A COMPARISON BETWEEN ABUNDANCE ESTIMATES OF THE BARENTS SEA CAPELIN AT THE LARVAL, 0-GROUP AND 1-GROUP STAGE IN THE PERIOD 1981-1991

by

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ABSTRACT

A larval abundance estimate, obtained during a Norwegian survey in June, an 0-group index, obtained during the International 0-group survey in August, and an acoustic 1-group estimate, obtained during the IMR/PINRO acoustic survey in September, are compared for the year classes of Barents Sea capelin in the period 1981 to 1991.

There was a strong correlation between the 0-group index and the 1-group estimate. This allows for predictions to be made about year class strength at the 1-group stage based on the 0-group estimates.

No correlation was found between the larval abundance estimate and the two other estimates when all the data was included in the analysis. The larval abundance in 1989 was probably grossly underestimated. When this year class was left out, a correlation was found between the larval estimate and the 0-group index.

INTRODUCTION

A reliable estimate of year class strength at an early stage in the life history of the fish, is important for stock assessment purposes. This will, for instance, give an early warning in case of recruitment failure. This particularly applies for short lived species like the capelin, which recruits to the fishery in the second year of life.

There are certain limitations to how early the year class strength can be assessed. In the first few weeks after hatching most species experience a massive mortality. The mechanisms may vary, but most species seem to be particularly vulnerable in the period just after hatching. An estimate of year class strength during this period may, even if it gives a reliable estimate at that particular time, be of little value in forecasting the strength some months later.

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When trying to measure year class strength during the fist year of life, one therefore faces two problems: To obtain a reliable estimate there and then, and to get an estimate that can be related to the year class strength for instance at age 1 or 2.

The capelin larvae are monitored at annual Norwegian surveys in June, and at the international 0-group surveys in the Barents Sea.in August. In June, a high speed plankton sampler (Gulf III), is used to catch the larvae, while in August, a fish trawl with a small meshed net in the cod end is used. The 1-group estimate is obtained during an acoustic survey in September.

The annual surveys result in acoustic estimates of number of individuals and biomass of each year class at age 1 and older. The reliability of the 1-group estimate has been questioned (e.g. Anon. 1993). The main reasons for doubt is the behavior of the capelin at this age. Individuals in this age group, 7-11 cm in length, are often found mixed with various larval fishes and plankton, which often ascends to near surface depths, i.e. near or even above the depth of the hull mounted echo transducers. The validity of the target strength value measured for larger capelin to these small individuals may also be questioned.

Nevertheless, from about 1980 onwards, the acoustic 1-group estimate has shown a relatively strong relationship with that of the two-year-olds, which is normally considered to be reliable. Moreover, much of the variability in the relationship between the 1- and 2-group estimates in this period may be explained by variable natural mortality (Anon. 1993). Previously, the 1-group was most years grossly underestimated (Figure 1). This can, however, at least partly, be explained by an insufficient coverage of the main distribution area of this age group; the southeastern part of the Barents Sea, during the annual autumn surveys prior to 1980.

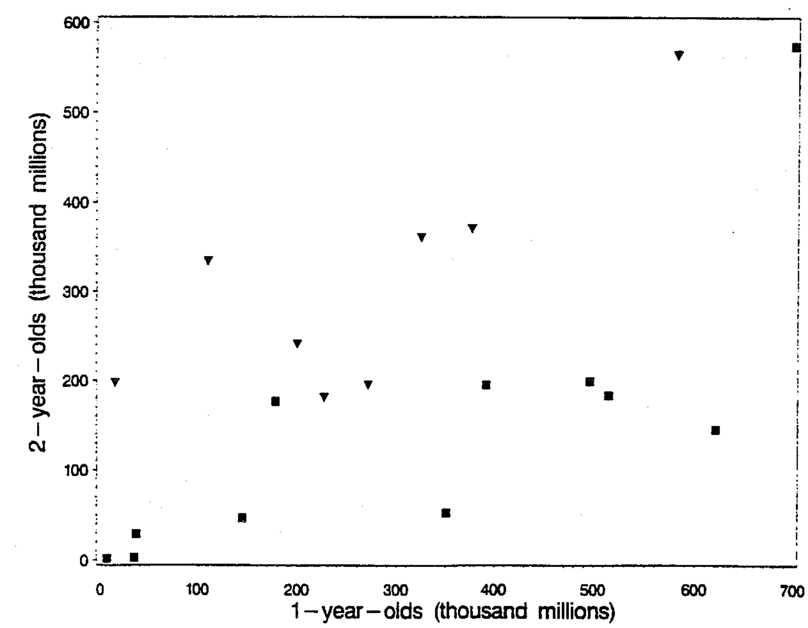

Figure 1. The relationship between abundance estimates of capelin at age 1 and 2 in the perod 1972-1992. The triangles denote the years before 1981, the squares denote the years after. Figures are given in million individuals.

The aim of this paper is to compare the abundance estimates and indices obtained during these annual larval, 0-group, and 1-group surveys. The findings will be discussed in light of the above mentioned problems: When is the right time for a first estimate of the capelin year class strength? How reliable are the estimates obtained so far for the actual amount of larvae at the time of the survey? In the discussion we will look for factors that may explain some of the variability observed, such as distribution, growth and mortality.

MATERIALS AND METHODS

Larval surveys

The larval surveys for capelin, on which the larval abundance estimates (Table 1) are based, have been conducted since 1981. The aim of the surveys are to determine abundance and distribution of larval capelin 1-2 months after hatching. The surveys routes are adjusted to the larval distribution, but in some years the western or the eastern borders are not detected. The stations are located in transects in a north-south direction.

Sampling has been conducted with a high speed planktonic sampler, Gulf III (Zijlstra 1971). Standard procedures for sampling capelin larvae in the Barents Sea are described by Alvheim (1985). The Gulf III is towed in the upper 60m of the water column. A measure of the flow of water through the Gulf III front opening makes it possible to estimate the number of larvae per unit area sampled. Interpolation of these results gives a total annual index of larval capelin abundance in the area of distribution. The method for larval abundance estimation is described by Alvheim (1985). The indices for 1981 to 1991 are published by Fossum (1992).

Table 1. Larval estimate ($N^{\cdot -12}$), 0-group ($N^{\cdot -9}$) index (without units), and acoustic estimate of 1-group capelin ($N^{\cdot -9}$) in the period 1981 to 1991.

Year class	Larval estimate	0-group index	1-group estimate
1981	9.7	2082	496
1982	9.9	1384	575
1983	9.9	1487	145
1984	8.2	1004	35
1985	8.6	508	75
1986	-*	186	37
1987	0.3	11	20
1988	0.3	349	178
1989	7.3	4612	700
1990	13.0	631	392
1991	4.2	1021	351

* No observations were made, the survey was conducted too early compared to main hatching time.

0-group surveys

The 0-group fish surveys in the Barents Sea have been conducted since 1965 (Anon. 1965; Loeng and Gjøsæter 1990). The surveys are made in late August - early September. The aims of the survey are to locate the distribution and determine year class strength of commercial species of the Barents Sea and adjacent waters, including capelin (Beltestad et al. 1975; Loeng and Gjøsæter 1990).

0-group fish are sampled by a pelagic trawl, originally a commercial trawl for capelin fisheries; "Harstadtrawl". The trawl is described by Bjørke *et al.* (1989). Trawl dimensions and the standard procedures are described by Randa (1981). Trawling is conducted in the depths 40-20-0m (Anon. 1980; Loeng and Gjøsæter 1990). Supplementary trawling down to 60m was made when the echo registrations showed layers of 0-group fish deeper than 40m. Abundance estimates of capelin (Table 1) have not been published in connection with the 0-group survey reports due to uncertainty of the catch results as the commercial trawl used for sampling is not fully suitable for catch of 0-group capelin as the capelin is not fully metamorphozed in August-September according to Vesin *et al.* (1981). The capelin tend to stick to the trawl meshes and may be lost during hauling in bad weather, which implements a underestimate of abundance in such occations.

0-group capelin indices (I) were estimated in respect of the total area of distribution based on local abundance indices described by Gundersen (1994).

$$I = A * D$$

I : indices of capelin abundance.
A : the area covered of capelin.
D : the average density of capelin in the distribution area.

Acoustic surveys

The acoustic surveys which yield the 1-group estimates have been conducted on an annual basis since 1972 (Table 1). The surveys are made during September and the first part of October. Standard published methods for acoustic stock measurements are used (e.g. Nakken and Dommasnes 1977; Foote 1991), where echo abundance data sampled by echosounders and echo integrators are distributed on species and age groups according to information from trawl samples of the fish registrations. Dommasnes and Røttingen (1985) gives a comprehensive account on these capelin investigations.

Statistical analysis

Since the data after 1980 seem to be the most reliable, and since larval estimates are available only from 1981, the period 1981-1991 was chosen for this study. Regression analyses were used to analyze the relationship between the three series of observations. The analysis was performed in three steps;

i) comparing larval estimate and 0-group index.
ii) comparing 0-group index and 1-group estimate.
iii) comparing larval estimate with 1-group estimate.

The statistical analysis and the plotting were made using the SAS software.

One of the assumption underlying regression analysis is that the measurements of each variable should be independent of each other. This assumption may be questioned when the data stem from a time-series, because the factors involved will have a tendency to affect consecutive datapoints in a similar way. The key question is, will the strength of a certain year class in some way imply the strength of the next? Obviously, there is a coupling between year classes in that the strength of one year class partly determines the size of the spawning stock two to three years ahead of time, which again partly determines the year class strength of the offspring. Nevertheless, the strength of a particular year class are also susceptible to a lot of stocastic processes, which may in many cases overshadow the predictable factors. Regression analysis should, in any case, be used with caution when studying time series data.

RESULTS

Larval estimate versus 0-group index

No correlation is found between the two variables (p=0.43). From the plot (Figure 2) it can be seen that there seems to be a positive relationship, but the low correlation coefficient (0.28, p=0.28) is mostly due to one data point; that for the 1989 year class. With a larval estimate close to average for the period, and an 0-group index more than twice as high as any of the other observations, this point represents an outlier in the analysis. If this point is left out of the analysis, the correlation coefficient increases to 0.81, and a correlation significant at the 5% level emerges (p=0.03). Conclusively, no definite judgement can be made about this analysis. Although no correlation is evident when the whole period is analyzed, this lack of correlation is due to one single observation; the 1989 year class.

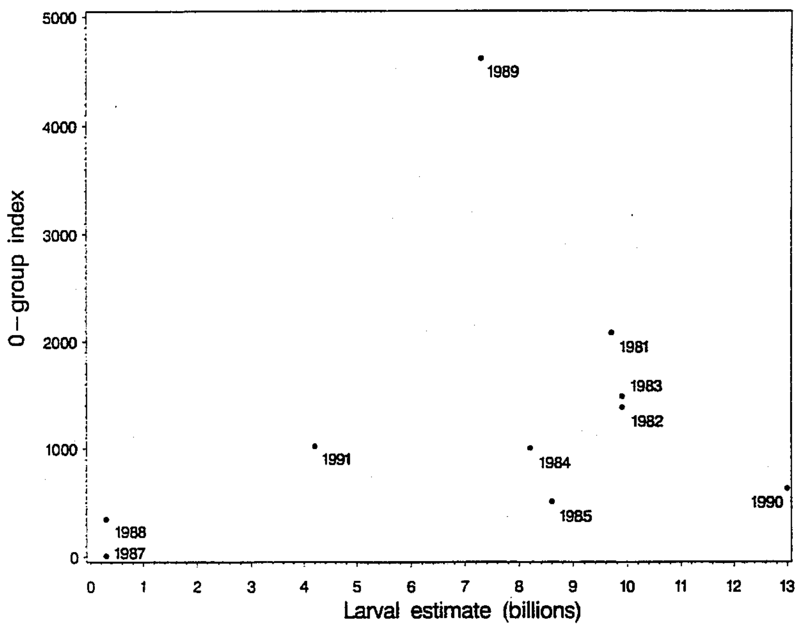

Figure 2. The relationship between larval estimate and 0-group index. The datapoints are labelled with year.

0-group index versus 1-group estimate

A highly significant correlation is found between the variables; p=0.006. About 60% of the total variation can thus be explained by the regression model. Nevertheless, looking at the corresponding scattergram (Figure 3), it is clear that the year class 1989 also in this case represent an extreme value. In this case, however, this point increases the goodness of fit. Abandoning this datapoint lowers the correlation coefficient from 0.77 to 0.73, but the correlation stays significant at the 5% level (p=0.04). It may be concluded that when all available data is taken into consideration, there is a strong correlation between the 0-group index and the 1-group estimate. The relationship is described by the equation:

$$N_{1\text{-}gr} = 98.7 + 0.14*I_{0\text{-}gr}$$

$N_{1\text{-}gr}$ is the number of 1-year-olds and $I_{0\text{-}gr}$ is the 0-group index for capelin.

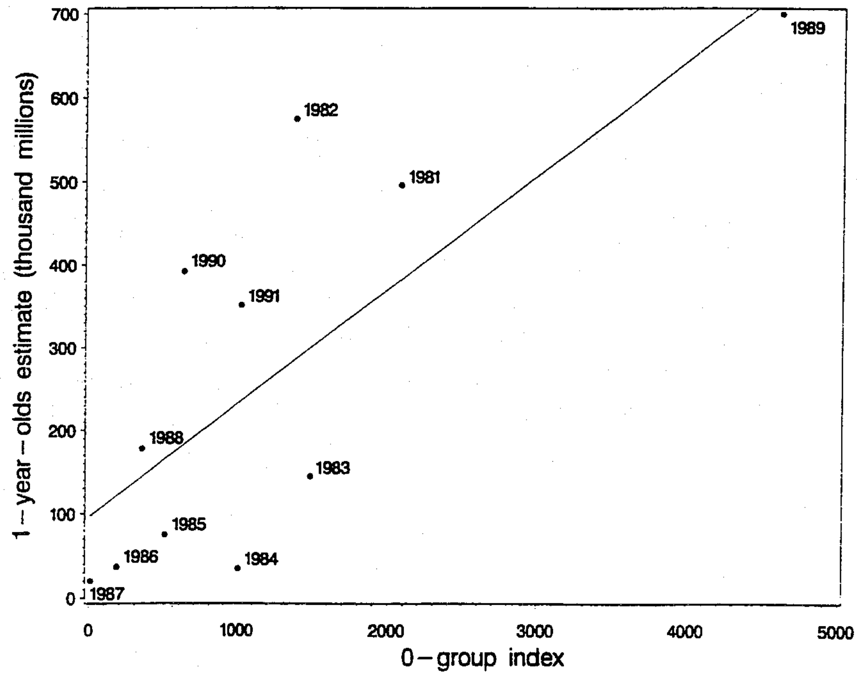

Figure 3. The relationship between 0-group index and 1-group estimate. The datapoints are labelled with year. The regression line is superimposed on the scatterplot.

Larval estimate versus 1-group estimate

No significant correlation is found between the two variables (p=0.29). There is no single outlier explaining the bad fit, the datapoints are scattered all over the graph (Figure 4). It can be concluded that there is no evidence for a relation between larval index and year class strength at the 1-group stage.

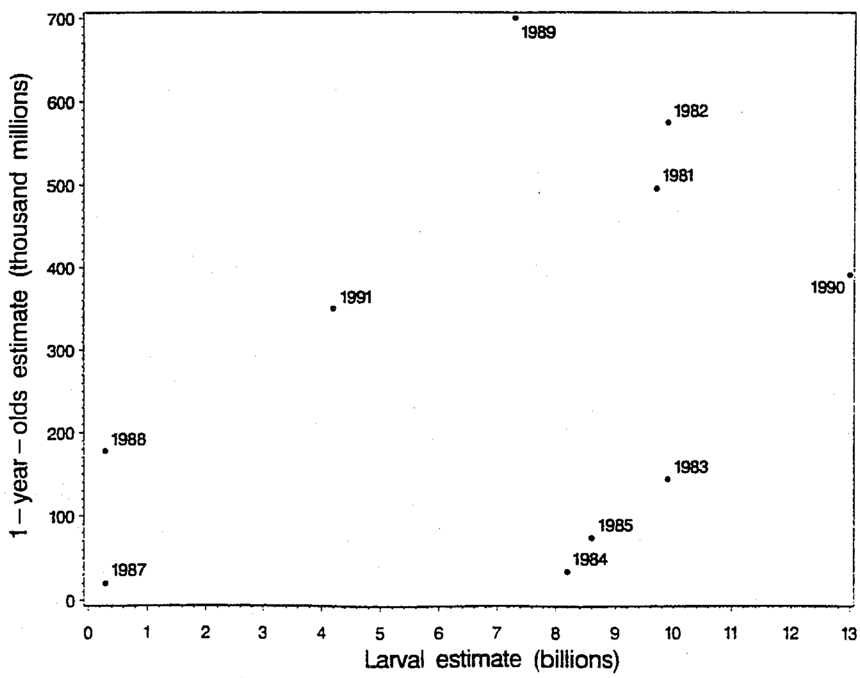

Figure 4. The relationship between larval estimate and 1-group estimate. The datapoints are labelled with year.

DISCUSSION

Larval estimate versus 0-group index

The rather low correlation between these two estimates of year class strength is due to one single year; 1989. This year class, which was classified among the strongest both on the 0-group stage and as one-year-olds, and which strength has been proven in the years after, was seemingly grossly underestimated in the larval estimate. What shows up as an underestimation may, however, be explained by a much lower than usual mortality rate between the measurements in June and August. How could such an unusual low mortality rate in 1989 be explained? This year was characterized by much inflow of Atlantic water, rich in nutrients and zooplankton according to Skjoldal *et al.* (1992). This may, of course, have given the capelin larvae favourable survival conditions. On the other hand, there was much young herring in the Barents Sea this year, which is thought to have a negative influence on the survival of capelin larvae (Hamre 1991, Gjøsæter, *in press*). Methodological errors could possibly cause a real underestimation of capelin larvae in June 1989. There does not seem to be any obvious reason for such an underestimation in the accomplishment of that particular survey. The whole larval distribution area was covered (Gundersen 1993b), and the standard methods applied. However, there is a possibility that a part of the spawning, and consequently the hatching, may have taken place later than usual, and that a part of the larval population had not yet been released from the spawning areas.

If excluding the data point for 1989 from the calculations as an outlier, the regression of 0-group indices on larval estimates becomes quite strong, as 65% of the total variation can be explained by the regression. Even in this case, the variation not accounted for is so large that only very approximate forecasts of year class strength in August may be made based on the larval survey in June. We may hypothize that this is because the survey takes place before or in a period with high and variable mortality. The larval surveys may be more valuable in "hindcasting", i.e. in giving an estimate for the amount of larvae produced, or even, of the spawning stock size. Such use of the larval estimates have not been assessed in this investigation.

0-group index versus 1-group estimate

There is, seemingly, a better correlation between the 0-group index and the 1-group acoustic estimate. The regression of the latter on the former accounts for about 60% of the total variation. There is only about 0.5% probability for such an outcome if the null hypothesis; that there is no correlation between the variables, was true. Admittedly, much of the high correlation can be ascribed to one single datapoint, but also when this point is excluded the correlation is significant at the 5% level. A reasonable interpretation of this fact is that at the time of the August survey, the year class strength is more or less established. The mortality will still vary from year to year, but this will show up as variation around the regression line rather than destroying the correlation altogether. The amount of deviation from the regression line each year, may give clues to quantify this mortality.

It is seen that in the period 1983-1987, and in 1989, the 1-group estimates are lower than expected from the regression line, i.e. the mortality between the two estimates is larger than the mean (Figure 3). In the other years the opposite is true. This is partly, but not totally, in accordance to what we know about mortality in the older parts of the stock. The data points for 1983, 1984 and 1985, which show the largest deviation from the regression line, the natural mortality in the stock, as measured in the one year olds and older part of the stock, was at a maximum for the whole investigation period. In 1986, 1987 and 1989, however, there is a much lower natural mortality among older individuals. There is a possibility that the mortality may be high at the younger stages and low among the older, because the sources of mortality do not have to be the same. Nevertheless, if the year class strength is seen in relation to the (calculated) spawning stock size from these years, we clearly get the impression that there must have been a high survival during the whole life span. This is also in accordance with what we know about possible sources of natural mortality on young capelin: the total amount of 0-group of herring and cod, which is known to predate on the capelin larvae, was low in 1986 and 1987, but high in 1989.

Also among the years with a higher than expected survival from 0-group to one-year-olds there are some years with a low natural mortality and some years with a high one, judged from measurements on older capelin and knowledge about the amount of predators present. The conclusion is, that the variation around the regression line cannot directly be interpreted as a measure of natural mortality. The dispersion due to measurement errors probably make up too much of the variability to make such interpretations feasible.

Larval estimate versus 1-group estimate

There is no correlation between the larval estimate and the 1-group estimate. The explanation is probably that the year class strength, as measured at the 1-group stage, is not yet determined so early in the larval phase, and that measurement errors will add to this variability, hiding week relationship that otherwise might be seen. It should be noted, however, that the same three years of low survival as seen from the 0-group to one-group relationship is evident; 1983, 1984 and 1985. This is probably not a mere coincidence, but lends support to the theory that there was an unusual high mortality on the young stages of capelin during these years.

CONCLUSIONS

Keeping in mind that possible connections between measurements in a time series (autocovariation) may lead us to conclude that there is a correlation when there is not, the results from the regression analyses show that:

1. There is no correlation between the larval estimates and the 0-group indices. The very strong 1989 year class, which was observed both at the 0-group stage and 1-group stage, was grossly underestimated in the larval estimate. If an exclusion of this year can be justified, a quite strong, positive correlation emerges. It's inferential strength is, though, quite low.

2. The strongest relationship is found between the 0-group index and the 1-group estimate. The correlation between these variables is positive and highly significant. This regression can be used to make an early forecast, although not a very accurate one, of the year class strength at the one-group stage.

3. There is no correlation between the larval estimate and the 1-group estimate, even if the 1989 data is left out. It is therefore not possible to make a forecast of year class strength based on this survey.

4. The variation due to measurement errors are too large to allow for any estimation of natural mortality based on the regression analyses. Years with extremely high or low survival rates at the young stages are, though, apparent in the scatterplots.

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