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Prediction of Year-class Strength of Cod off West Greenland

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Abstract.

In prediction of the year-class strength of cod a number of factors has been used in the past: temperature, density stratification, larvae abundance and spawning stock biomass. The value of these factors as predictors are evaluated and discussed.

Only temperature and larvae abundance give some usable information, but a more detailed knowledge of the relative proportion between recruitment from East Greenland/Iceland and West Greenland is required before a proper prediction can be performed.

1. Introduction.

With the present stock size and composition of cod off West Greenland (NAFO Subarea 1) forecasts are very dependant upon presumed year-class strength of recruting year-classes. For this reason the latest forecast (Cornus *et al.* 1985) covers only the year 1986, as the number of recruits in 1987 is supposed to amount to more than 50 % of the fishable stock size by numbers.

The Greenland Fisheries and Environment Research Institute has in the past collected data on the hydrographic conditions and the number of gadoid larvae in the plankton samples off West Greenland. These data were used in attempts to predict year-class strengths by various correlation and regression procedures (Hermann 1953, 1961; Hermann *et al.* 1965) and in more informal ways in later assessment works (Horsted 1980,1981,1982; Horsted *et al.* 1983, 1984 and Cornus *et al.* 1985).

The continuous grading down on the expectations to the 1982 year class, which in 1983 was expected to be fairly large (200 mill. recruits at age 3), to the present low value of 20 mill. has demonstrated that hydrographical and larvae abundance data should be used with great care.

The purpose of the present paper is to present the data which could be used in predicting year-class strength and to make a first evaluation of their quality in predictions.

2.Data (Table 1)

2.1 Year-class strengths.

Year-class strength was computed by VPA. Age composition data from the catches are taken from Schumacher (1971), Horsted _et al_. (1983, 1984) and Cornus _et al_. (1985). Natural mortality has been set at M = 0.2. Emigration coefficients for 1983 and 1984 is taken from the German trawl surveys (Horsted _et al_. ,1984 and Cornus _et al_. 1985). Earlier years emigration is set at E = 0.05 for age-group 6 and older. Terminal-F values for 1984 are taken from Cornus _et al_. (1985) and F-values for the oldest age groups are taken as the average of F from age-group 5-8 in earlier VPA-runs (Schumacher, 1971 and Horsted _et al_. 1983). The resulting year-class strength is expressed as numbers of 3 years old cod.

2.2 Spawning/stock biomass (SSB).

SSB is taken from the same VPA run as mentioned above. Maturity ogives and weight-at- age data used are given in the publications listed above. As there were no maturity data worked up for years prior to 1960 values for this latter year were used for all pre-ceeding years. Similary, weight-at-age data prior to 1965 are taken as the values from that year. The resulting SSB is expressed in 1000 tonnes.

2.3 Temperature.

Observations of the temperature on top of Fylla Bank have been made in the middle of June since 1950, and the mean temperature of the water column has been calculated by averaging the observations from the standard depths 0,10,20,30 and 40 m.

One may raise the question of how representative the temperature on top of Fylla Bank in the middle of June is for the West Greenland area. The spatial and temporal temperature variations off West Greenland were discussed by Buch (1984). It was shown that the temperature trends in neighbour areas and periods were closely related with the trends at Fylla Bank due to the processes of advection and solar heating, and therefore the medio-June temperature from Fylla Bank must be considered as a representative index of the overall West Greenland temperature conditions.

2.4 Density stability.

The amount of food for cod larvae (plankton) might be closely related to the amount of nutrients in the surface layer of the sea at the time of the plankton bloom, which in turn may be dependant on the effectiveness of the vertical convection process during the previous winter (Meyer, 1968).

Stein and Buch (1984) suggested that low stability of the surface layers during the autumn of the preceeding year could be indicative for good environmental conditions during the egg and larval stage of the cod.

The mean stability of the upper 200 m of the water column at station 4 at the Fylla Bank section in November was calculated using

$$E = \frac{1}{\bar{\rho}} \frac{d\rho}{dz}$$

$\bar{\rho}$ being the mean stability of the individual layers.

2.5 Cod larvae abundance.

Plankton surveys for determining the number of gadoid larvae have been carried out since 1953 at the beginning of July on the NAFO standard sections between Fylla Bank and Store Hellefiske Bank using stramin net (diameter: 2m, mesh size: 1mm, 30 min. oblique hauls with 225-0 m wire, speed about 2 knot, maximum fishing depth about 50 m). The larvae abundance is expressed as mean number pr. 30 min. hauls.

It is not possible to distinguish between larval cod and Greenland cod, but it is generally believed that the majority of larvae caught will be cod due to the restricted coastal distribution of the Greenland cod.

3. Results and discussion.

3.1 Year-class strength and temperature.

In Fig. 1 the year-class strength is plotted versus temperature. Although the year-class strength is positively correlated with temperature (Spearman nonparametric correlation coefficient equal to 0.67; P <0.001) a precise prediction is impeded by variable year-class strengths at fixed temperatures i.e. temperatures around 2°C result in 50 - 500 mill. recruits.

The main spawning areas off West Greenland are located at the banks in Div. 1E and D, but in some years there is also evidence of a larvae drift from Iceland/East Greenland to the West Greenland area (Harden Jones, 1968). Smidt (unpublished manuscript) has collected data on this subject and has classified some of the year-classes as being mainly of eastern origin. This is based on observations of the distribution of the younger age groups (1-3 years). A distribution at southeast and southwest Greenland is assumed as being "easterners" whereas a northwestern distribution is thought as being of western origin. Using this criterion the year-classes 1956, -61, -63 and -73 can be classified as "easterners".

If these data points are excluded, the following picture emerges

i) year-classes with less than 150 mill. recruits show a liniar increase with temperature (YC = 44.6 x T, R^2 = 0.89)

ii) four outlayers (1953,57,60 and 62) all with high temperature and great year class size.

If high temperatures in some years can be taken as a sign of great inflow of Irminger water it is tempting to classify these outlayers as also being of eastern origin despite the fact that these year-classes as young fish were observed mainly in the northern area

(Div. 1C - 1A). Some considerations should then be made on the possibilities of larvae drift from Iceland and East Greenland to this area.

Direct current measurements off West Greenland are scarce. Hermann and Thomsen (1946) report on drift bottle experiments giving velocities of about 0.2 m/s, and measurements with Aanderaa current-meters carried out during the summers 1975 - 1979 gave mean velocities of the same magnitude, and maximum velocities of about 0.3 m/s (DHI, 1979 and Buch, 1982).

Indirect determinations of the current velocity using geostrophic calculations confirm that on the average the velocities are about 0.2 m/s, but show great variations from year to year (Alekseev et al., 1972). For instance, using the July hydrographic observations from the Fylla Bank section gives geostrophic surface velocities of 0.26 m/s in 1981 and only 0.06 m/s in 1982.

Also seasonal variations occur. As discussed by Saule et al. (1963) and Buch (1984) the West Greenland current is intense during spring and autumn with a minimum intensity during the summer. The current velocities referred to above are all from observations made during the summer, i.e. the period of minimum intensity while geostrophic calculations using hydrographical data from November give velocities around 0.4 m/s.

It is, therefore, likely that velocities at the beginning of the period of egg and larvae drift is more than o.2 m/s.

A mean drift velocity of 0.2 m/s implies that cod larvae found between Fylla - and Store Hellefiske Bank in July were spawned in the Southeast Greenland area. If current velocities, due to seasonal variations as well as year-to-year variability, in some years can reach values of 0.4 m/s then the larvae could originate from the spawning area southwest of Iceland.

It should however be remembered that even if this explanation is the right one, the problems using temperature as the only factor in prediction of year-class strength still remain (i.e. not knowing whether a recruitment from the eastern areas has taken place).

3.2 Year-class strength and density stability.

Year-class strength is plotted versus stability in Fig. 2. No correlation is found between these factors (Sperman correlation coefficient = -.16, P =0.57).

For the years when it was possible to compute the stability factor the relationship between year-class size and temperature could be described as

$$YCS = -6.2 + 42.9 \times temp. \qquad R^2 = 0.72$$

It was tried to include stability in this model (i.e. YCS = a + b x temp. + c x stability), but this inclusion of stability gave no better explanation of the total variation (R^2 improved only from 0.72 to 0.74).

3.3 Year-class strength and spawning stock biomass (SBB).

Year-class strength is plottet versus SSB in Fig.3. These two factors are positively correlated (Sperman correlation coefficient = 0.62, P=0.001). One should note, however, that SSB is highly correlated with time (high SSBs in the start of the period and low SSBs in the seventies), so it is possible that both the year-class strength and the SSB is correlated with some unknown factors which has changed during the period.

Looking only at recruitment by SSB sizes of less than 500.000 no correlation with SSB is found. The stock size of the West Greenland cod has been within this range for the last 20 years.

There is no sign of any reduction in recruitment at high SSBs and therefore no justification for computing Ricker-type stock-recruitment curves.

3.4 Year-class strength and larval abundance.

Year-class strength is plotted vs. larval abundance in Fig. 4. These two factors are positively correlated (Spearman corr. coef. = 0.60; P = 0.002).

High larval abundance (i.e. mean > 5 per haul) have historically given rise to large year-classes. The 1982 year-class, which gave the second largest larval abundance index on record (a mean of 14 per haul) has, however, not shown up in later surveys (Cornus *et al.* 1985), suggesting that this year-class will end up as a poor one.

Looking at the larger year-classes (> 200 mill. recruits) it is interesting to note that the year-classes which later, as young fish, showed a southern distribution (1956, 61, 63 and 73) are found in lower larval abbundance than the year-classes 1953, 57 and 60 which later had a predominantly northern distribution. Although not necessarily showing the origin of the larvae (cf. Section 3.1) this pattern does relate the larval and the youngfish distributions. Similar, the 1973 year-class, which as young fish showed up in great quantities in southern Greenland, were found in great numbers in Icelandic 0-group surveys off East Greenland in autum 1973 (Anon. 1984).

4. Conclusions

Based on the previous discussions one might tentatively conclude:

1) Autumn stability and size of SSB do not seem to be of much help when trying to predict later year-class strength.

2) Temperature and larval abundance off West Greenland give some information on later year-class size, but predictions based on these data will be quite speculative unless more is known about the relative proportions of recruitment from East Greenland/ Iceland and West Greenland.

Old information, such as plankton data, which might show different species compositions related to different watermasses and tagging results, which might show variable year-class migration ought therefore to be reanalysed. This, of course,, will not help in predicting future recruitment but might give a better insight in the processes which generate year-class variability.

For future recruitment estimates the problems might be circumvented by using young fish surveys instead of hydrographical and larval data. The institute is planning to carry out a pilot study in this year.

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Table 1

Year	Year-class size (mill. 3 year old)	Spaw. St. Biomass (000 tonnes)	Temp. (^{o}C)	Stability factor (E)	Larvae index (nos./30 min.)
1953	451		2.1		8.44
1954	86		2.3		2.38
1955	91		1.2		2.21
1956	247	1496	0.9		1.22
1957	516	1335	2.3		45.67
1958	164	1210	2.2		3.46
1959	95	1031	1.6		2.15
1960	391	985	2.7		5.00
1961	530	883	3.2		4.36
1962	225	711	2.2		
1963	244	605	1.6		1.54
1964	77	478	2.3	2.2	1.12
1965	86	403	2.1	5.5	
1966	69	339	1.6	6.0	2.89
1967	40	324	1.5	7.5	
1968	88	286	2.1	7.0	6.94
1969	15	256	0.3	5.2	2.09
1970	12	200	0.3	9.1	0.75
1971	18	171	0.8	2.3	1.00
1972	22	118	0.7	4.7	1.05
1973	228	78	1.7		0.93
1974	46	66	1.0	9.0	0.72
1975	52	54	1.9	3.0	3.00
1976	60	31	1.4	6.6	0.67
1977	139	27	2.1	3.0	0.77
1978	20	41	0.9	2.2	0.29
1979	74	78	2.2	0.8	1.22

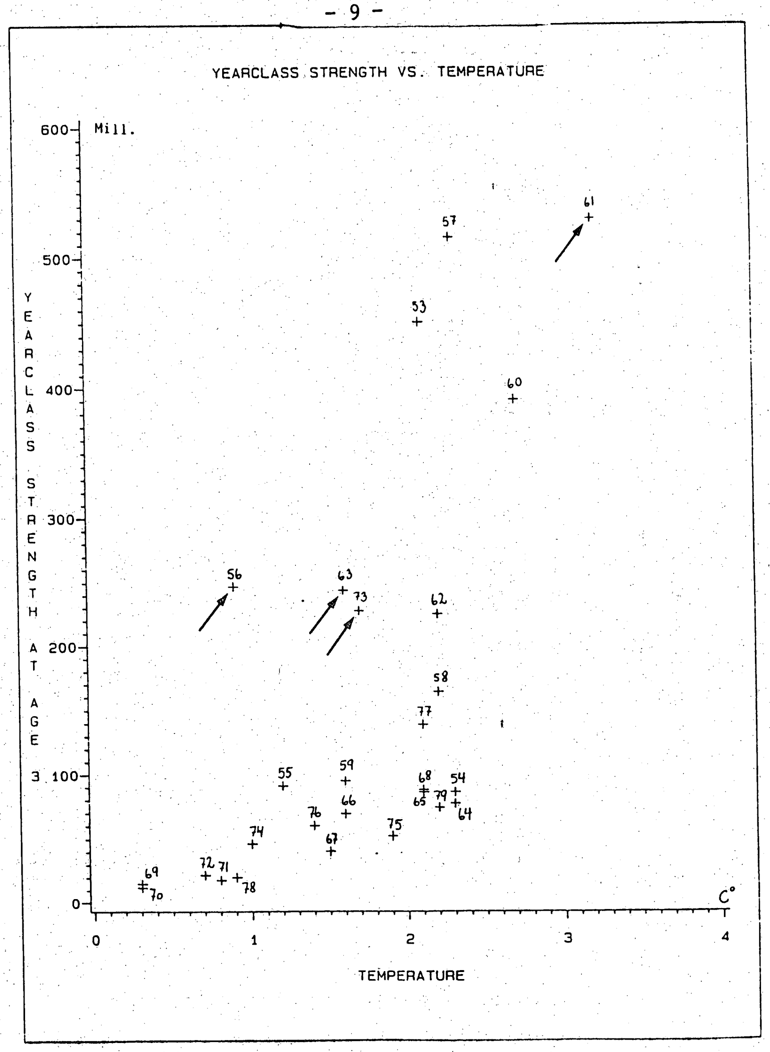

Fig. 1 : Year-class strength vs. temperature. Year-classes classified by Smidt as of mainly eastern origin are marked by arrows, cf. text.

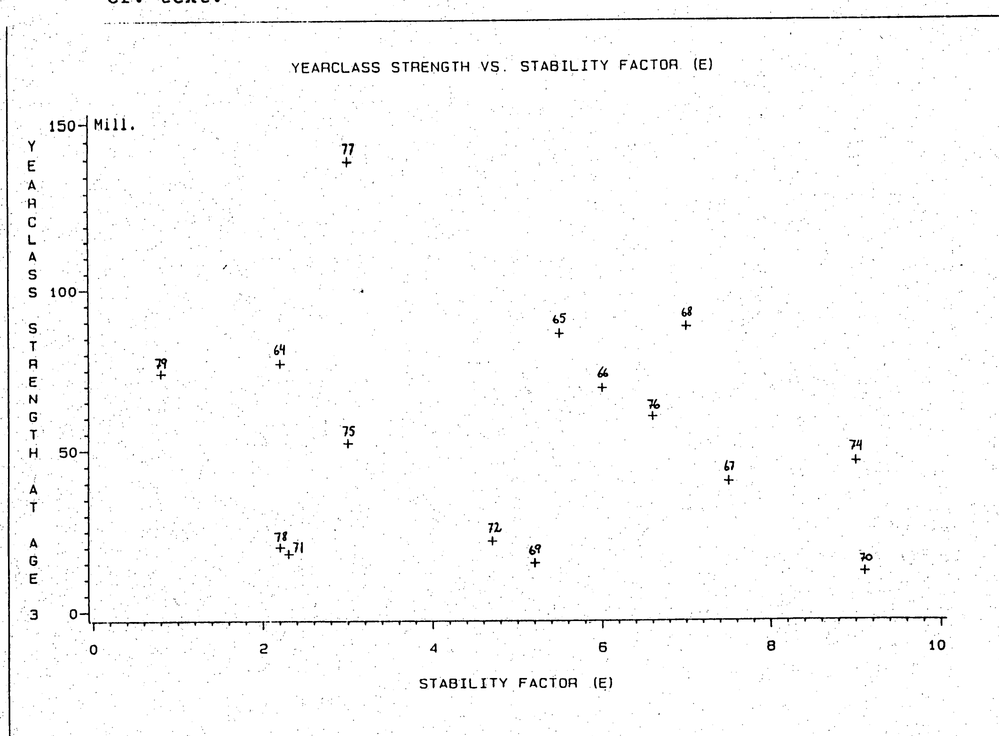

Fig. 2 : Year-class strength vs. autumn density stability.

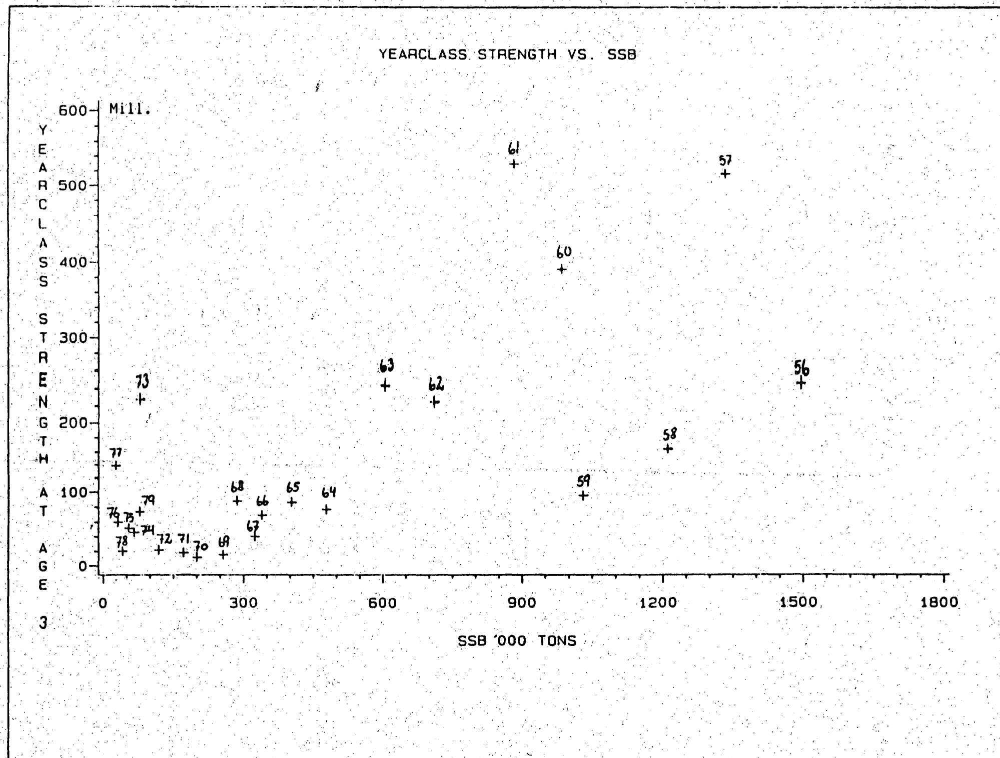

Fig. 3 : Year-class strength vs. spawning stock biomass.

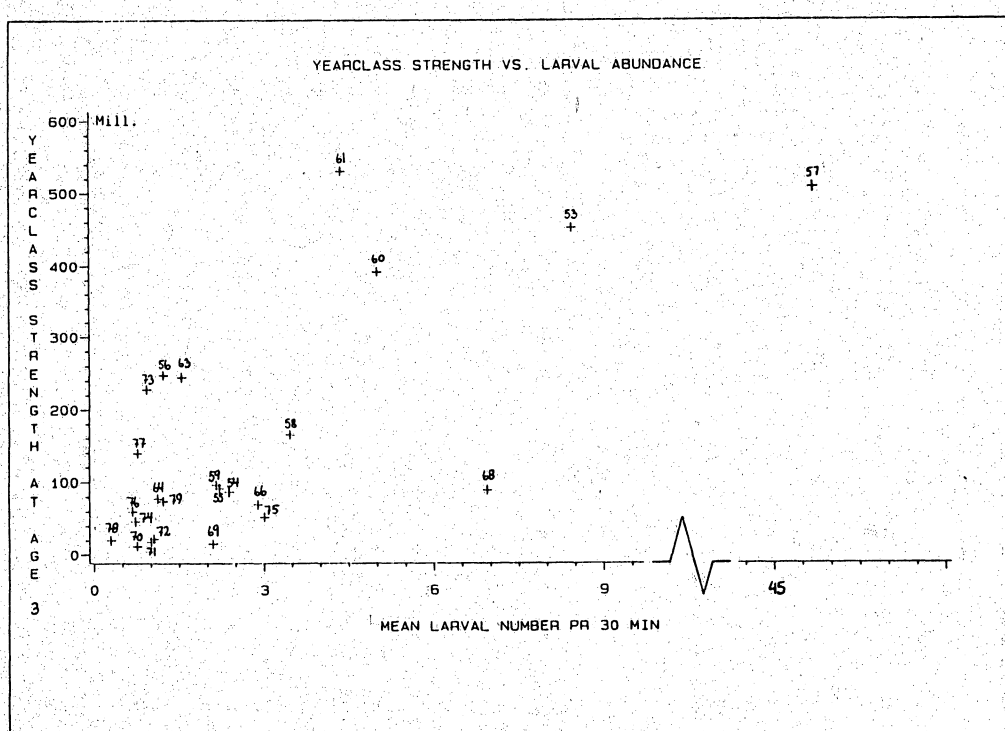

Fig. 4 : Year-class strength vs. mean larval number pr. 30 min. hauls.