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An attempt to use the CAGEAN model to assess the biomass of the Baltic cod stock in Sub-divisions 25-32 */

by

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Abstract

The CAGEAN model has been applied to assess the state of the Baltic cod stock as an alternative method to the virtual population analysis used by the Baltic Demersal Working Group. The model confirmed the dramatic state of the stock - the estimated biomass (ages 2-8) decreased from over 1000 thous. tons in 1982 to slightly above 300 thous. tons in 1990. The recruitment shows also a strongly decreasing trend with the estimate of 1987 and 1988 year-classes at a level of 80 and 120 million of individuals, respectively, which is only 13-19% of a rich 1980 year-class. The estimates of the fishing mortality are less variable in time than the VPA estimates, and they vary in the range of 0.7-0.9 in 1982-1990.

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Introduction

Cod is one of the most important species in the Baltic and its catches were in the last decade very profitable. In the 1980-1985 period the yearly catches of cod in the eastern Baltic (ICES Sub-divisions 25-32) exceeded 300 thous. tons with the peak in the year 1984 - 391 thous. tons. After 1984 the catches show a decreasing trend and the catch in 1990 equalled only 154 thous. tons. The high level of catches was the result of very abundant year-classes of 1975 - 1980, and the decreasing trend of catches is connected with the low abundance of year-classes born after 1981. Last report of the Working Group on assessment of demersal stock in the Baltic (Anon., 1991) shows a dramatic situation of the eastern Baltic cod. Therefore the authors attempted to check the state of the stock using an alternative method.

The Working Group on assessment of demersal stock in the Baltic has been using lately the ad hoc tuning method to estimate the state of the cod stock. The method used has been that of Laurec-Shepherd. The aim of this paper is to verify the estimates using the CAGEAN model (Deriso et. al., 1985), which belongs to the family of so called "integrated" methods. Though it was not clearly demonstrated that the integrated methods are significantly better then ad hoc tuning methods, they have some advantages. These are (Anon, 1988, 1990):

- a better statistical basis of the model,
- capability of allowing for errors in both catch and CPUE or effort data.

On the other hand, these methods are much more laborious and require more user experience.

Material and methods

The basic data were taken from the report of the Baltic Demersal Working Group (Anon, 1991). The data consist of catch-at-age numbers and CPUE and fishing effort values from 6 countries (Denmark, Finland, Germany, Poland, Sweden and Soviet Union). Weight-at-age data were also supplied. The years 1982-1990 and ages 2-8 were covered.

The calculations were performed using the computer program (Deriso et.al., 1985) supplied by Mr P.R. Neal. As the available version of the program allows for disaggregation of the data for two fleets only, some data were pooled together to give two sets of catch and effort values. Namely the catches and effort of Denmark, Poland and Sweden constituted one group while the data of Finland, Germany and Soviet Union were allotted to the second group.

The CAGEAN model assumes that the fishing mortality F(t,a) at age a and in year t may be separated into

$$F(t,a) = s(a)f(t),$$

where s is selection and f is full recruitment fishing mortality. Basing on the Baranov catch equation, catch C(t,a) may be presented as a function of series of s and f, recruits numbers $N(t,a_r)$, numbers at age at first year of data N(1,a), natural mortality M and catchability coefficients q. The parameters s ,f ,q ,$N(t,a_r)$ and N(1,a) are estimated by minimization of the sum of squares

$$(1)\quad SS = \sum_{t,a}(\ln C^{obs}_{t,a} - \ln C^{model}_{t,a})^2 + \lambda\sum_{t}(\ln f_t - \ln(qE_t))^2$$

where E is observed fishing effort and λ is a weighting factor indicating the importance of the auxiliary information. The sum of squared terms representing stock-recruitment relationship may also be added to the model (1).

In the present paper the λ was assumed to be 7 (number of age group taken into account) to simulate equal number of catch and effort terms in the analysis. The Baltic cod stock parameters were found by minimization of (1) assuming M=0.2. The calculations were stopped when subsequent SS's differed by less than 10^{-5} or when number of iterations was 100. The first approximation of the terminal F at age 4 was assumed to be 1 (Anon, 1991) but some other approximation of terminal F's equalling 0.25, 0.50, 0.75 and 1.25 were also tried. The sensitivity of results to the choice of λ was examined.

3. Results and discussion

The estimates of the stock biomass (ages 2-8), recruitment at age 2, fishing mortality and surplus production are presented in Table 1. The catch is also given for comparison with exploited surplus production. The figures confirm the tragic state of the cod stock which has decreased about 3-4 times in the 1982-90 period - from above 1000 thous. tons to nearly 300 thous. tons. Recruitment shows also strong decreasing trend which is one of the main reasons for cod depletion. The other reason may be seen when comparing catch and surplus production values. In all the years since 1982 the catch has been much higher than the estimated surplus production.

The modelled stock biomass is in good agreement with the Baltic Demersal Working Gruop estimates (Anon, 1991), (Fig. 1). The bigest relative difference refers to 1990 and is equal to 11% while the mean difference is 6%. Similarly good correspondence occurs between the modelled recruitment numbers with the Working Group estimates. Mean relative difference is 7% and the highest difference refers to 1990 equalling 23%. Mean fishing mortality at ages 4-7 determined by the CAGEAN model is more stable than the Working Group estimates (Fig. 1).

To check the assumptions of the model, the residuals were analysed. In Fig. 2 the log catch residuals visualised as notched box plots (Quinn et.al., 1990) are presented. The notcher represents 95% confidence interval for the mean, the boxes contain

50% of residuals. In Fig. (a) the log catch residuals are a function of year, in Fig (b) they are a function of age. The residuals distributions show that the analysis has worked well. Almost all confidence intervals contain the value 0. The two parts of boxes are of similar size so the assumption of the lognormality of errors distribution is probable. The notched box and whisker plots of fishing effort residuals as the function of the fleet also confirm the model assumption (Fig. 3).

The simulations are not too sensitive to the choice of first approximation of the terminal fishing mortality at age 4 (Table 2). The values by 25% lower or higher than the selected first approximation give almost the same results.

Table 3 presents the sensitivity of the stock estimates to the choice of λ. It may be seen that the influence of the λ on the final biomass estimates is moderate or even low in the interval of the most probable λ values (0.5-10). Only very low λ values, practically meaning excluding of the fishing effort information from the analysis, give significantly different biomass estimates. The bigger the λ value, the bigger the biomass estimate.

References

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Table 1. The CAGEAN estimates of the cod biomass (10^3 tons), recruitment (10^6 individuals), mean fishing mortality and exploited surplus production (10^3 tons), and the catch figures (10^3 tons) for 1982-1990. Biomass estimates are provided with their standard errors.

Year	Biomass (age 2-8)	Recruitment at age 2	Mean F (age 4-7)	Surplus production	Catch
1982	1024 +/-47	618	0.73	284	316
1983	939 +/-41	403	0.76	271	332
1984	835 +/-42	284	0.90	269	391
1985	660 +/-34	250	0.83	99	315
1986	471 +/-24	233	0.85	218	253
1987	488 +/-22	339	0.83	152	207
1988	464 +/-27	202	0.77	122	194
1989	366 +/-26	81	0.77	153	179
1990	314 +/-22	122	0.88	-	154

Table 2. The sensitivity of the estimated mean fishing mortality of cod in 1990 to the choice of the first approximation of the terminal fishing mortality at age 4 (λ=7).

First approx. of terminal F	0.25	0.50	0.75	1.00	1.25
Mean F in 1990 (age 4-7)	0.75	0.83	0.86	0.87	0.87

Table 3. The sensitivity of the modelled cod biomass (10^3 tons) in 1990 to the choice of the λ value.

λ	0.01	0.1	0.5	1.0	7	20	50
Biomass	166	214	300	319	335	354	377

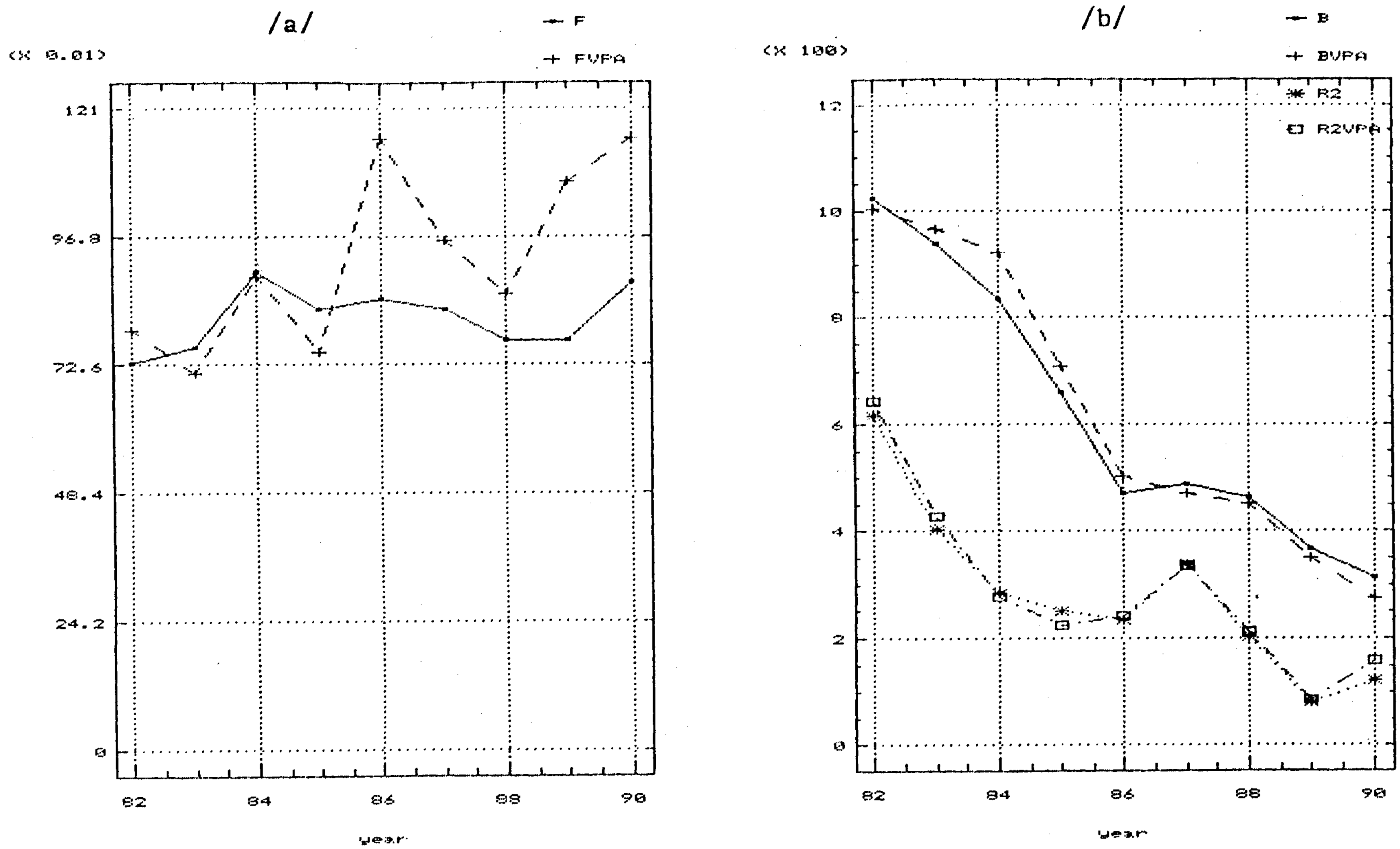

Fig. 1. The comparison of the CAGEAN and VPA estimates of
(a) fishing mortality, (b) recruitment and stock biomass (ages 2-8).

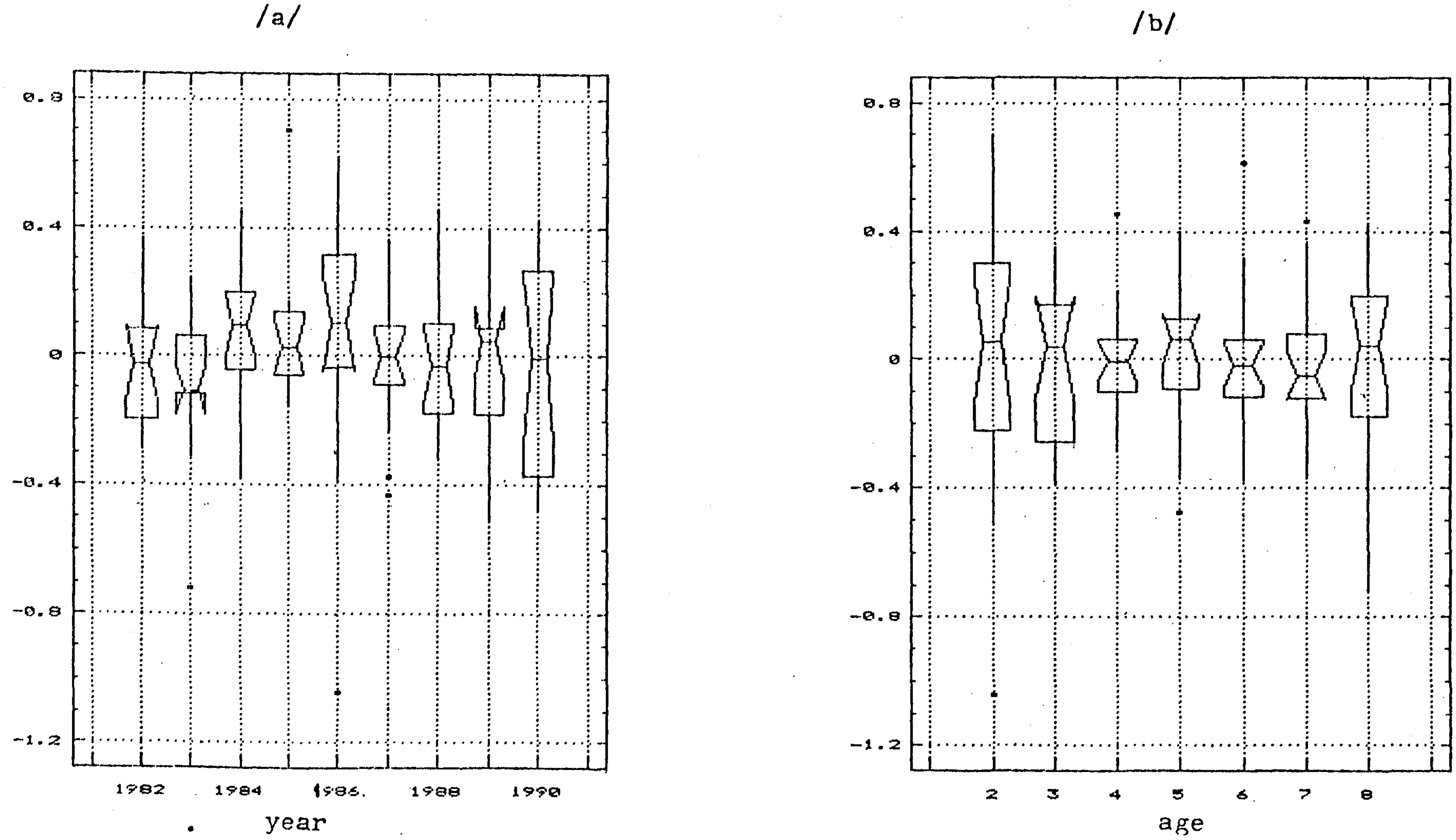

Fig. 2. The notched box and whisker plots of the log catch residuals as function of year (a) and age (b).

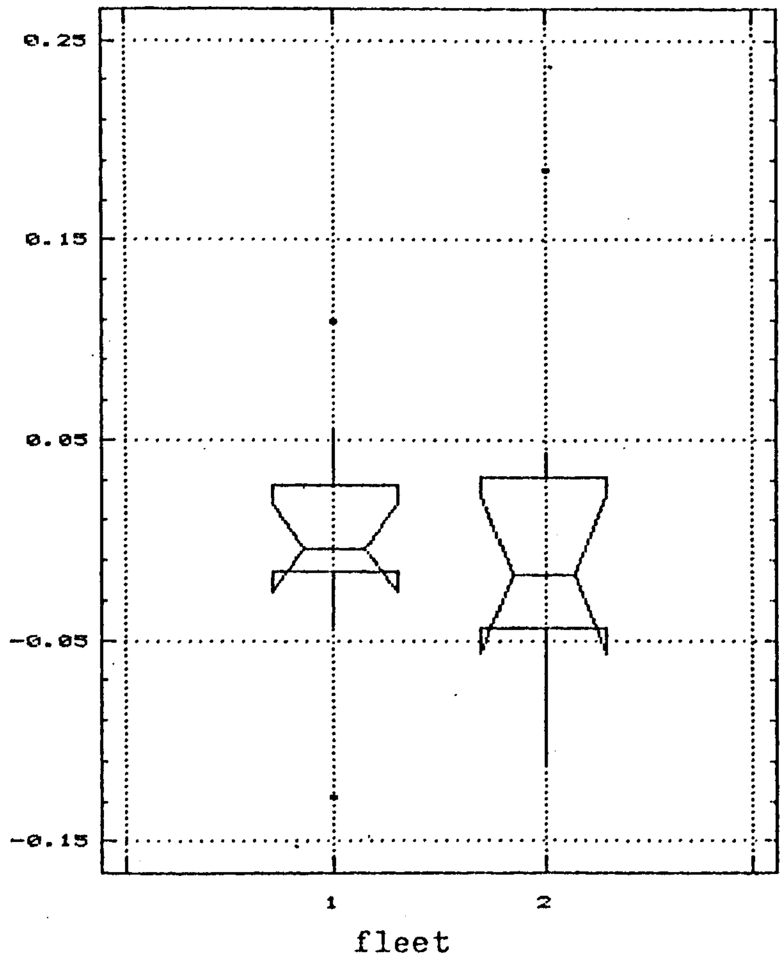

Fig. 3. The notched box and whisker plots of the log fishing effort residuals as a function of fleet.