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COMMENT ON THE EASTERN ATLANTIC AND MEDITERRANEAN BLUEFIN TUNA

Enrique de Cárdenas[1]

SUMMARY

The SSB and R series, resulting from the case base scenarios "Inflated" and "Reported" explored during the last E BFT assessment, were used to fit three different S-R models (Beverton & Holt, Ricker and smooth Hockey-stick). The results show that the stock has maintained its full reproductive capacity throughout the time series from the 50s and that a Ricker S-R relationship cannot be rejected for this stock. This last result adds more uncertainty to the estimate of B01, which makes it useless as a biomass reference point for this stock. As an alternative we propose the use of Bloss as Blim and then, to estimate Bpa from this value. This allows us to simulate the behavior of some HCR and select the most suitable for this stock.

RÉSUMÉ

Les séries de SSB et R résultant des scénarios du cas de base utilisant des prises « réajustées » et « déclarées » explorés pendant la dernière évaluation sur le thon rouge de l'Est ont été utilisées pour s'ajuster à trois différents modèles S-R (Beverton & Holt, Ricker et bâton de hockey lisse). Les résultats montrent que le stock a maintenu son entière capacité reproductive pendant toute la série temporelle à partir des années 50 et qu'une relation S-R de Ricker ne peut pas être rejetée pour ce stock. Ce dernier résultat ajoute davantage d'incertitude à l'estimation de B_{01}, ce qui la rend inutile comme point de référence de la biomasse pour ce stock. Comme alternative, il est proposé d'employer B_{loss} comme B_{lim} et ensuite d'estimer Bpa à partir de cette valeur. Ceci nous permet de simuler le comportement de certaines HCR et de sélectionner la plus adéquate pour ce stock.

RESUMEN

En este documento se han utilizado las series temporales de SSB y R resultantes de los escenarios del caso base con capturas "aumentadas" y "decaradas" explorados durante la última evaluación de atún rojo del Este, para ajustar los tres modelos S-R diferentes (Beverton & Holt, Ricker y smooth Hockey-stick). Los resultados muestran que el stock mantuvo toda su capacidad reproductiva a lo largo de la serie temporal, desde 1950, y que la relación S-R de Ricker no puede descartarse para este stock. Este último resultado añade más incertidumbre a la estimación de $B_{0,1}$, lo que hace que no pueda utilizarse como punto de referencia de biomasa para este stock. Como alternativa, se propone el uso de B_{loss} como B_{lim} y, posteriormente, estimar B_{pa} a partir de este valor. Esto permite simular el comportamiento de algunas HCR y seleccionar la más adecuada para este stock.

KEYWORDS

Bluefin tuna, Stock-recruitment relationship, Biomass reference points

[1] SGP Velázquez 144 Madrid; edecarde@magrama.es

Introduction

All the biomass reference points (*B01*) estimated for the three recruitment scenarios considered by the SCRS in the 2012 assessment (SCRS, 2012), exceed the highest value observed (300,000 t) in historical series of 60 years of the fishery and in one case, reaches more than three times that value.

The SCRS set 3 stock productivity scenarios: one of low recruitment that identifies with the period of the 70s, a scenario of average recruitment that identifies with the period 1950-2006 and a scenario of high recruitment that identifies with the 90s. In each of these scenarios, the SCRS estimates the reference point multiplying the SSB would produce on average each new recruit incorporated to the fishery, by the average recruitment of the period, if it is exploited at F01.

Thus in all three cases it is assumed that at high levels of SSB, recruitment becomes independent of it.

This assumption is valid when the compensation factor that regulates the mortality of pre-recruits is its density. In this case, density decreases with time because of the mortality, which in turn is reducing competition. This behavior was modeling by Beverton & Holt (1957) in its relationship. The assumption is also valid if the recruitments are made independent of SSB from a given size of biomass as in the ratio of type Hokey stick (Barrowman and A. Myers., 2000).

However this assumption is violated if the dense dependent compensatory phenomenon is related more to the size of the spawning stock, as it is in the Ricker model (1954). In this case, recruitment reaches its maximum at medium values of SSB, thereafter recruits tend to decrease, with increasing SSB.

The aim of this paper is to check whether we could reject the hypothesis that the SSB-R relationship for Eastern bluefin tuna could be Ricker type, or not, discuss the implications if we could not reject it and propose the use of alternative levels SSB reference for this stock.

Material and methods

The time series of SSB and R were provided by ICCAT and come from the two base case scenarios “Inflated” and “Reported” from the 2012 assessment.

These series go from 1951 to 2011. However only information from 1951 to 2008 were used, to ensure the convergence of the VPA, given the uncertainties that exist in abundance indices

The fits to the different models were carried out using PlotMSY program. This program was presented by de Oliveira and Earl in last ICES Methods Working Group (ICES, 2013). This program fits three stock–recruit functions, namely the Ricker, B.–H., and a smooth Hockey-stick (Mesnil & Rochet, 2010).

Blim was estimated as the average between the values estimated for *Bloss* in the two scenarios “Inflated” and “Reported”.

The range of Bpa was calculate as $Bpa = Blim \, . \, e^{1.645 \, . \, \sigma}$, ranging σ between 0.2 and 0.3.

Results

The scatter diagrams show a decline in recruitment with increasing SSB in both series reported and inflated (**Figure 1**).

When this happen Beverton–Holt fits are problematic, because these can result in a very high steepness estimate implying little possibility of recruitment overfishing, when in fact the relationship is more likely to be Ricker-like (ICES, 2013).

The results of the fits to the different models allow us to draw three main conclusions, which are similar for both reported and inflated series (**Figure 2 & 3**):

- As expected the best fits to the data are obtained with the Ricker model (Ricker model was selected as best fitted in a 100% of the iterations).

- The Beverton and Holt model do not fit the data well, and the results obtained in a deterministic way, differs from those obtained from the MCMC samples. This is particularly evident in the case of the inflated series.
- The break point for the hockey stick fits occurs at *Bloss* **(*L*owest *O*bserved *S*pawning *S*tock)**.

Blim is estimated around 136 000 t and Bpa in the range 189 000 – 223 000 t.

Discussion

The most surprising outcome of the adjustments is provided by the hockey stick model, where the breakpoint occurs at *Bloss*, which means that the stock has maintained its full reproductive capacity throughout the historical period. Bearing in mind that public opinion believes that the BFT is, or at least was until recently an endangered species, so it was considered for to list it in CITES.

A Ricker type compensation phenomenon occurs if cannibalism or competition for food with adults happens. Although in the case of BFT these phenomena do not seem likely to occur. However, a high level of SSB may lead to a high density of individual which produce food shortages affecting their condition and in consequence the quality of the eggs, which affect their survival potential. So we can not reject the hypothesis that a Ricker S-R could exist.

This complicate even more the SCRS recommendation, taking into account that currently, it is proposing six different values for B01, being the maximum more than three time the minimum one and now the possibility of a Ricker relationship will introduce two more possible values, taking into account that the SCRS recommended biomass which would produce a very low average recruitment, making difficult to reach and/or maintain these proposed levels in the long term.

In conclusion the use of B01 as Biomass Reference Point, is very uncertain and for hence not very useful. As an alternative it should find a more consistent biomass reference point.

Sissenwine and Mace (1993) stated that although some types of overfishing may be permissible (for growth, localized pulse), management must guard against recruitment overfishing.

The purpose of Limit Reference Points (LRF) is to serve to trigger alarms and additional management measures to avoid this recruitment overfishing.

For stocks where quantitative information is available, ICES indicate that a limit biomass reference point (*Blim*) may be identified as the stock size below which there may be reduced reproduction resulting in reduced recruitment. A precautionary safety margin incorporating the uncertainty in ICES stock estimates leads to a precautionary reference point Bpa, which is a biomass reference point designed to avoid reaching *Blim*. Therefore, when *SSB* is above Bpa the probability of impaired recruitment is expected to be low (ICES, 2012).

This definition corresponds to that of MBAL (Minimum Biological Acceptable Level), that would form part of the LRP which tend to be classified by some authors as nonparametric since their determination does not depend on any particular model of the SR relationship (Cadima, 2003).

Consistent with this ICES define *Blim* as the biomass below which the recruitment is expected to be 'impaired' or the stock dynamics are unknown.

Cadima (2003) suggest in determining *Bpa*, to estimate *Blim* and from these apply the empirical rule:

$$Bpa = Blim \cdot e^{1.645 \cdot \sigma}$$

where

σ = constant associated with the estimation uncertainty measure.

The values obtained indicate various fisheries σ values in the interval (0.2, 0.3) (ICES, 1997). In practice it can be said that Bpa is between 1.39 and 1.64*Blim.

In the case of *BFT* no series is able to detect a biomass below which recruitment falls. Applying ICES general criteria, we would select *Bloss* as *Blim*, because the stock dynamic bellow this point is unknown. However, there are some ICES stocks, in which *Bloss* is selected as *Bpa* - see for example the case of sole in ICES Div. VIId, sole in Div. VIIfg, or sole in Div VIII ab, or saithe in Div. Vb (ICES, 2012) – when, as it is the case in *BFT*, there are no indications of impaired recruitment at this point.

However, taking into account the uncertainty involve in the *BFT* assessment, a good solution may be to select an average value between both *Bloss* estimated in the two series, as *Blim* and estimate from this Bpa, using the empiric relationship proposed by Cadima (2003).

Having values for Blim and Bpa and assuming a hockey stick S-R relationship, with the break point at Blim, it will be possible to simulate different HCR, with different values Ftg (F01, F_{MAX}, F_{MSY}), obtained from programs like plotMSY, or eqSim (ICES, 2013). These HCR could something like:

$$Fnext = Ftg * P_{Blim}$$

Being

Fnext = Fishing mortality vector for catch projection
Ftg = Target fishing mortality vector
P_{Blim} = Probability of SSB to be above Blim.

This HCR gradually reduced F, as we approach Blim, where only apply 50% of it. Below this value of F falls drastically, but the HCR allows a certain by-catch mortality.

Or a HCR which reduces F linearly between Bpa and Blim like:

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If SSB > Bpa
        Fnext = Ftg * 1
Else
        If SSB < Blim
                Fnext = Ftg * 0
        Else
                    Fnext = Ftg *(SSB – Blim)/(Bpa – Blim)
```

Being

SSB = Current SSB

To check which F is the most convenient as target and which HCR is the most appropriate, may be used, among others, the following statistics:

- Average long-term yield.
- Probability of falling below *Blim*.
- Number of years spent below *Blim* after a fall.
- The probability that the stock collapse

If any of these HCR is applied, the stock will be exploited around F_{MSY} and hence will naturally converge in the long time around B_{MSY}, whatever its value is.

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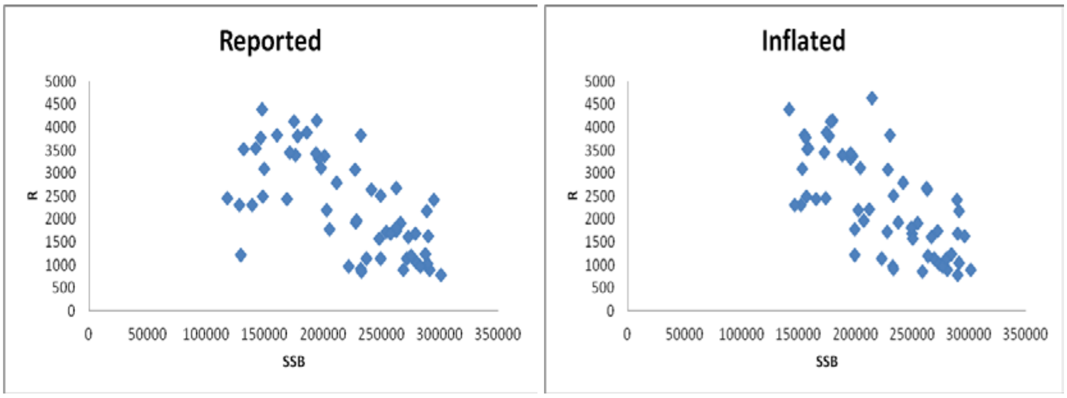

Figure 1. SSB – R scaterplot for reported and inflatedcatch scenarios.

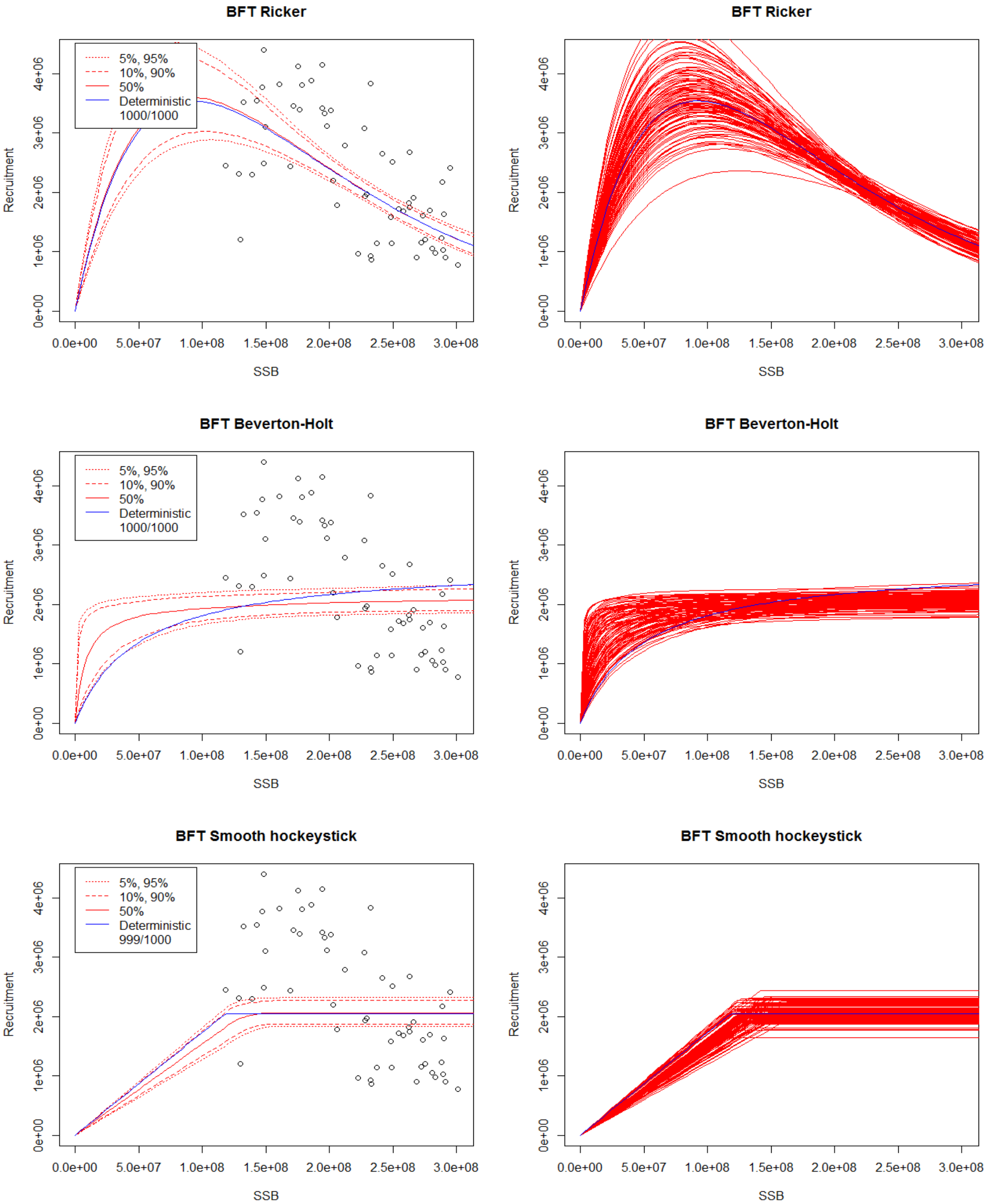

Figure 2. BFT stock-recruit fits for reported catch series: Ricker (top), Beverton-Holt (middle) and smooth hockey stick (bottom). The left hand figures illustrate the 95th, 90th, median, 10th, and 5th percentiles from the MCMC samples, plotted with the assessment data points; the right hand figures provide 100 illustrative re-samples. The estimates derived from MCMC sampling are in red; the deterministic estimates in blue.

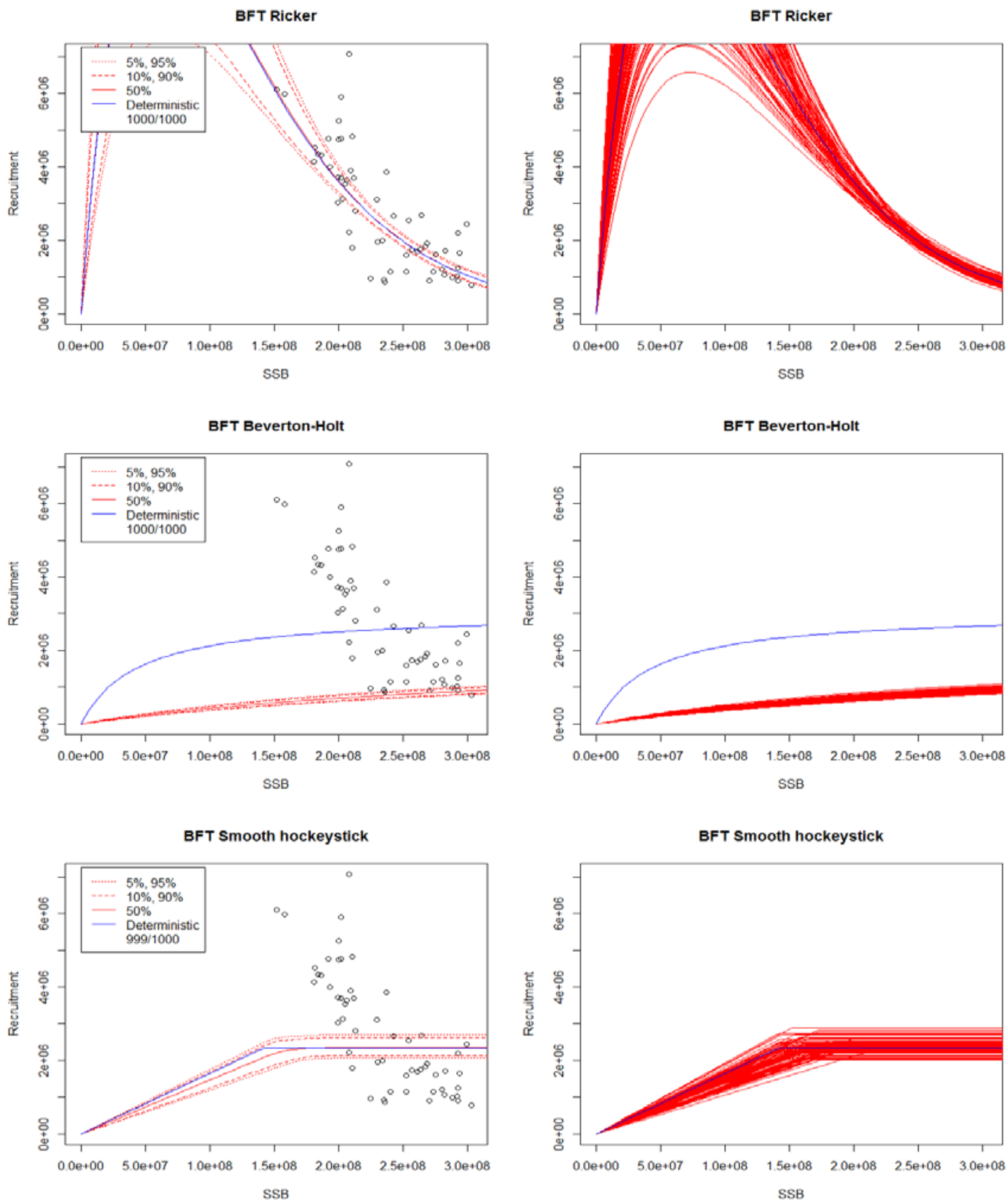

Figure 3. BFT stock-recruit fits for inflated catch series: Ricker (top), Beverton-Holt (middle) and smooth hockey stick (bottom). The left hand figures illustrate the 95th, 90th, median, 10th, and 5th percentiles from the MCMC samples, plotted with the assessment data points; the right hand figures provide 100 illustrative re-samples. The estimates derived from MCMC sampling are in red; the deterministic estimates in blue.