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Time series analysis of Icelandic cod, haddock and saithe

by

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The estimates of stocks and fishing mortality rates were obtained from a joint analysis of catch-at-age data from 1984-2001 and survey data from 1985-2002. The relationship between survey indices and stock is modelled as

$$U_{at} = \varphi_a \psi_t N_{at}\, e^{-\tau Z_{at}} + \varepsilon_{U,at}$$

where

U_{at} is the catch per unit effort of age a in year t,
N_{at} is the stock of age a at the beginning of year t
Z_{at} is the total rate of fishing mortality
$\varepsilon_{u,at}$ = residuals, serially uncorrelated, $N(\mathbf{0};\sigma_U^2\mathbf{\Omega}_{Ut})$. The matrix $\mathbf{\Omega}_{ut}$ is predetermined.to account for the main changes in magnitude by age and cohorts.

The catchability is the product of a function of age, φ_a and a function of time, ψ_t which will be our main concern. It is modelled as

$$\ln\psi_t = \eta_{t-1} + \delta_{7t}$$

$$\eta_t = \eta_{t-1} + \lambda + \delta_{8t}.$$

where δ_{7t} and δ_{8t} are residuals and λ a constant annual change.

In this model λ and δ_{8t} represent permanent variations and there is no indication of such variation in the survey indices for these stocks. The residual δ_{7t} represents joint transitory variation at all ages included from the survey. The estimated standard deviations of the residuals δ_{7t} and $\varepsilon_{U,at}$ (in the best observed ages, transformed to ln-scale) were as follows, including the s.d. of the catch-at-age residuals in the second column:

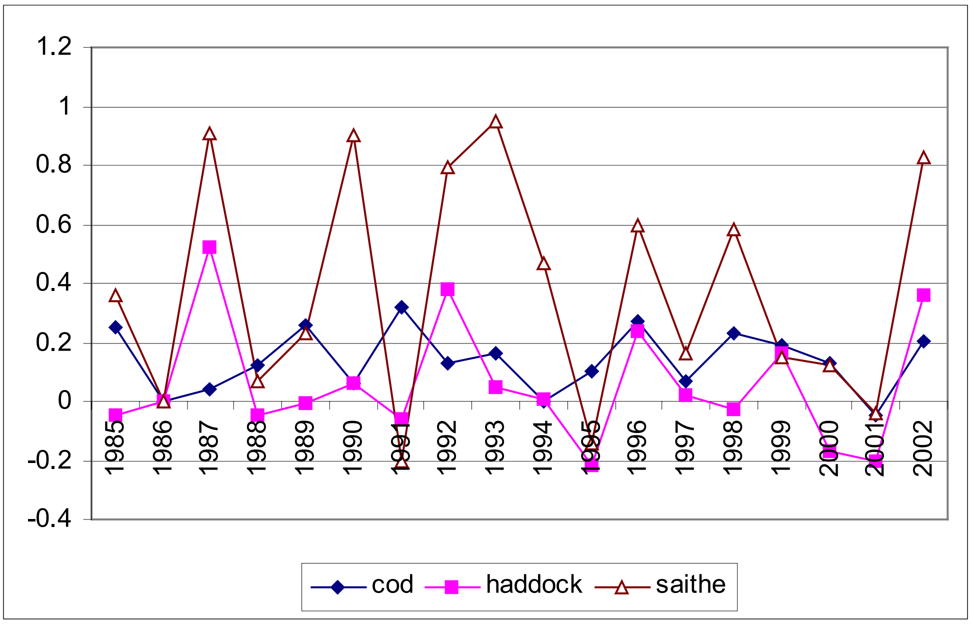
	ε_{at}	$\varepsilon_{U,at}$	δ_{7t}
Cod	0.065	0.15	0.13
Haddock	0.077	0.19	0.22
Saithe	0.089	0.31	0.41

We have not encountered serious difficulties in the estimation of stocks and fishing mortalities of cod and haddock with these data. Test statistics from the standardised residuals of prediction errors of catches and CPUE indices are satisfactory and also the retrospective analyses.

The parameters of the time series models do not determine the stocks and fishing mortality rates; these are obtained from the observations by the Kalman filter by means of the estimated time series model. The main features of the models were as follows (for explanation of terms see "Time series models in fish stock analysis" (GG, April 2002):

The initial values of lnF were mainly produced by the constant and parabolic terms for all stocks. Joint random walk changes at all ages (δ_1) were significant for all stocks. For cod and haddock permanent changes in selectivity were also significant, but not for saithe.

The estimated pattern of ln ψ_t is presented in the figure:



For saithe the variances from the survey are much higher than for cod and haddock and results from a joint analysis with catch-at-age data tend to differ little from results obtained from analysis of catch-at-age data alone.

The best retrospective analyses are obtained by using a linear trend between constant values in the three first and last years as a recruitment index. This is, however, not a very satisfactory arrangement and liable to produce biased results if the trend comes to a halt or changes course. We have found that a fairly accurate recruitment index (at 4 years) is obtained by the average over 3-5 years indices from respective cohort in the survey. Estimates of catchable biomass in 2001 are about 10,000 tonnes higher with this index than the trend. It is highly significant compared with the trend according to the likelihood function. The retrospective analyses in the last years are satisfactory, but actually worse than with the trend further back.

CPUE indices for saithe from trawlers have much lower transitory variations than the survey, but appear to have changed systematically over the time period included here so that the variations represented by λ and δ_{8t} are not negligible. Estimates obtained from trawl indices without these terms produce much higher values of catchable biomass than other estimates.