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A regression model for recruitment of 3-year-old NEA cod based on capelin biomass, survey index and climate.

by

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Introdution

In the recent years the effect of climate on recruitment of fish stocks has received increasing attention. In the assessment of NEA cod climate responses has until now been neglected. Here we present a regression model for the recruitment of NEA cod at age 3, based on the temperature in the Kola section, capelin biomass and survey index (1 year old cod). Due to time lag between model variables this model allows for a two-year prognosis. By the use of 2003 survey and prognostic values for the capelin stock in 2003 it is also possible to extend the prognoses until 2005.

Material and methods

A multiple linear regression model has been developed for the number of 3 year old NEA cod (Fig 1).

$$\mathrm{Re}\,c3_t = 3.3\times10^8 \times Temp_{t-3} + 0.064 \times \mathrm{Re}\,c1_{t-2} + 6.2\times10^7 \times \log(Cap_{t-2}) - 1.7\times10^9$$

where *Rec3* is the number of 3 year old NEA cod from the AFWG 2002 assessment with cannibalism, *Temp* is the yearly average temperature between 0 and 100 m depth in the Kola section 3 years earlier (degree C), *Rec1* is the age 1 ~~one-year~~ index of NEA cod from the Norwegian bottom trawl survey in January/February 2 years earlier and Cap is the maturing biomass (tonnes) of capelin from survey estimate of individuals larger than 14 cm 2 years earlier. The subscripts ~~index~~ in the formula indicate~~s~~ the time lag used.

The Kola temperature represents climate response in the model. The one-year index of NEA cod from the Norwegian bottom trawl survey represents the spawning stock. Other indices~~exes~~ and also the SSB was tested, but with lower fit. The capelin biomass may be looked at as a term describing a combination of food availability and inverse relationship between capelin biomass and cannibalism ~~term~~. The log representation of the capelin biomass mimics maximum food availability for the cod.

Results

The model gives a fit of R^2=0.74 for the period 1983-2002, and a P-value of much less than 0.01 (all individual P-values are also less than 0.01).

The model gives a two-year prognosies (2003-2004), but after the winter survey and the use of a capelin prognoses (2003: 1.17 mill tonnes) the prognosies is extended to 2005 (Fig 2). The recruitment estimates areis given in Table 1.

Due to increased uncertainty in the 2002 value of the assessment, the model was tested by omitting the 2002 data. The R^2 then increased by 10 % from 0.74 to 0.83. The coefficients also changed slightly, and the model is given by

$$\mathrm{Re}\,c3_t = 3.4\times10^8 \times Temp_{t-3} + 0.059 \times \mathrm{Re}\,c1_{t-2} + 7.4\times10^7 \times \log(Cap_{t-2}) - 1.9\times10^9$$

Tableel 2 gives the correlation between the different variables. Best fit is for the temperature in the Kola section with a correlation coefficient of 0.69, but all variables contribute to the fit of the model, which has a correlation of $\sqrt{R^2} = 0.86$ towards the data.

Validation of the model

Fig. 5 shows a retrospective analysis of the model. We omitted one and one year of data for 12 years and then make a new fit to the data, and then a new prognoses. Fig. 6 shows the show the accordingly R^2 response. The worst fit involved the whole time series, while the R^2 remained high for all the other retrospective years. This may be due to a higher uncertainty in the number of three year olds from the assessment in 2002 than in previous years.

A comparison was made to the error in prognoses made by previous assessments. Fig. 7 shows the error in previous assessments, compared to the 2002 assessment. This was achieved by going through the two year prognoses given by earlier assessments. The different lines are for the 1 and 2 year projections. In the same plot we similarly added the projections from the retrospective analysis from the regression model. In general the errors made are within the same range. In Fig. 8 the data are scaled by the number of 3 year olds, thereby giving -thean error relative to the number of three year olds.

Tables and figures

Table 1. Prognosis for the number of 3 year old NEA cod 2003-2005
In the last column the data for 2002 are omitted from the regression model.

year	# of recruits	# of recruits (omitting 2002)
2003	$7.9*10^8$	$8.4*10^8$
2004	$6.8*10^8$	$7.3*10^8$
2005	$8.3*10^8$	$8.6*10^8$

Table 2. Correlations between variables in the model.

	Rec3	Temp	Rec1	Cap
Rec3	1	0.69	0.46	0.40
Temp		1	0.11	0.27
Rec1			1	-0.20
Cap				1

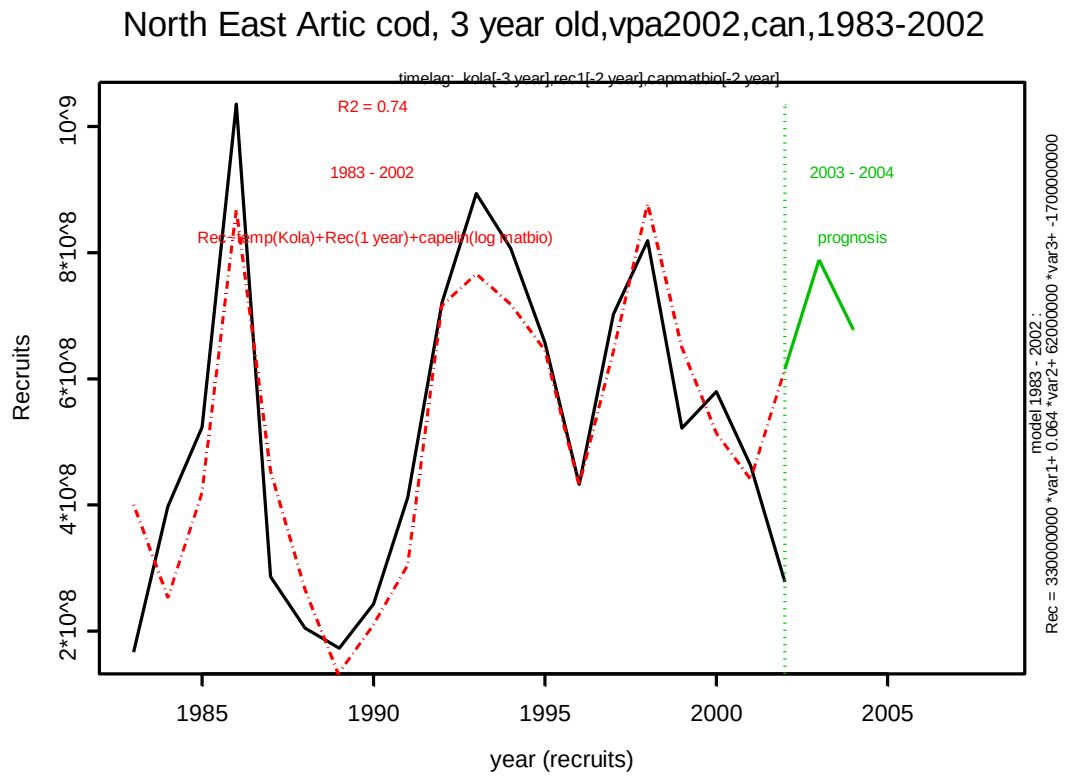

Figure 1. The number of three- year old cod from the AFWG 2002 assessment (black solid line), together with the regression model (red dashed line) and the prognoses for 2003-2004 (green solid line).

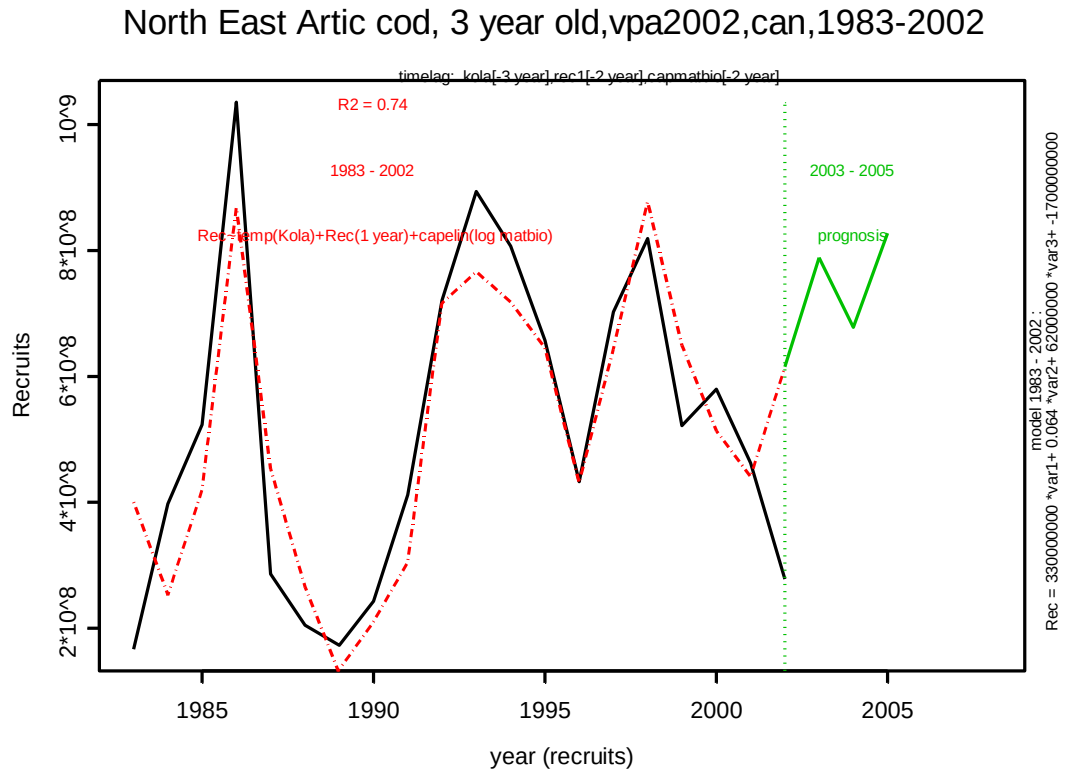

Figure 2. The same as Fig.1, but prognoses extended to 2005.

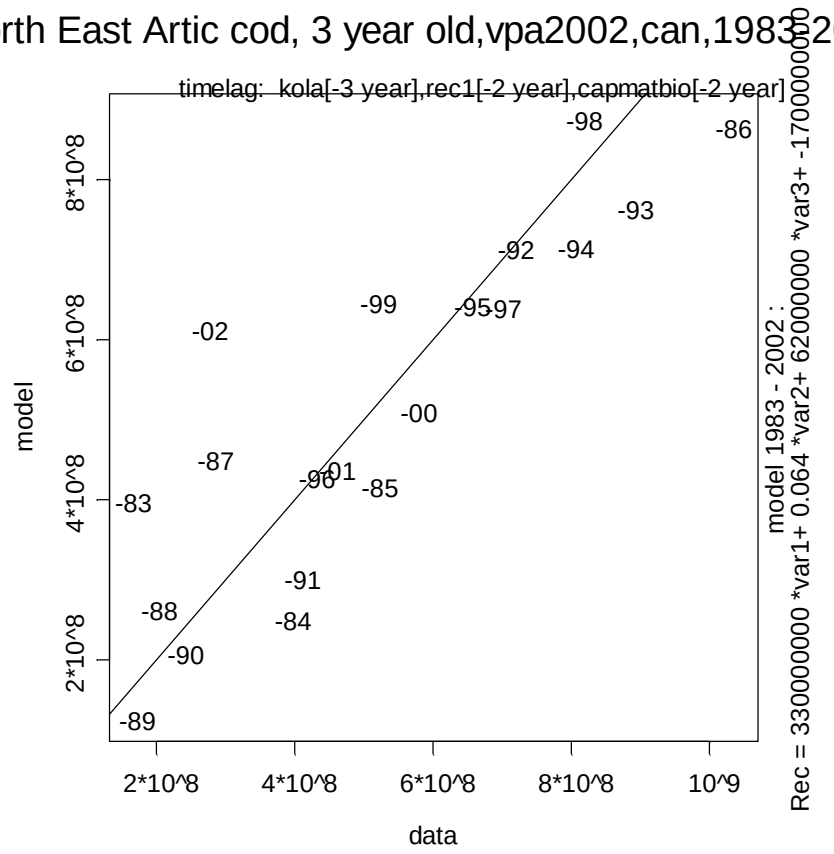

Figure 3. Model vs data..The given year is the year they are 3 year old.

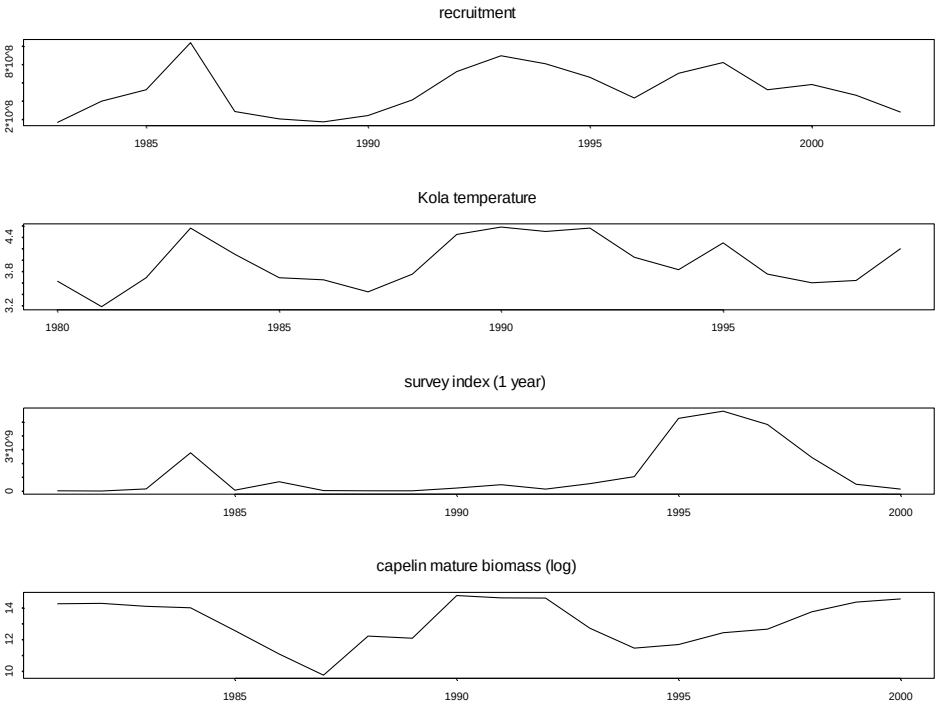

Figure 4. Time series of the individual variables in the model. Notice that the year axis has been adjusted so it fits the time lag of the model.

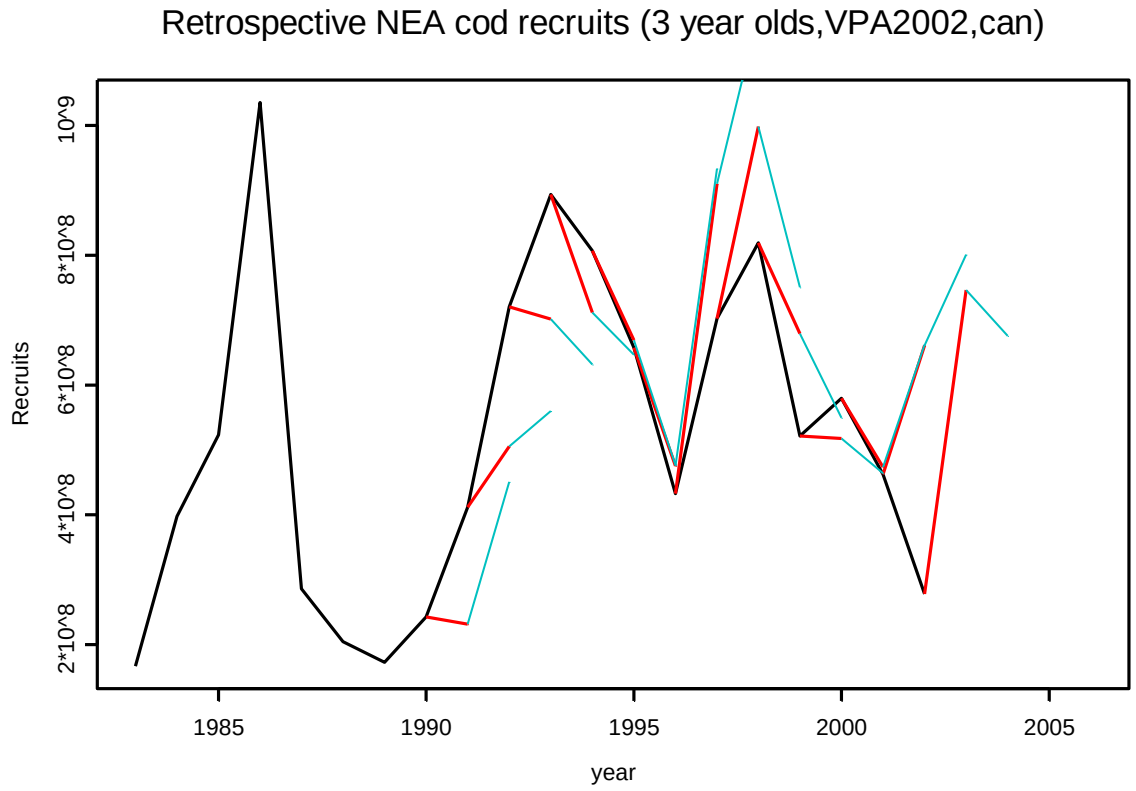

Figure 5. Re~~s~~trospective plot of the progn<u>osis</u>~~oese~~. The red solid line is the first year estimate and the blue line is the second year estimate for the 12 proceeding years.

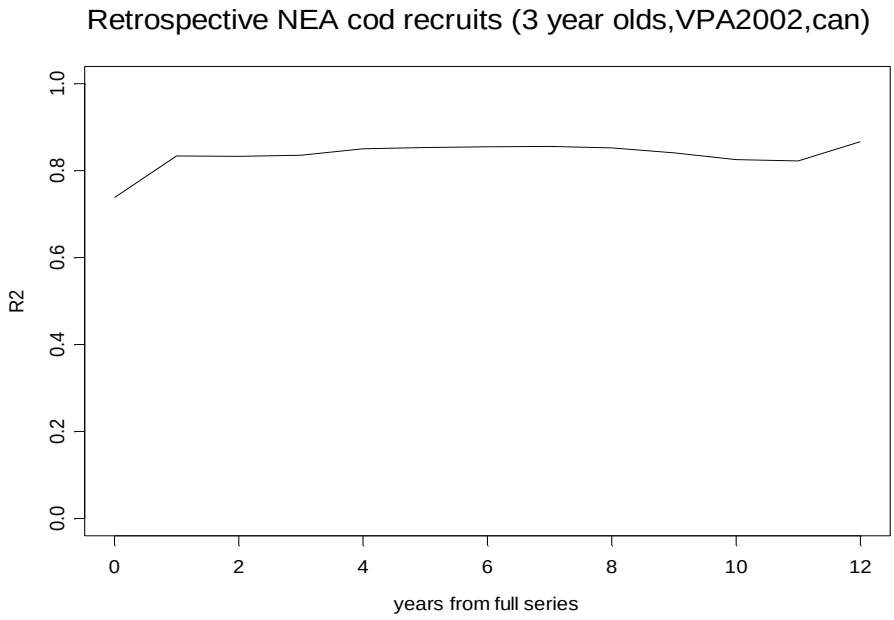

Figure 6. R^2 for the 12 years of the retrospective analysis in Fig. 5. The year axis shows the years backwards.

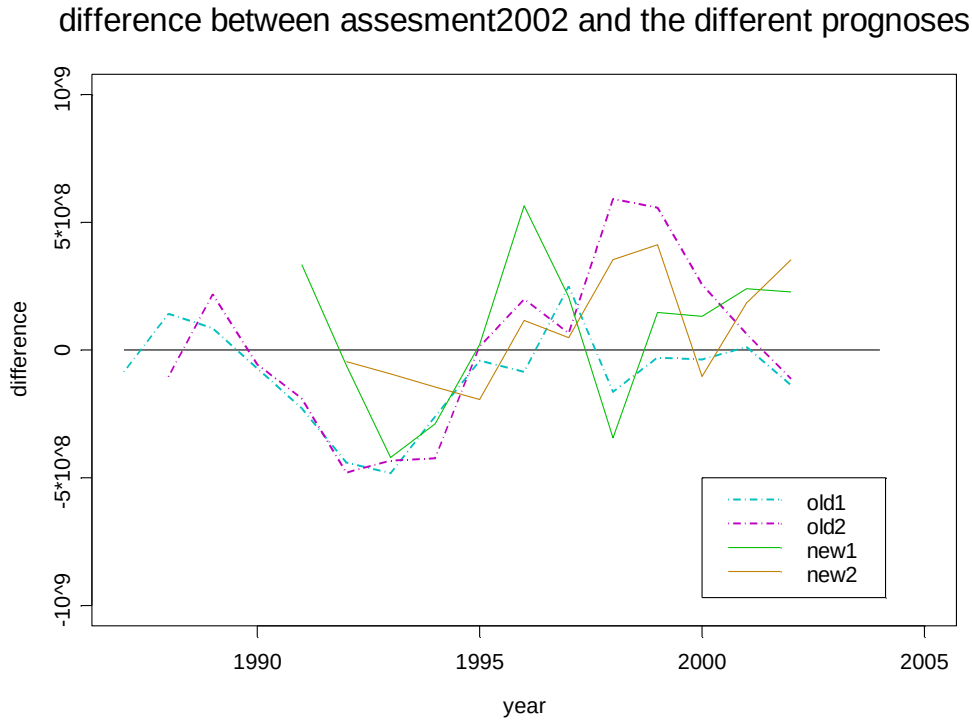

Figure 7. The error made in prognosies compared with the AFWG 2002 assessment. Dotted lines (old 1 and 2) are taken from the AFWG 2002 prognoses and solid line from the regression model (new 1 and 2). The number indicates the 1 and 2 year projections.

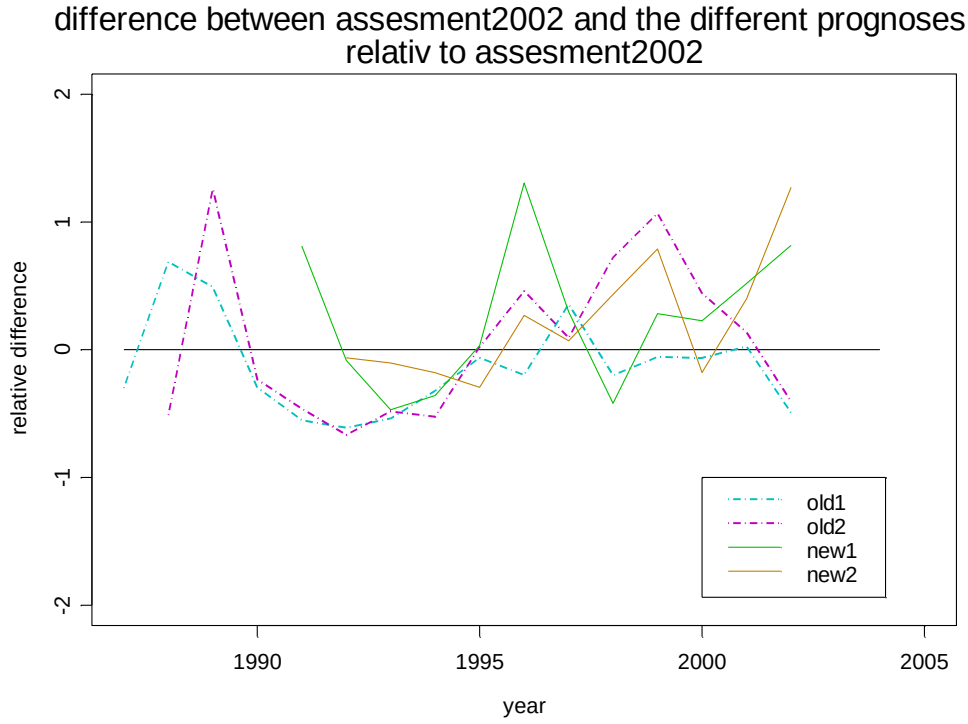

Figure 8. Same as Fig 7, but scaleds by the number of 3 year olds from the AFWG 2002 assessment.