Catch rates vs survey index: on the effects of using them in a single ADAPT framework.

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ABSTRACT

This study investigates, for cod in NAFO Divisions 2J, 3K and 3L, the effect of the relative importance of the two independent indices of abundance on the precision of parameters estimated with a non-linear procedure. It is concluded that, when more weight is given to the commercial catch rate index (age-aggregated), the estimation of survivors for the younger age groups would have to come from additional constraints on the system. For instance, the structure of the system could be changed to estimate them from the historical averaging of partial recruitment coefficients. A side-effect of introducing the age-aggregated catch rate index into the age-structured formulation is that this additional index, which by itself contains no information for estimating survivors at younger ages, nevertheless had an impact on survivor estimates and decreased their precision. These observations point out the need, in the case of this cod stock, to treat the two indices in separate formulations where age-disaggregation is used with the research survey index and a more structured model is adopted for calibrating with the CPUE.

RÉSUMÉ

On étudie ici, pour le stock de morue des Divisions 2J, 3K et 3L, l'effet de l'importance relative des deux indices indépendants de l'abondance sur la précision des paramètres estimés au moyen d'une méthode non-linéaire. On conclue que, lorsque plus d'importance est allouée à l'indice tiré des taux de capture commerciaux (combinés pour tous les âges), l'estimation des survivants pour les plus jeunes groupes d'âge doit provenir de l'imposition de contraintes additionnelles sur le système. Par exemple, la structure du système pourrait être modifiée afin d'estimer ces groupes d'âge à partir des moyennes historiques du recrutement partiel. En plus, l'introduction d'un indice du taux de capture unique pour tous les âges, qui en lui-même ne contient aucune information pour l'estimation des groupes d'âge les plus jeunes, dans une formulation où chacun des groupes d'âge apparaît explicitement a un impact sur les estimés des survivants et diminue leur précision. Suite à ces observations, il apparaît que les deux indices devraient être traités pour ce stock de morue dans des formulations distinctes où un modèle par groupe d'âge est utilisé avec l'indice provenant des relevés scientifiques, et un modèle plus structuré est adopté pour l'ajustement en fonction des taux de capture.

Introduction

This paper investigates the effect of combining, within the ADAPT framework (Gavaris 1988), two independent indices of stock size in a single objective function expressed as the sum of weighted least squares. The analysis is based on the application of the ADAPT framework to the cod stock in NAFO Div. 2J, 3K and 3L. The question investigated here stems from the observation that "giving more weight" to the commercial catch rate index in alternate formulations was leading to survivor estimates exhibiting higher coefficients of variation than an estimation based solely on the research survey index.

Method

The formulation of the ADAPT framework is presented in Annex I. In order to investigate the effect of each index on parameter estimates, the objective function was formulated as

$$\Sigma\, w^2\, (7/8)^2\, (\ln \mathrm{CPUE}_{observed} - \ln \mathrm{CPUE}_{estimated})^2$$

+

$$\Sigma\, (1-w)^2\, (1/8)^2\, (\ln \mathrm{RV}_{observed} - \ln \mathrm{RV}_{estimated})^2$$

where w ($0<w<1$) represents the relative contribution of the commercial catch rates to the sum of residuals^2. The quantities (7/8) and (1/8) represent fixed weights which are included to adjust the sums of squares of residuals coming from the CPUE index to that of the research vessel (RV) index.

Note also that the partial recruitment coefficients for the offshore fleet (used for the calculation of the exploitable biomass) were assumed to be unity for all ages in the age range identified as being fully recruited (rather than truncating to unity, as is sometimes done).

Results

The coefficient of variation of the estimated survivors (ages 4 to 9), of the commercial catchability coefficient (q) and of the research calibration coefficient at age 7 (K) were obtained and plotted against w.

For ages 4-6, the coefficient of variation increases rapidly as the relative contribution of the commercial catch rates increases (Fig. 1). In other words, the commercial catch rates do not contain any information on the survivor estimates for these ages. The coefficient of variation improves significantly for $w > 0.7$ at ages 7, 8 and 9. Also, for ages 8 and 9, the coefficient of variation becomes smaller than when the estimation is based solely on the research vessel index.

The observation made that the survivor estimates exhibit a larger coefficient of variation as more weight is given to the commercial catch rates does not hold when $w > 0.7$, i.e. as the commercial catch rates become the predominant index for tuning. From Figure 1, it can be seen that the opposite is true for ages 8 and 9.

The relative precision of q and K are plotted against w in Figure 2. The relative precision degrades rapidly when $w < 0.2$ for q, and when $w > 0.8$ for K.

Conclusions

Younger ages. The commercial CPUE has little or no useful information for the estimation of survivors at ages 4-6 (Fig. 1). Consequently, in a tuning based on CPUE, the estimation of survivors for these ages would have to come from additional constraints (structuring) on the system. For instance, these could be estimated from the historical average of partial recruitment coefficients. As the model formulation adopted here is aimed at an age-by-age tuning in conformity with survey data, there is not enough structuring in the underlying model to estimate separate survivors for each age from a global catch rate index. However, this does not mean that survivor estimates based on a different structure, such as estimates based on historical averaging of the partial recruitment coefficient, would necessarily be less precise than one based on age-by-age tuning from a survey index. It simply means that the current formulation of the ADAPT framework is not suited for calibration with a global CPUE index. An annoying side effect of introducing the commercial catch rates in such a formulation is that this addition, which contains no information for estimating survivors at early ages, has a *significant effect on these survivor estimates and on their measure of precision.*

Older ages. For older ages (e.g. >7), the CPUE can produce estimates of survivors which are as precise, or more precise, than those arising from the research vessel index. The major issue, though, is not precision in this case but bias: each index suggests separate trends in stock size for the recent years and it is not possible with a single VPA stock trajectory to reconcile both trends. The consequence of this is that the relative weight w applied becomes an arbitrary way to combine two different trends. The initial intent behind defining the weights in a least-squares criterion is not to reconcile different trends but to address the question of the relative precision of each index.

These observations point out the need to treat the two indices, i.e. the CPUE and the research vessel index, in separate formulations of ADAPT where, for instance, age disaggregation is used with the research vessel index and a more structured model is adopted for tuning with the CPUE. Then, if there is no indication that one index is a better indicator of stock size than the other, the population estimates can be combined *a posteriori*, using relevant (probably arbitrary) weights. When the survivor estimates are combined outside the ADAPT framework, each index is given a fair chance to perform as it is treated with its best model formulation.

This study should be expanded to other stocks where multiple indices are used. The observations made here are related to the relative information content of each independent index of abundance and, thus, cannot be generalized.

Bibliography

Gavaris, S. 1988. An adaptive framework for the estimation of population size. CAFSAC Res. Doc. 88/29. 12 pages.

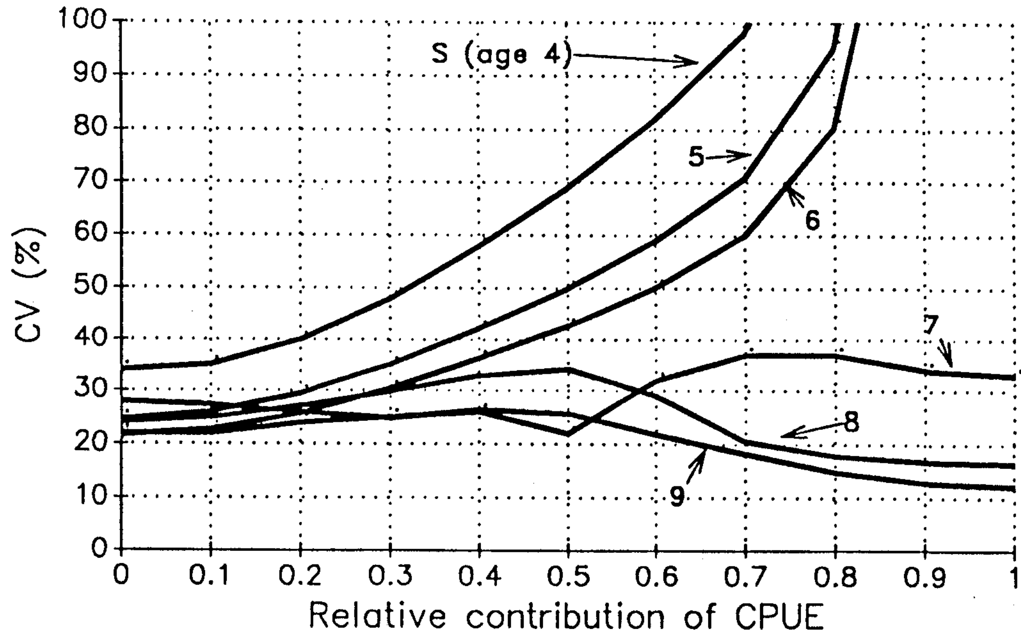

Figure 1. Coefficient of variation of survivor estimates at ages 4-9 against the relative contribution of CPUE to the objective function.

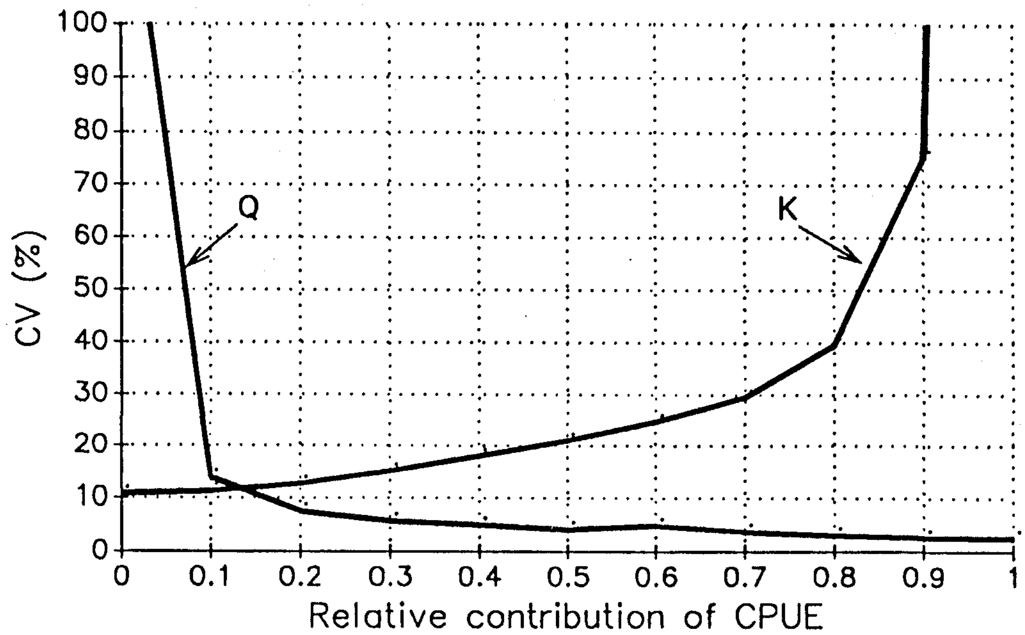

Figure 2. Coefficient of variation of the calibration coefficients against the relative contribution of CPUE to the objective function. The symbol Q identifies the calibration coefficient for the commercial catch rates series; the symbol K identifies the calibration coefficient for the research survey series (age 7 was chosen for illustrative purposes).

Annex I

The adaptive framework was used to estimate stock size with the following formulation.

Parameters:

-Year-class estimates: $N_{i,1988}$, i = 4 to 10

-Calibration coefficients for RV numbers: K_i, i = 3 to 9

-Calibration coefficients for CPUE: K' (aggregated for all ages)

Structure:

-natural mortality assumed to be 0.2
-error in catch-at-age assumed negligible
-F for age groups 11-13 in 1987 set equal to the "full" F for ages 7-10 in 1987
-F on age group 13 calculated as "full" F for age groups 7-11
-intercepts not included

Input:

-$C_{i,t}$, i = 4 to 13, t = 1978 to 1987

-$RV_{i,t}$, i = 3 to 9, t = 1978 to 1987

-C/E_t, t = 1978 to 1987

-Fall RV related to the population at the beginning of the next year

-CPUE related to average offshore exploitable biomass

Objective function:

Minimize (see text)

$$\Sigma\, w^2 (7/8)^2 (\ln CPUE_{observed} - \ln CPUE_{estimated})^2$$

+

$$\Sigma\, (1-w)^2 (1/8)^2 (\ln RV_{observed} - \ln RV_{estimated})^2$$

Summary:

-number of observations = 80
-number of parameters = 15