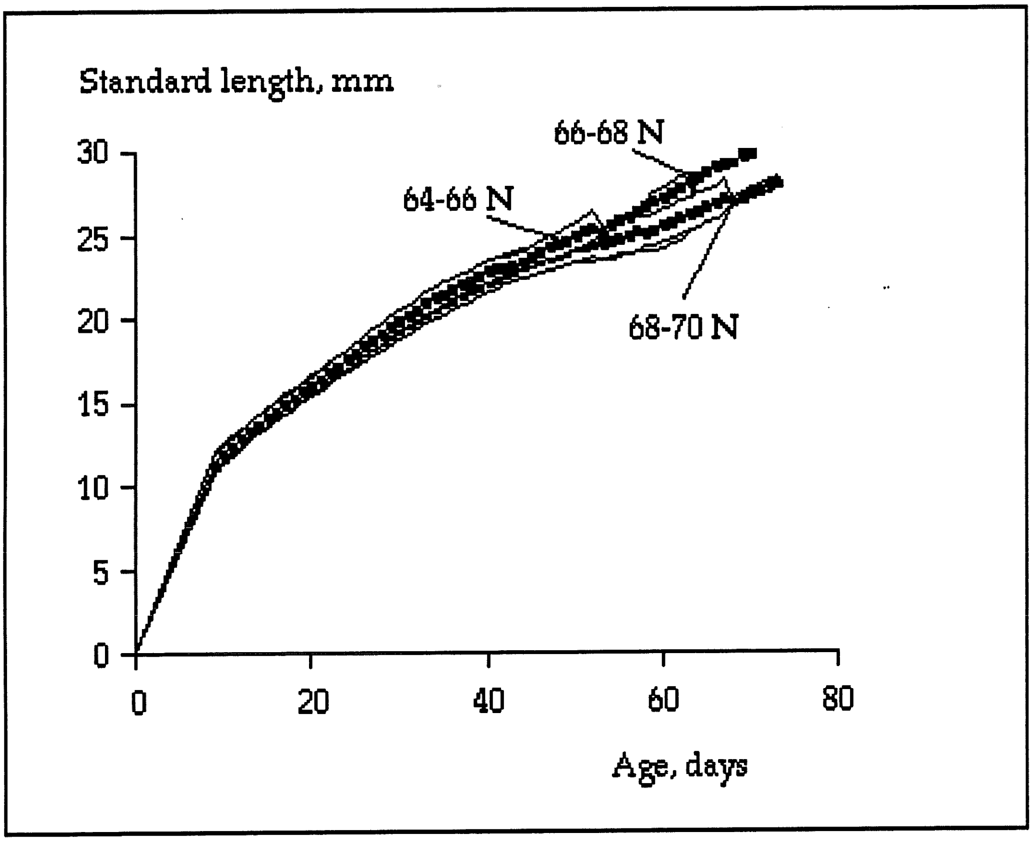


Figure 8. Growth of the larvae sampled in the three different areas, 64-66 °N 66-68 °N and 68-70 °N.

A comparison between the back-calculated hatching distribution and what was actually seen on the spawning grounds in March/April is shown in Figure 9. The number of larvae that were back-calculated to have hatched in five days intervals commencing 3 March, are compared with the number of larvae that actually hatched in the same periods. This is shown as an index of survival. The figure indicates that survival was poor during March and the first days of April. In the period 5-9 April, however, the survival rate changed dramatically and even though the production of larvae ceased, many of the surviving larvae orginate from this time period.

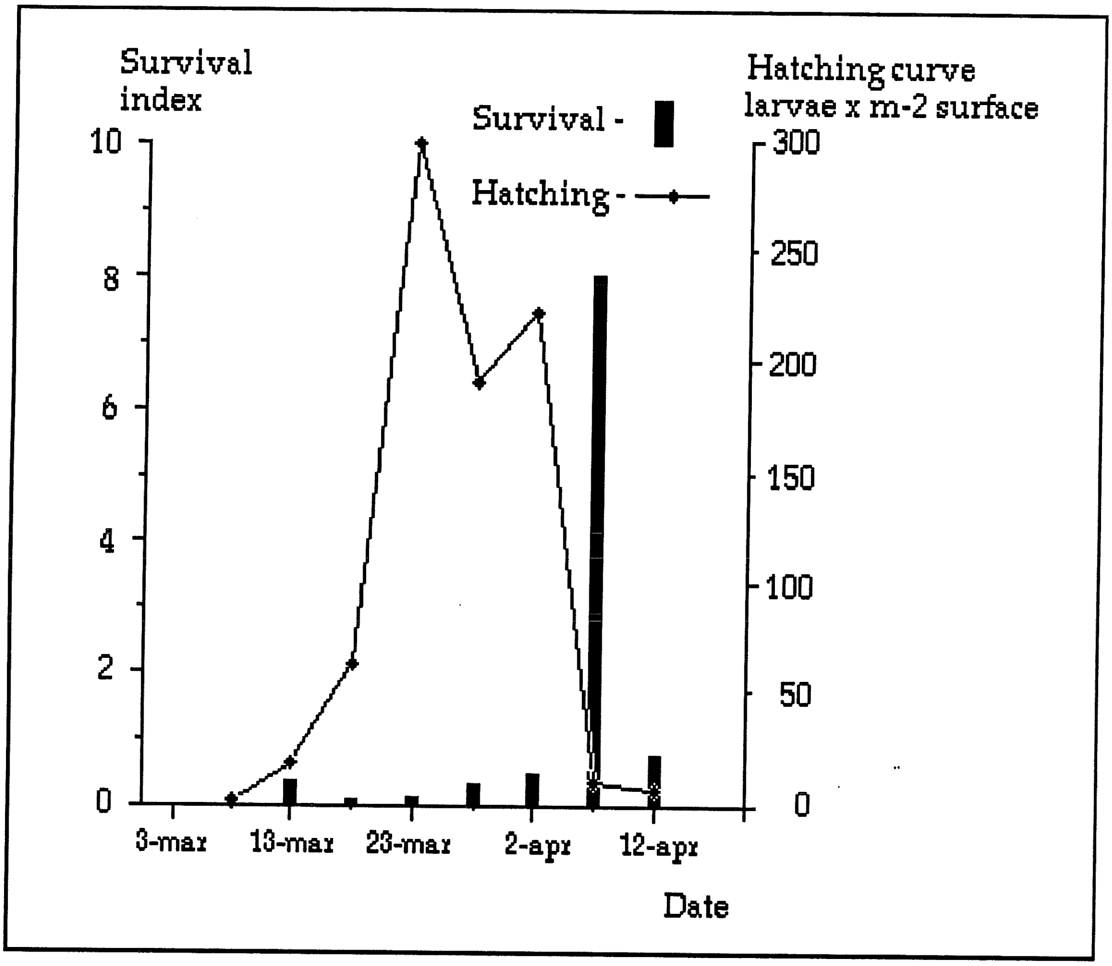


Figure 9. The hatching curve measured on the spawning grounds and an index of survival of the 1990 yearclass of spring spawning herring.

## DISCUSSION

Since Panella (1971) first described daily increments in the otoliths of some marine fish larvae, there has been an increased use of the otolith microstructure in the study of fish recruitment.

The crucial thing about the use of increments as indicators of age is the verification of the 1:1 relationship between real age in days and number of increments. If the ring deposition is irregular in periods with slow or fast growth rate, the value of the information evolved from the otolith microstructure can be greatly reduced. The intercalibration study conducted resently by Campana and Moksness (in press) with spring- spawned herring larvae in a concrete enclosure showed clearly that this relationship (between age in days and number of increments) was 1:1 for the larvae examined in the present study .The relationship was also valid within a much wider range of increment widths (somatic growth rates) than is normally seen with herring larvae caught from the field.

Moksness (submitted) estimated the birth date with ± 4 days accuracy corresponding to a similar range of the end of the yolksac stage, the starting point for ring deposition. In the field, however, there is a strong selective mortality against the smallest larvae and this probably improves the precision of the age estimate.

Gjøsæter and Øiestad (1981) were also able to give a correct estimate of the day of hatching by otolith readings in another mesocosm investigation with herring larvae. Since the present material is very uniform with only small deviations in increment size from the mean, we believe that the use of daily increment counting and measuring is a reliable and useful method.

The present study is the second one in which the back-calculated hatching curve is compared with the observed one. This was also done with samples from the 1985 and 1989 yearclasses (Moksness and Fossum in press). In 1985 we found a match between the larval production and the distribution of back-calculated birth dates, indicating that all larvae experienced equal survival opportunities. The result was a relatively strong yearclass later consumed as 0- and 1-group cod in the Barents Sea (Mehl 1989).

In 1989, however, the spawning stock and thereby larval production had increased significantly. In that year the larvae produced in the beginning of the hatching period, in the end of March, had the highest survival. This can be explained by a mismatch between occurence of larvae and their food items in that year. However, the number of larvae coming through the window of survival towards the end of March was enough to produce a yearclass above average in size. This yearclass had much better survival opportunities in the Barents Sea and will recruit to the spawning stock in 1993-94.

In 1990 the primary and secondary production commenced relatively late . On a cruise in this area in late March there was no sign of the spring bloom. An investigation on microzooplankton was carried out in the center of the first feeding area of the herring larvae. This investigation revealed that after a period in late March and early April when relatively low numbers of microzooplankton were found (5-10 per liter), the abundance of copepod nauplii increased in the period 7-17 April from 5 to 20 nauplii per liter (H. Bjørke and L. Rey, pers. comm., Institute of Marine Research, Bergen). The larvae hatched in the period 5-9 April, previously found to have extraordinarily high survival rates, were in their first feeding phase during this period of marked increase in nauplii abundance.

The overall growth was reduced in 1990 (0.28 mm $day^{-1}$) compared to 1985 and 1989 (0.32mm $day^{-1}$); this reduction was most pronounced in the period after 40 days when the growth in 1990 was as low as 0.20 mm $day^{-1}$ compared to 0.32 mm $day^{-1}$ in 1985 and 1989. This reduced growth may have increased the mortality in 1990 if there is an inverse growth mortality relationship as indicated by Houde (1987).

The validity of the survival index may be somewhat questionable. The correct hatching curve is difficult to estimate, because of the relatively small set of data resulting from from bad weather conditions this year. The larvae which experienced the highest survival rate were from the period when hatching was culminating and decreasing rapidly to almost zero. In such a period it is quite difficult to give the correct estimate. However the index of survival of this period is so large that it is still exceptional even if the estimate of newly hatched larvae is twice or three times as high as the one presented.

The material sampled in 1990 in spring-spawned larvae seems to be a rather uniform one. No differences in the back-calculated birth date and growth were observed between the three different areas investigated. The material originated from one cohort. This indicates that the whole yearclass was produced on the spawning beds off Møre, the most important spawning site of the last 10 years.

The autumn-spawned larvae were mainly distributed on the outer parts of the shelf indicating their more southerly origin relative to the spring-spawned ones. They were probably hatched in the North Sea in the last part of October 1989. They may have entered the Norwegian Coastal Current from Skagerrak or directly from the North Sea. These larvae will eventually be distributed in the western part of the Barents Sea and up until Spitsbergen. However, there still remains the unresolved question as to what the fate of these larvae will be. Will they return to the North Sea, will they intermingle with the spring- spawned herring, or will they die out?

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