USE OF DELAY-DIFFERENCE MODELS TO ASSESS ATLANTIC BIGEYE TUNA

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SUMMARY

Previous age-structured assessments of Atlantic bigeye tuna have been characterized by uncertainty due to the inability of the models used to fit all of the available data. Therefore, management advice has primarily relied upon simpler, lumped-biomass production models. The document proposes the use of Delay-Difference models for the assessment of Atlantic bigeye tuna. This class of models could be characterized as falling between age-structured and biomass production models. A test example is presented using data from the 1999 bigeye assessment.

RÉSUMÉ

Les précédentes évaluations structurées par âge du thon obèse de l'Atlantique se sont caractérisées par l'incertitude étant donné que les modèles utilisés ne parvenaient pas à ajuster toutes les données disponibles. Par conséquent, l'avis de gestion reposait principalement sur des modèles de production de biomasse regroupée plus simples. Ce document propose d'utiliser les modèles à différences retardées aux fins de l'évaluation du thon obèse de l'Atlantique. Ce type de modèles pourrait être caractérisé comme se situant entre les modèles structurés par âge et les modèles de production de biomasse. Un exemple de test est présenté en utilisant des données de l'évaluation de thon obèse de 1999.

RESUMEN

Las anteriores evaluaciones estructuradas por edad del patudo atlántico se habían caracterizado por una incertidumbre debida a que los modelos utilizados no fueron capaces de ajustar todos los datos disponibles. Por tanto, el asesoramiento de ordenación dependía sobre todo de modelos de producción más simples de biomasa agregada. El documento propone utilizar los modelos de diferencia retardada para la evaluación del patudo atlántico. Este tipo de modelo podría ser caracterizado como un modelo que se sitúa entre los modelos de producción de biomasa y los modelos estructurados por edad. Se presenta una prueba a modo de ejemplo en la que se utilizan los datos de la evaluación del patudo de 1999.

KEYWORDS

Stock assessment; Tuna fisheries; Mathematical models

1 BACKGROUND

The Atlantic bigeye stock has been assessed in the past using age-structured models such as ADAPT or XSA, as well as biomass production models (PRODFIT, ASPIC). The uncertainties in the results of the traditional age-structured analytical methods create doubts about the use of such methods to assess the Atlantic bigeye stock. On the other hand, the traditional production models give only a rough idea of the status of the stock.

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The Bigeye Tuna Year Program (BETYP) is developing an integrated statistical assessment model for bigeye, with the aim of addressing some of the uncertainties that have been experienced with age-structured models. However, This is a complex model that will need some time to be completely operative.

While the integrated statistical model is being developed, we propose the use of delay-difference models (Quinn and Deriso, 1999). These models represent an intermediate level between biomass-based production models and age-structured models and have already been tested in ICCAT assessments (e.g., for blue marlin in 2000). To show its applicability, we have prepared a spreadsheet that can be used for parameter estimation. An example is shown based on the data used for the last assessment (1999).

2 MODEL

The basic model uses the following notation (Quinn and Deriso, 1999):

α, β Stock-recruitment parameters
r Recruitment age
R Number of recruits
B Biomass
ρ Ford growth parameter
ℓ Annual survival from natural sources = e^{-M}
E Fishing Effort
Y Yield
U CPUE = Y/E
S Survival = $(B-Y)$
ε Process error term for population
ω Observation error for CPUE = $(\ln(U) - \ln(\hat{U}))$
q Catchability

Stock dynamics are governed by the following equations:

Recruitment $$R_t = \frac{\alpha B_{t-r}}{1+\beta B_{t-r}} e^{\varepsilon_t}$$

Biomass $$B_t = (1+\rho)\ell S_{t-1} - \frac{\rho \ell^2 S_{t-1} S_{t-2}}{B_{t-1}} + R_t$$

Virgin Biomass (equilibrium) $$B_0 = \frac{\left(\dfrac{\alpha}{(1-\rho\ell)(1-\ell)} - 1\right)}{\beta}$$

Predicted yield: $$\hat{Y}_t = (1 - e^{-qE_t})B_t$$

Predicted CPUE $$\hat{U}_t = \frac{\hat{Y}_t}{E_t}$$

For estimation, we suggest an approach like that used in the 2000 blue marlin assessment, which attempts to incorporate both process errors and observation errors. For this purpose, there are two log-likelihood components that need to be maximized as the objective function:

Log-likelihood for observation errors $\lambda_O = -\frac{n_o}{2}\ln(\sum \omega^2)$

Log-likelihood for process errors $\lambda_P = -\frac{n_P}{2}\ln(\sum \varepsilon^2)$

There should be as many process error terms as there are observations for effort. We note, however, that maximizing these two likelihood terms is not a statistically-rigorous approach, since there are more defensible methods for mixed process-observation error models (see Quinn and Deriso, 1999). However, what we have done is relatively simple to implement, though we ignore if a more rigorous method would provide substantially different point estimates of the parameters.

During estimation, we fix ρ and ℓ based on external (literature) information. Parameters to estimate are α, β, q and all of the ε terms. We set $B_t = B_0$ for at least r years before the first observation and then use the population dynamics equations to project the population forward. Parameter estimates are obtained by maximizing $\lambda_O + \lambda_P$.

2.1 Possible extension for a recruitment index

In addition to an overall CPUE index (which is assumed to be proportional to overall biomass), a second observation error series could be introduced with an index of recruitment abundance, *I*:

$$\xi_t = \ln(\kappa I_t) - \ln(R_t)$$

and the maximization would involve the additional log-likelihood $-\frac{n_I}{2}\ln(\sum \xi^2)$. However, such a series is not yet available for bigeye tuna and we were not able to test it.

2.2 Parameters values used for Bigeye

2.2.1 Growth (Cayre, P. & T. Diouf, 1984)

$L\infty = 285.4$ cm.
K= 0.11 this value is used as initial guess, in the process it is indirectly estimated through ρ
$t_o = 0$, using $t_o = -0.018$ produce mean weights by age equal to that used in the last assessment

Length-weight parameters (Parks et al.,1981): $a = 0.000024$; $b = 2.98$

2.2.2 Other Biological Parameters

l =0 .6 (equivalent to M =0 .51)

Age of Recruitment (r) = 1

3 RESULTS

An example run was conducted without any constrain using as input the above parameter values. Regarding t_o a value of –0.018 was used in order to produce mean weights by age equal to that used in the last assessment. **Figure 1** shows yield, biomass and ln(CPUE) observed and predicted values.

Figure 2 shows fishing mortalities and recruitment estimated compared with values estimated in the last assessment. Fishing mortalities values are intermediate between values obtained in the last assessment by XSA and very close to ADAPT estimates for the recent time period. Values obtained for the very last years seem more realistic than those obtained by ADAPT following a trend similar to XSA estimates. Regarding recruitment, estimates are much higher than values currently considered to this stock. **Figure 3** shows observed data fit to equilibrium yield.

4 DISCUSSION

Delay-difference models are intermediate in complexity between production models and VPAs and, yet, they use very simple types of data like production models do. We believe that they can be a useful addition to the toolbox of models that are tried during SCRS assessments; the example shown here for bigeye tuna suggests that the Delay-difference model fits the available data reasonably well.

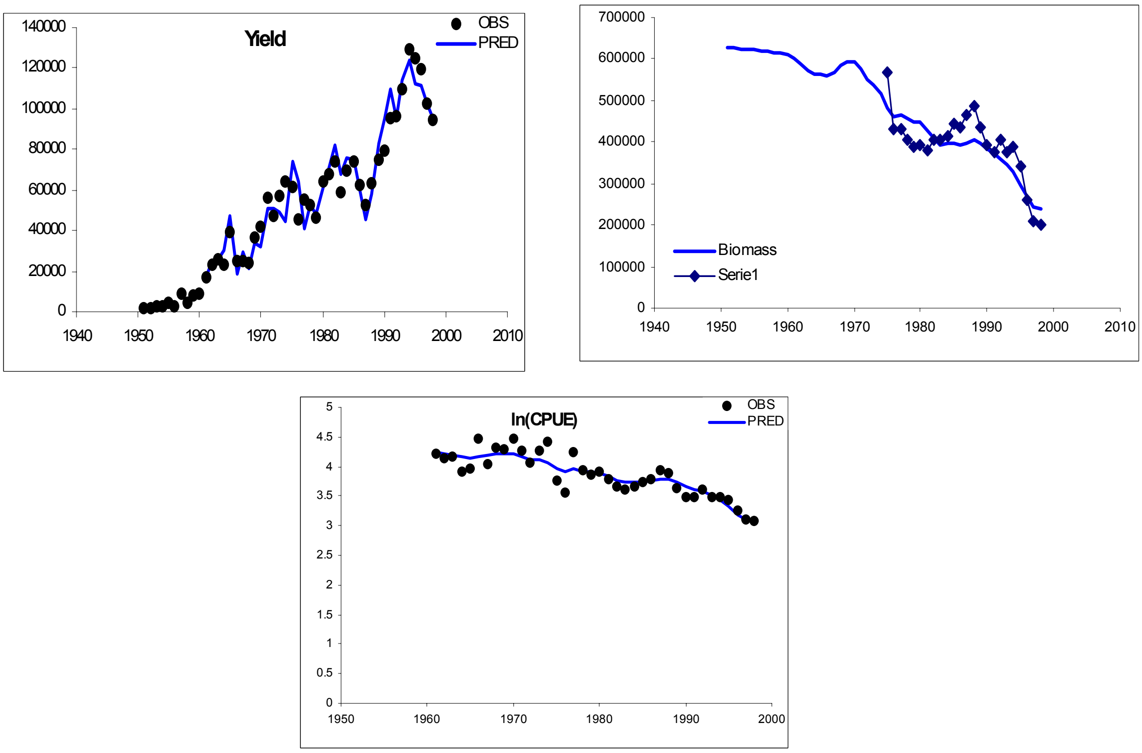

Figure 1.- Run1 without constrains. Yield, biomass and ln(CPUE) observed and predicted values.

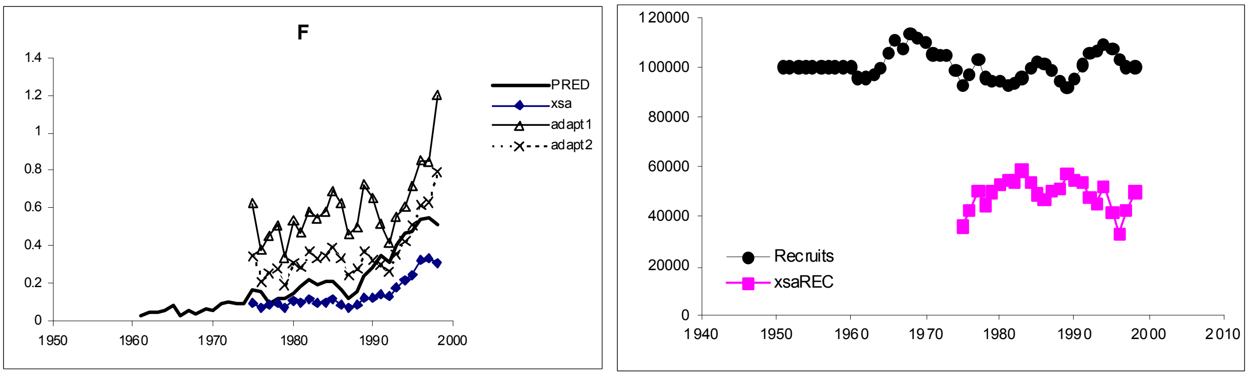

Figure 2.- Fishing mortality and recruitment predicted in Run 1 compared with F obtained by different runs of ADAPT and XSA and recruitment estimated in XSA.

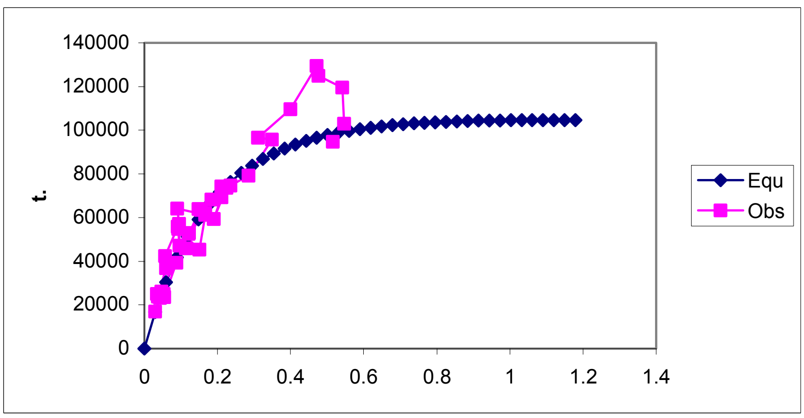

Figure 3.- Observed and equilibrium yield.