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A study of first feeding herring (*Clupea harengus* L.) larvae during the period 1985-1993.

by

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Abstract

Hatching and distribution of first feeding larvae of Norwegian spring spawning herring have been monitored on the Norwegian shelf in March and April since 1985. During this period the spawning stock increased from 0.5 to 2.0 mill. metric tonns with the recruitment of the 1983 yearclass to the spawning stock. This was seen as a significant increase in the number of larvae over the spawning beds since 1988. During the same period the recruitment of herring changed dramatically, with low to moderate recruitment in the period 1985-1988 and good recruitment in 1989-1992. Samples of first feeding herring larvae were taken within the central area of herring larvae distibution. Length, weight and gut content were measured. Plots of length versus dry weight are presented together with results from gut content analyses. The importance of these parameters as an early indication of recruitment is discussed.

Introduction

Yearclass strength of Norwegian spring spawning herring (Nss-herring) has been the subject of several investigations over a long period of time (Dragesund, 1970). Year-to-year variations in yearclass strength are known to vary up to two orders of magnitude between a strong and a weak yearclass (Lea, 1930). Hjorts (1914) suggested that variations in abundance of prey may be the main reason for variation in yearclass strength. His hypothesis find some support in recent works by Moksness and Fossum (1992), Fossum and Moksness (1993) and Fossum and Moksness (in press) where the age distribution of the 1985,1989,1990 and 1991 yearclass as 1-2 month old larvae were compared with the hatching curve and the abundance of prey in the first feeding area of the larvae.

Herring larvae investigations have been carried out since 1985. During the period 1985-1993 the recruitment of herring has changed dramatically, with low to moderate recruitment in the period 198ɔ-1988 and good recruitment in 1989-1992 (Toresen, 1990; Anon, 1992). The main results from these investigations during the period 1985-1987 are given in Bjørke et al (1986); Fossum et al (1987); Sætre et al (1988) and Fossum (1988). In the present paper some results from the larval surveys during the period 1988-1993 are presented. The results are compared with the findings from previous periods.

Materials and methods

The present surveys for first feeding herring larvae were carried out during the first fourteen days of April on the Norwegian shelf within the area between 58⁰-66⁰30´N. 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 ms^{-1}. The larvae were sorted out from the samples and 50 larvae were staged according to Doyle (1977). The herring larvae were preserved in 2% formalin, and 20 larvae were selected from each station for standard length, dry weight and gut content analysis.

Additional sampling of yolksac herring larvae were carried out at 12 different stations over the spawning beds off Møre twice a week from March 15 to April 24 (Bjørke and Rey, 1991). The mean number of 4 - 7 days old larvae (stage 1b) were used to estimate a hatching curve for each year.

A more detailed description of sampling and preservation of herring larvae are given in Fossum and Moksness (1993).

Results and discussion

Since the start of the recovery of the Nss-herring stock, the main spawning has taken place on the shelf off Møre in the area between 62-63⁰30´N (Røttingen, 1992). During the last few years there has been a tendency of southward movement of the spawning, and in 1993 there also seemed to be a more northward extension. This follows the increase of the spawning stock with the recruitment of the 1983 yearclass. In the period 1988-1992 no new recruitment to the spawning stock has occured and the growth of the spawning stock has been regulated by individual growth and mortality. In 1993, however, some new recruitment of the 1988 yearclass and the fastest growing individuals of the 1989 yearclass may have occured. Although there has been a tendency of southward and northward extension of the spawning in this period, more than 90 % of the spawning stock has been spawning in the central area off Møre.

In Fig. 1 the distribution of herring larvae sampled on the Norwegian shelf in the period April 19-26, 1988 is shown together with the hatching curve from the same year. The figure shows that the main distribution of larvae is found on the shelf off Møre. The hatching curve had a bimodale shape this year, probably because of the strong 1983 yearclass recruited to the spawning stock and spawned later than the older component of the spawning stock. The survey took place in the middle of the haching period of the larvae from the 1983 component. The statistic of the larvae sampled during the period 1985-1993 are shown in Table 1.

In 1989 the 1983 yearclass dominated the spawning stock completely, and most of the hatching (Fig. 2) took place in a relative short period in the last days of March and the first days of April. The survey took place at the same time and was dominated by recently hatched larvae.

In 1990 the hatching started somewhat earlier and most of the larvae hatched during the last fourteen days of March. The main concentration of larvae was found in the same area as in previous years with high concentrations of larvae off Møre (Fig. 3). Most of the hatching had taken place in the period just before the survey period, and the larval samples were dominated by yolksac larvae.

In 1991 the hatching took place in the middle of March. This was significantly earlier than the previous years. The survey was carried out 3-4 weeks later. Most of the larvae must have been advected out of the area or were so large that they were able to avoid the dip-nets. Fig. 4 shows the abundance of larvae in April.

In 1992 no hatching investigations were carried out. Independent information on the age structure of this yearclass in May, indicates early hatching (Fossum and Moksness in prep.). The results from the herring larvae survey shown in Fig. 5, showed high concentrations of larvae in stage 2a in good growth condition in the first feeding area off Møre. The investigation in 1993 (Fig. 6) indicated a northward movement of the spawning. The reason for this may be that the 1988 yearclass and the fastest growing fish in the 1989 yearclass have recruited to the spawning stock. Herring from these yearclasses may prefer different spawning beds than the older part of the stock when they are spawning for the first time. There seemed to be a time lag between the spawning in the northern and the central parts of the spawning area i.e. the larvae in the northern areas were in the last yolksac stages while most of the larvae in the southern areas were in the post yolksac stage.

A coarse index of the larval abundance ($N*10^{-12}$) is calculated for the period 1985-1993 (Fig. 7). The larval indices were calculated according to Map-Library described in Knutsen and Westgård (1988). The size of the index is

very much dependent on the timing between the hatching of the larvae and the survey period. However, it appears that there has been a shift from low to high abundance of larvae with the recruitment of the 1983 yearclass in 1988 and that the spawning stock have produced high larval indices in the period from 1988. The highest value of the index for the whole period was found in 1993. This year there might have been an increase in the spawning stock and it seem to have been good timing between the hatching and the survey in the northern part of the area.

The statistics of the larvae are given in table 1. There is a sigificant length and weight loss due to shrinkage during preservation. Fossum(1988) measured a length and weight loss of 6 different samples on 5.9%±3.9 and 40.6±3.7 respectively. Length and weight in the different stages are remarkably stable during the period of investigation. However, there are some exceptions. The small size of 1a larvae in 1991 can be a result of a different handling technique used during this survey. Another issue is the increasing size of the 1a larvae since 1989. The explanation for this may be that there was no new recruitment to the spawning stock in the period 1989-1992, and the the spawning stock was completely built up by the 1983 yearclass. The herring from this yearclass have been more and more advanced spawners from year-to-year producing larger eggs and larvae.

The larvae hatch with a relatively high dry weigth which is reduced in the period where the larvae are dependent on internal feeding. During the first feeding period this weight loss is reduced and when the larvae starts to be more advanced feeders they start to gain weight. In 1992 this drop in weight was reduced compared to the rest of the years, indicating a successful first feeding period. This was also seen in the gut content analyses of these larvae.

The larvae that survive through the first feeding period and that start to grow are identified in the samples as stage 2 larvae. The indices of 2a larvae ($N*10^{-10}$) are shown in Table 2. A comparison between years must be based on the assumption that there is a time lag between the hatching and the survey period. However, this time period must not be so long that the larvae are advected away from the area. This assumption is not completely fulfilled in 1987, 1989, 1990 and 1991. However, from these data there seem to be a successful first feeding period in 1988-1989, 1991-1993 and partly 1985, giving the impression of a good period of recruitment in the 90´ies.

The length-to-weight relationship (ln dry weight = a*standard length + b), for larvae with standard length above 9 mm is shown for 1993 in Fig. 8. The slope of the regressions, the regression coefficients and the number of larvae for the period 1985-1993 are shown in Table 3. The slopes indicate that the growth rate in the larval poulation is rather constant for all the years where the older stages (>1d) are present in the samples, such as 1987-1989 and 1991-1993.

The gut content of first feeding herring larvae is shown in Fig. 9. The relative importance of copepod eggs and nauplii, the dominant prey organisms in this period, were established with the material sampled in1985-1987. (Fig 8a) In Fig. 8b the total feeding ratios from copepod eggs and nauplii are shown for the period 1988-1993. The feeding ratio of the herring larvae caught in 1992 is much higher than in the rest of the samples, indicating very good first feeding conditions this year. During the period 1988-1991 the feeding ratios are similar, while the guts of the larvae in 1993 contained very few prey organisms. The gut clearence observed in herring larvae (Hay, 1981; Blaxter and Holliday, 1963) makes the gut analyses difficult to perform. This effect appear to be more pronunced in the larger larvae in stage 2a. The largest feeding ratios are found in the stage 1c larvae estimated to be 8 days old at the prevailing temperature. The feeding ratios in Fig. 8 are just a momentary picture of the feeding situation of the herring larvae caught during the survey and tells nothing about the earlier feeding conditions of the larger larvae.

The recruitment of the herring is a very complex process and the herring larvae pass through several difficult stages on its way to stable mortality. There seems to be correlations between the temperature in the Norwegian coastal current and the formation of good yearclasses (Sætersdal and Loeng, 1987) where high temperature is a necessity, but not sufficient alone to produce a good yearclass. The same phenomenon is observed with cod (Ellertsen et al., 1990), but the link between the temperature and other factors are not fully understood. Possible explanations can be that the temperature is linked to the flux in the system, where high temperature is coupled with strong flux and good transport of the larvae into optimal nursery areas, or that high temperature increase the growth rate and reduces the length of the period where mortality is highest.

Match between the herring larvae and their prey seem to be the first important step towards the formation of a good yearclass. After this period the larvae are extremly vulnerable to predation, and there may exist a relationship between growth and mortality as indicated by Anderson (1988). However, the growth rate, both estimated from the length/dry weight relationships during the larval survey and the investigations carried out by Moksness and Fossum (1992), Fossum and Moksness (1993) and Fossum and Moksness (in press) on one to two month old larvae, indicate surprisingly similar growth rates. Preliminary results with larvae from the extreme strong 92 yearclass show the same trend in growth rate as the previous years with an increase in the otolith increment widths from 1-2µm in the period 20-40 days post hatching.

A match between the hatching and the abundance of prey seem to be important in Nss-herring. Folowing the first feeding period there seem to be a period with relative constant growth between years. The size of the

yearclass, after a successful first feeding period, seems to be dependent on the predation on the late larval and 0-group stages and the flux in the transport route eventually bringing them into favourable nursery areas in the Barents Sea.

Acknowledgement

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Table 1. The statistics of the herring larvae with one standard deviation sampled on the Norwegian shelf in early April during the period 1985-1993. Data for 1985-1987 are taken from Fossum(1988).

Stage	Nos. of larvae	Standard length,mm	Dry weight, µg
1985			
1a	62	8.2±0.9	144±35
1b	118	9.0±0.7	120±27
1c	87	10.2±1.1	135±34
1d	193	10.3±1.2	142±38
2a	632	13.0±1.2	248±71
2b	45	16.4±0.9	486±91
1986			
1a	60	8.1±0.9	144±30
1b	193	9.1±0.9	127±25
1c	186	10.0±0.8	133±26
1d	121	10.6±0.8	151±28
2a	87	11.8±0.8	199±36
1987			
1a	86	8.3±0.8	147±33
1b	331	8.4±0.9	120±26
1c	281	9.4±0.9	123±28
1d	338	10.1±0.8	147±30
2a	487	12.2±1.5	258±104
2b	9	16.4±1.1	636±109
1988			
1a	97	7.9±0.6	136±34
1b	621	8.6±0.7	117±27
1c	567	9.4±0.6	121±25
1d	893	10.0±0.5	136±22
2a	781	11.6±1.1	207±63
1989			
1a	753	8.0±0.7	176±33
1b	-	-	-
1c	50	9.5±0.5	137±31
1d	55	10.2±0.4	148±20
2a	52	10.9±0.5	200±44
1990			
1a	61	7.2±0.6	165±45
1b	50	8.4±0.5	146±40
1c	50	9.1±0.6	136±23
1d	53	9.9±0.5	155±23
2a	19	10.3±0.3	189±29
1991			
1a	28	6.9±1.0	173±46
1b	154	8.3±0.9	155±34
1c	77	9.3±0.7	167±29
1d	49	9.5±0.5	172±24
2a	225	10.8±1.4	260±90
2b	6	14.5±1.0	641±130
1992			
1a	39	8.3±0.6	169±43
1b	50	9.6±0.9	162±43
1c	50	10.5±0.6	175±34
1d	51	10.5±1.5	175±36
2a	200	13.0±1.3	354±119
1993			
1a	-	-	-
1b	49	8.7±0.8	178±38
1c	32	9.8±0.7	187±38
1d	53	9.6±0.6	170±25
2a	202	11.7±1.2	292±98

Table 2. The number of stage 2a larvae ($Nx10^{-10}$) and the mean sampling date in April, during the period 1985-1993.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993
Mean date of catch	13	11	4	20	8	4	8	5	12
Nos. of 2a larvae	53	10	20	110	120	22	100	170	890

Table 3. The relationship between standard length versus ln dryweight for the period 1985-1993 (ln dry weight = a* standard length+b).

Year	85	86	87	88	89	90	91	92	93
N	970	467	1161	1986	148	107	357	343	294
a	0.19	0.17	0.22	0.22	0.26	0.12	0.22	0.23	0.22
r^2	0.84	0.52	0.83	0.74	0.54	0.10	0.66	0.85	0.86

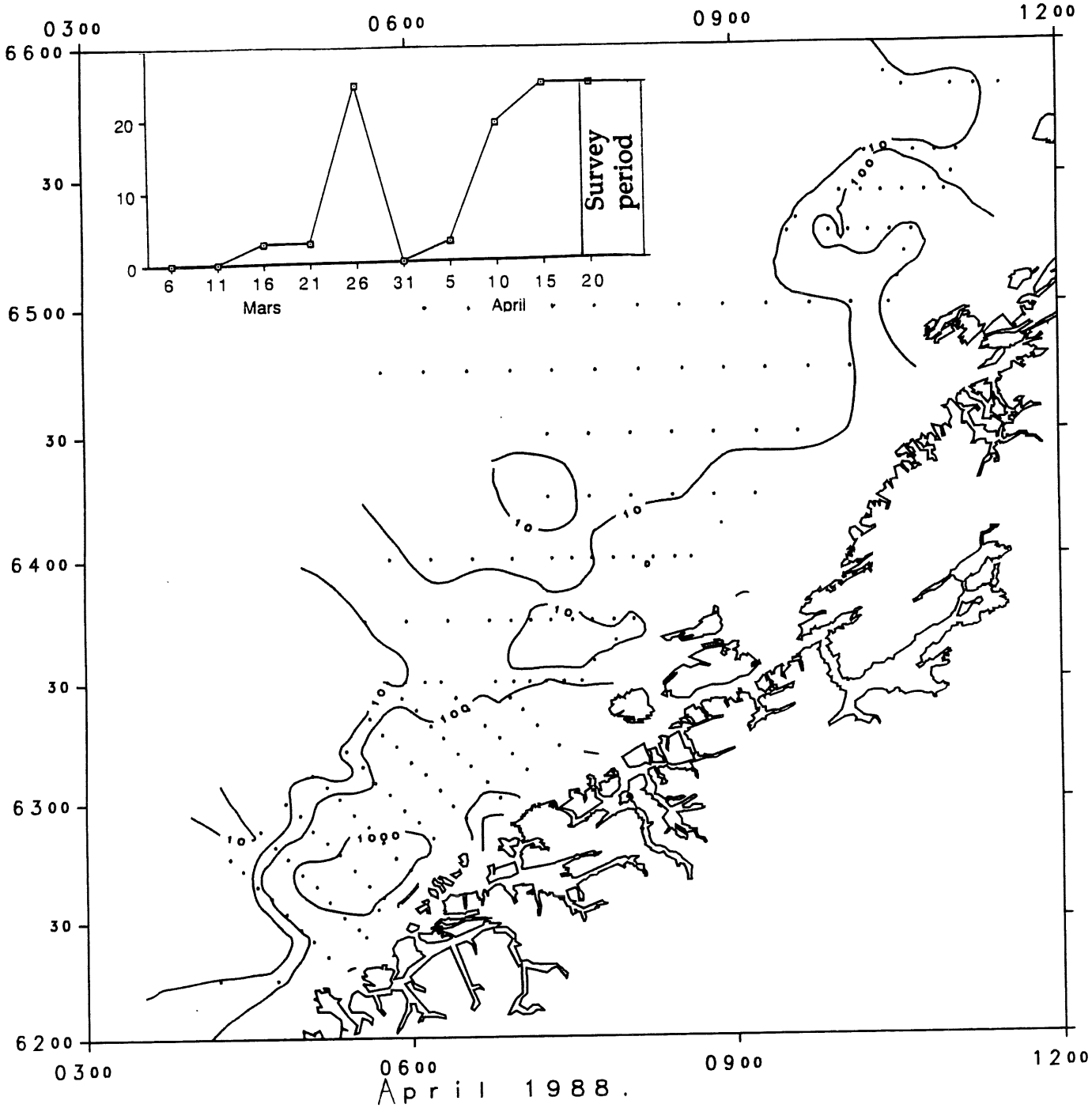


Fig. 1. The abundance of Nss-herring larvae ($N*m^{-2}$) during a survey on the Norwegian shelf in the period 19-26 April 1988 , and the hatching curve of herring larvae the same year.

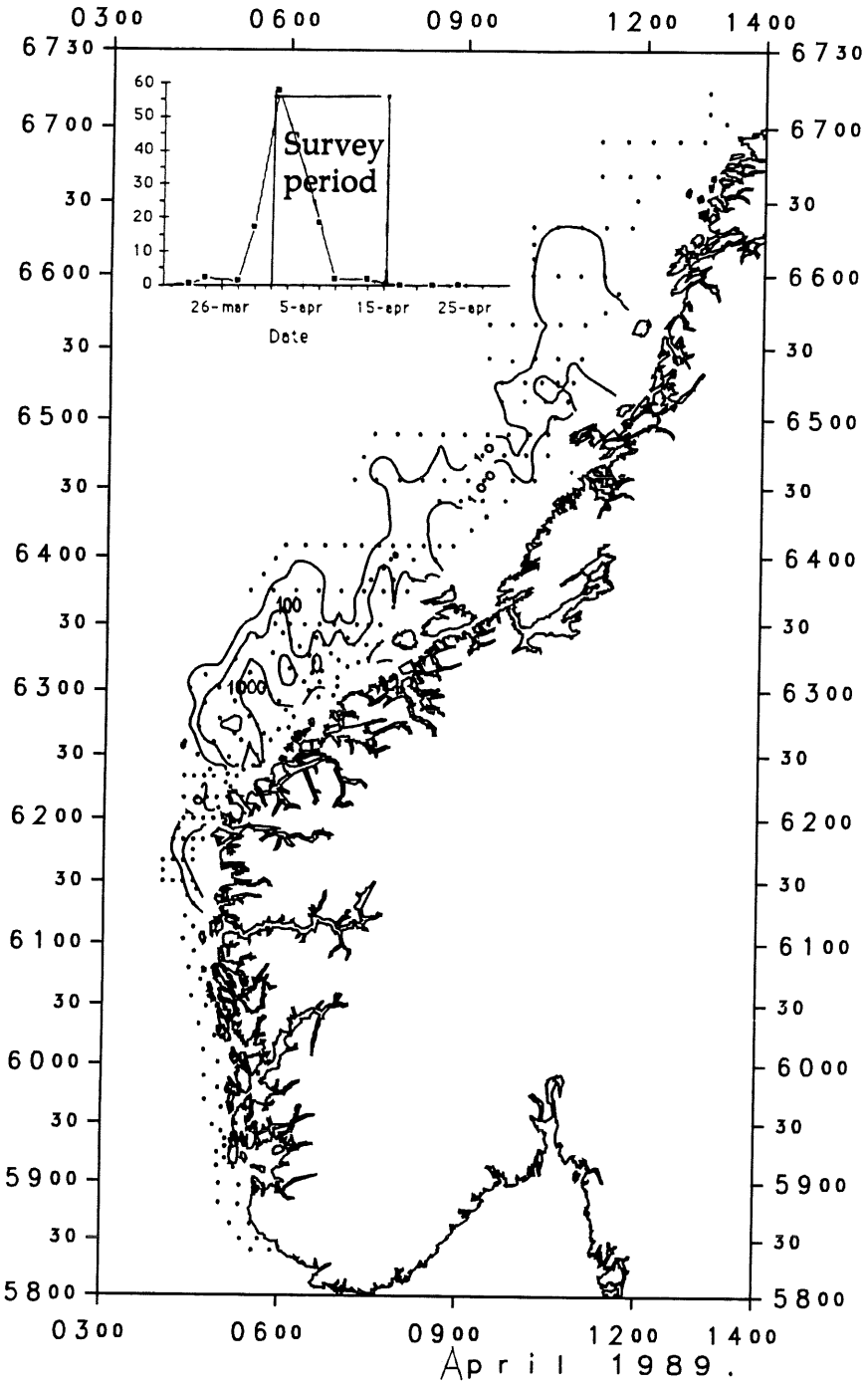


Fig. 2. The abundance of Nss-herring larvae ($N*m^{-2}$) during a survey on the Norwegian shelf in the period 1-16 April 1989 , and the hatching curve of herring larvae the same year.

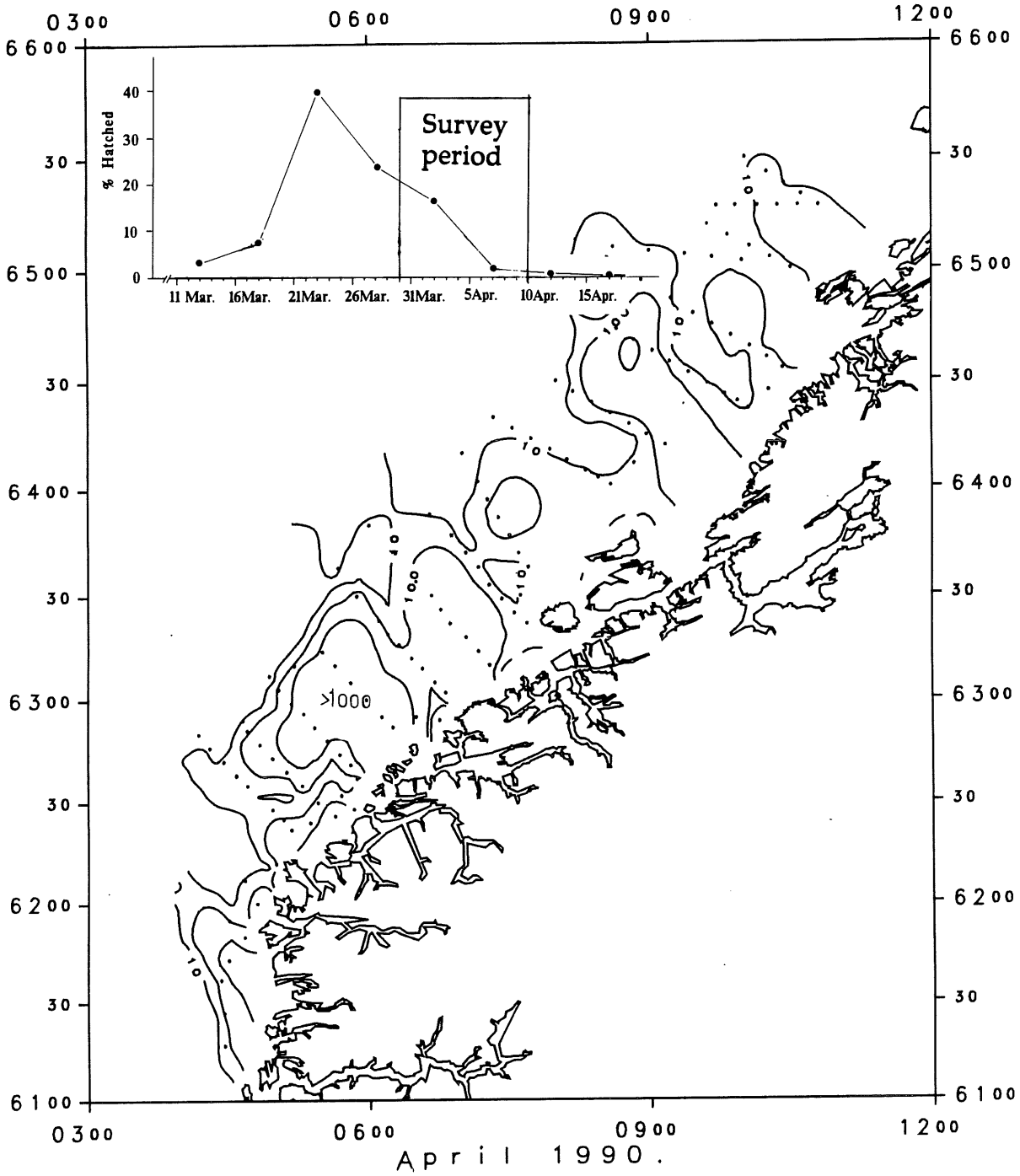


Fig. 3. The abundance of Nss-herring larvae ($N*m^{-2}$) during a survey on the Norwegian shelf in the period 30 March - 10 April 1990 , and the hatching curve of herring larvae the same year.

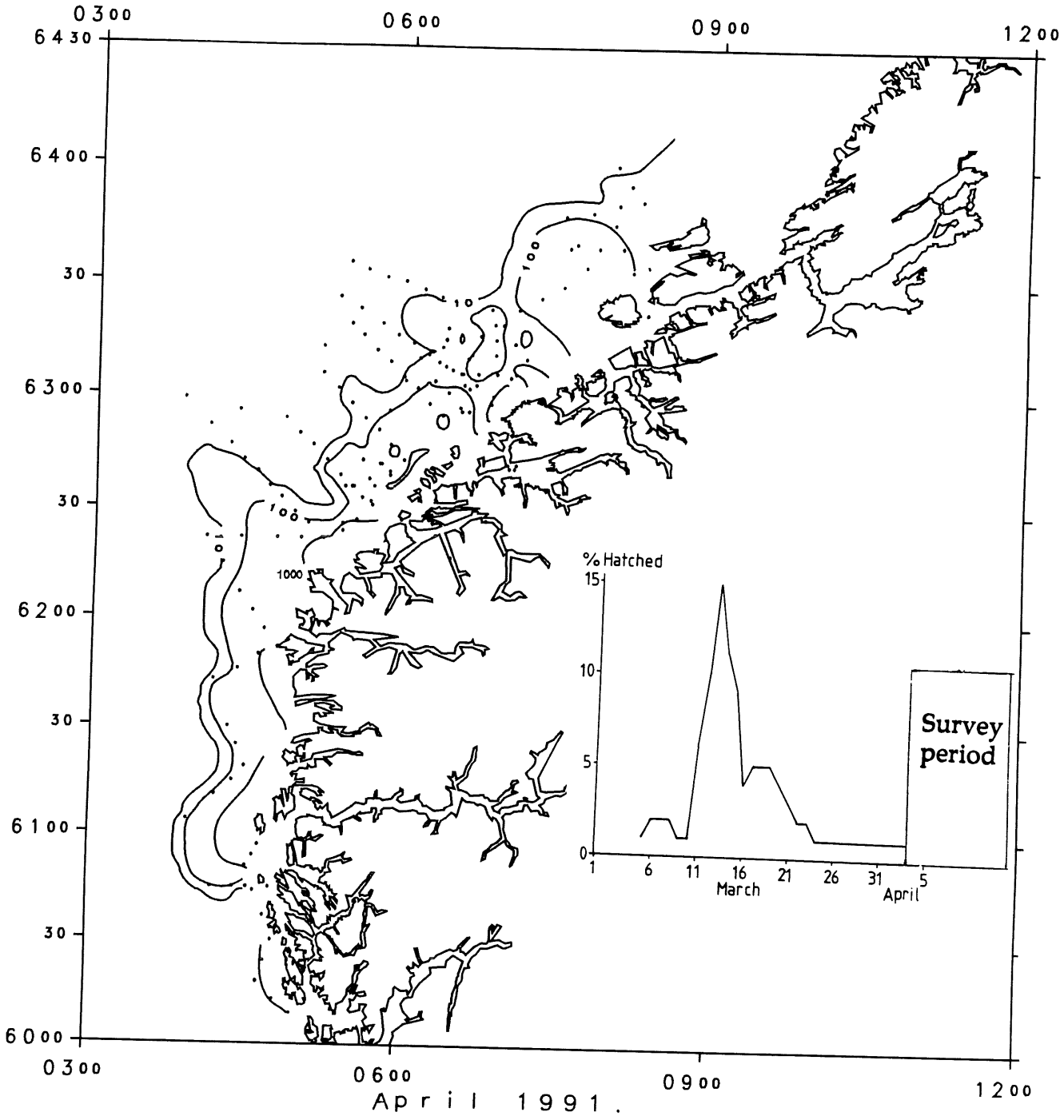


Fig. 4. The abundance of N*ss*-herring larvae ($N*m^{-2}$) during a survey on the Norwegian shelf in the period 3-14 April 1991 , and the hatching curve of herring larvae the same year.

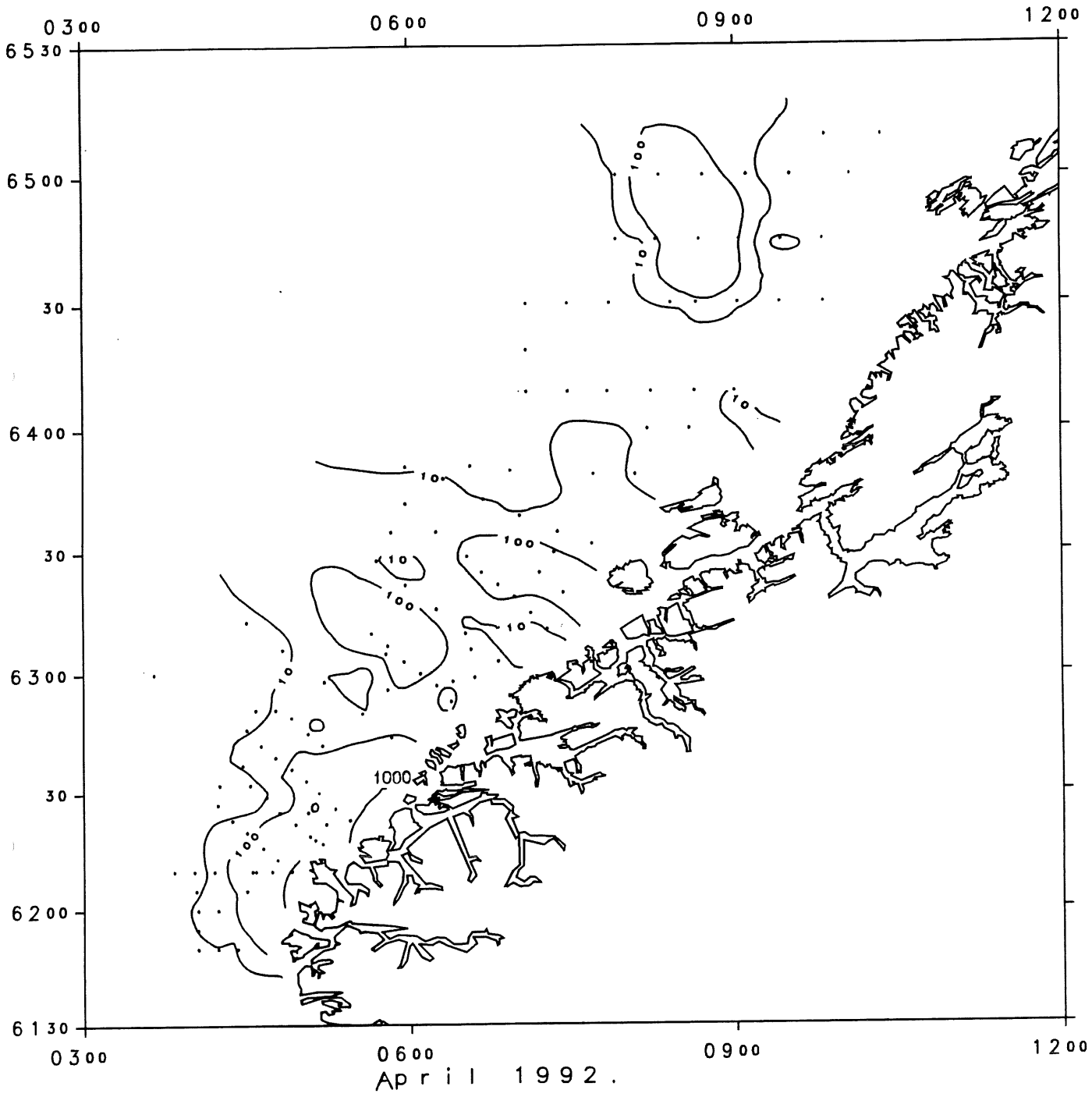


Fig. 5. The abundance of Nss- herring larvae ($N*m^{-2}$) during a survey on the Norwegian shelf in the period 31 March - 9 April 1992.

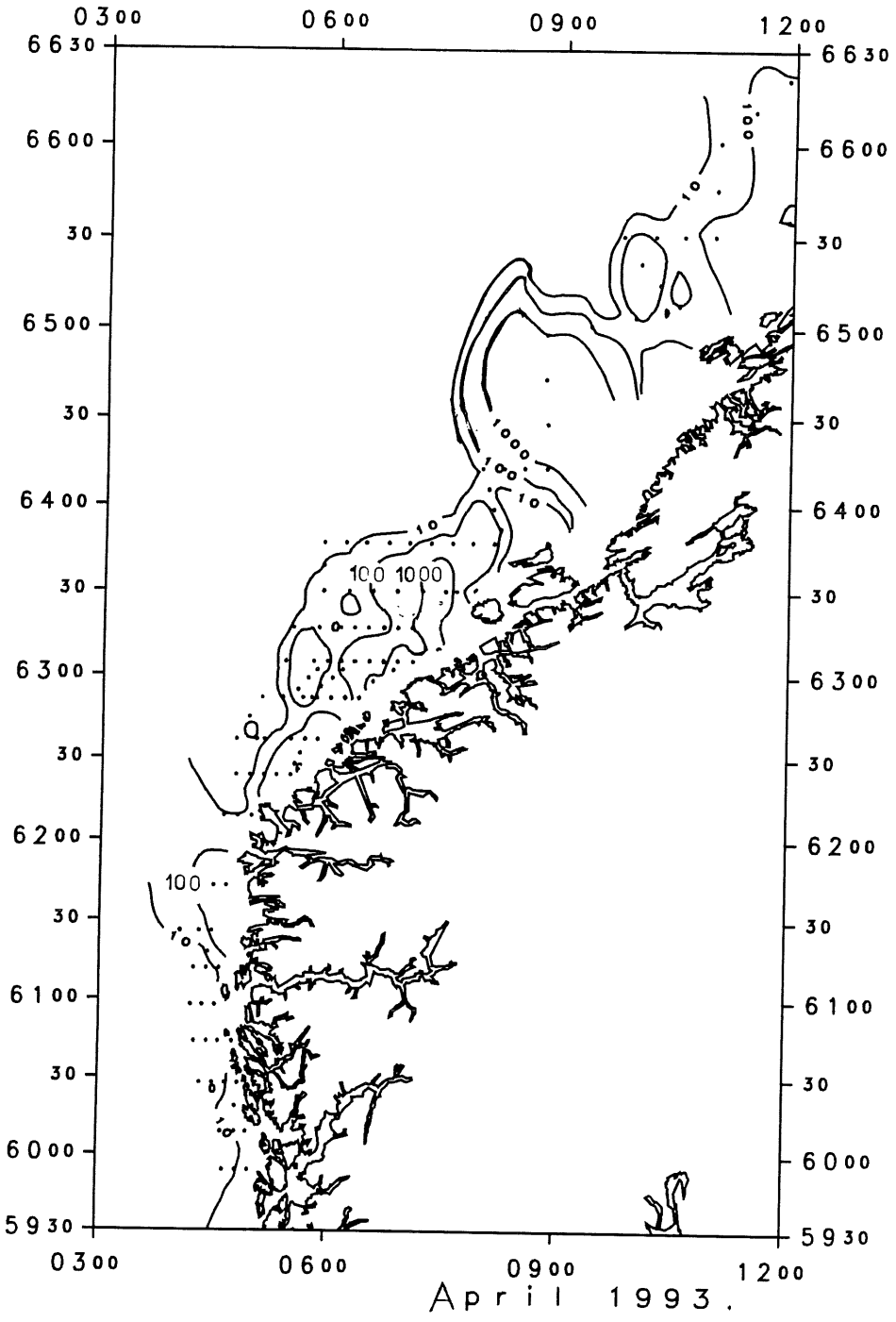


Fig. 6. The abundance of Nss-herring larvae (N*m-2) during a survey on the Norwegian shelf in the period 6-18 April 1993.

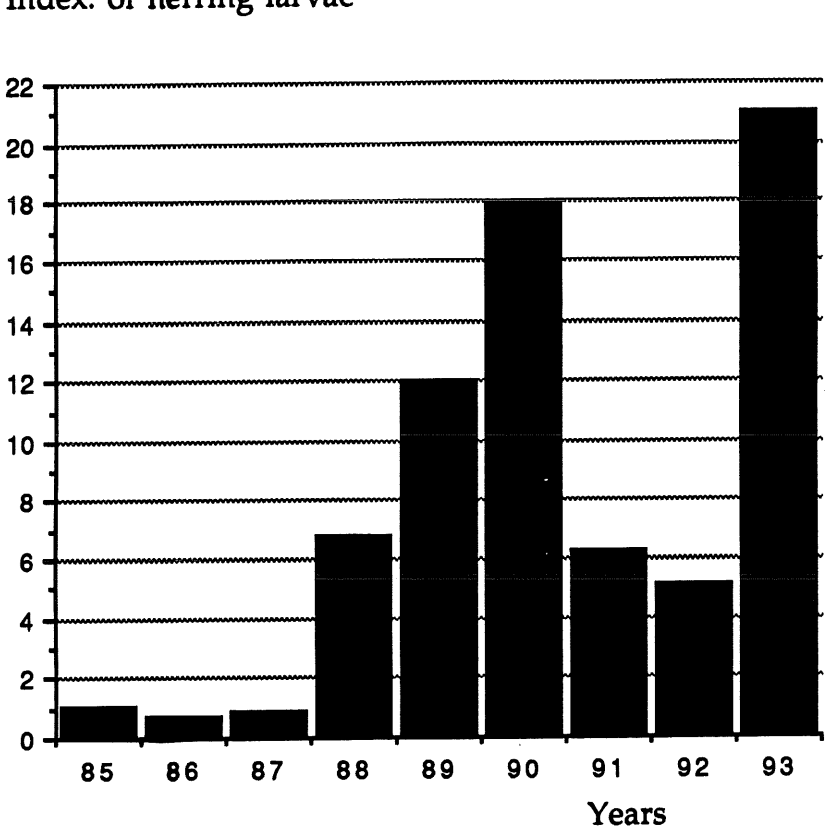


Fig. 7. The index of herring larvae calculated for the period 1985-1993.

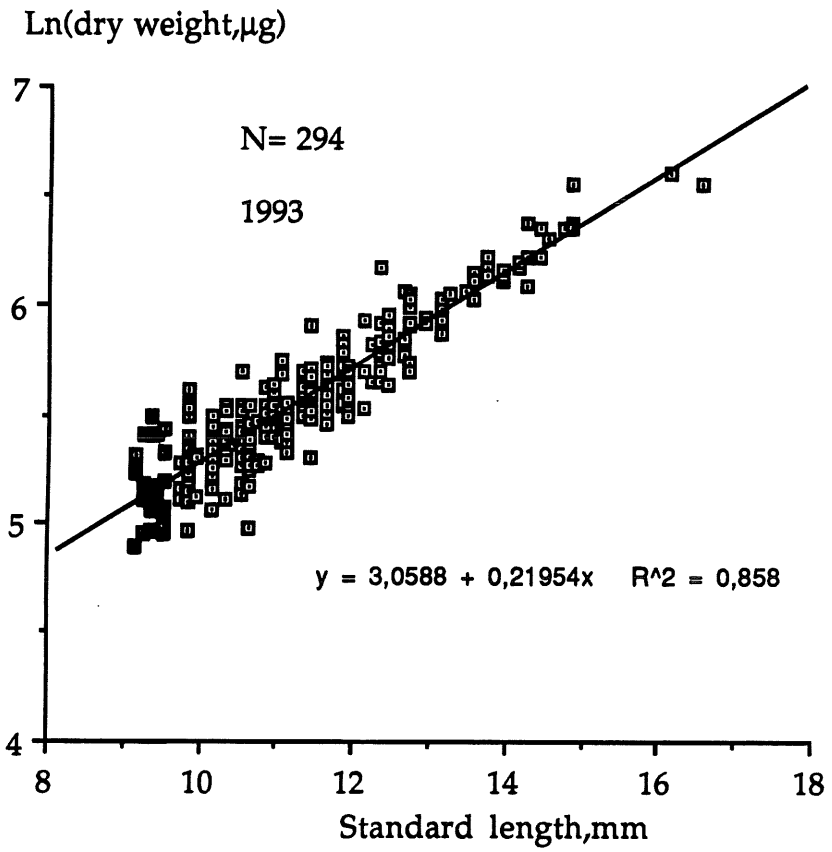
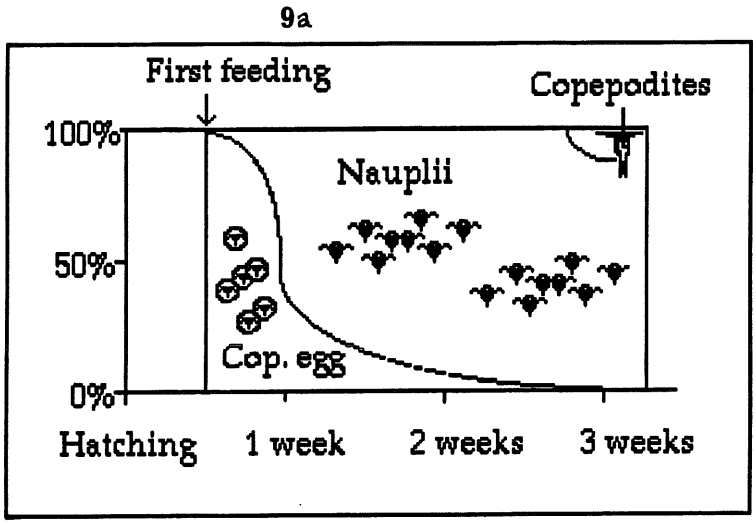


Fig. 8. The length versus ln dry weigth of the herring larvae (l>9mm) sampled on the Norwegian shelf during the period 6-18 April 1993.



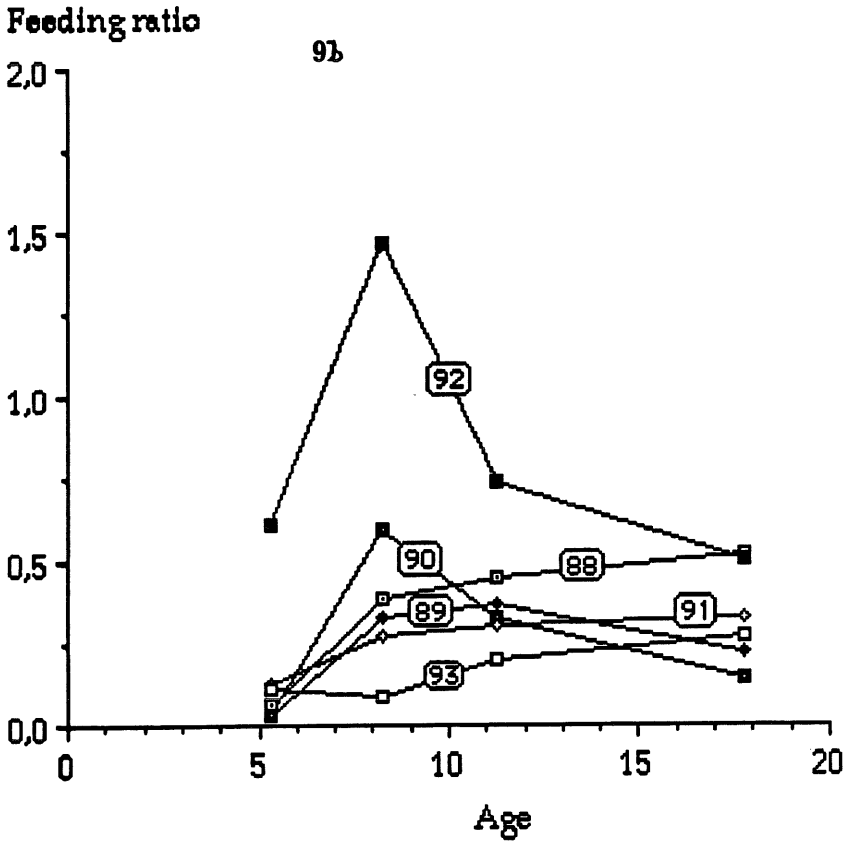


Fig. 9. The gut content of herring larvae, 9a shows the relativ importance of different copepod stages and 9b the feeding ratio for the period 1988-1993. (9a is taken from Øiestad and Fossum 1992).