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AN EVALUATION OF THE IMPORTANCE OF THE ASSUMED BIOLOGICAL PARAMETERS FOR MANAGEMENT ADVICE: ATLANTIC YELLOWFIN

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SUMMARY

When providing scientific advice it is important to include a statement about the robustness of that advice to uncertainty. Often the biological processes are assumed to be known without error and that they do not vary over time. The impact of the biological assumptions can be evaluated by conducting sensitivity analyses or Management Strategy Evaluation. However both procedures can be complex to apply and require considerable computing time. Therefore we use a simpler technique, i.e. elasticity analysis that is widely used in economics and conservation management although to date has not been used in fisheries management. We evaluated the importance of biological parameters for the Kobe II Strategy Matrix and found that natural mortality was 3 orders of magnitude more important than the next important parameter, i.e. the steepness of the stock recruitment relationships.

RÉSUMÉ

Aux fins de la formulation de l'avis scientifique, il est important d'inclure un libellé concernant la solidité de l'avis à l'égard de l'incertitude. Il est souvent postulé que les processus biologiques sont parfaitement connus et qu'ils ne varient pas dans le temps. L'incidence des postulats biologiques peut être évaluée en réalisant des analyses de sensibilité ou une évaluation de la stratégie de gestion. Néanmoins, ces deux procédures peuvent être difficiles à appliquer et nécessitent beaucoup de temps de traitement. Nous utilisons dès lors une technique plus simple, à savoir l'analyse d'élasticité qui est largement utilisée en économie et dans la gestion de la conservation, bien qu'elle ne soit pas encore utilisée dans la gestion des pêcheries. Nous avons évalué l'importance des paramètres biologiques pour la matrice de stratégie de Kobe II et avons découvert que la mortalité naturelle était mille fois plus importante que le paramètre important suivant, c'est-à-dire la pente à l'origine de la relation stock-recrutement.

RESUMEN

A la hora de facilitar asesoramiento científico es importante incluir una declaración sobre la robustez de dicho asesoramiento ante la incertidumbre. A menudo se asume que se conocen perfectamente los procesos biológicos y que éstos no varían en el tiempo. El impacto de los supuestos biológicos puede evaluarse realizando análisis de sensibilidad o mediante una evaluación de estrategias de ordenación. Sin embargo, ambos procedimientos pueden ser complejos en su aplicación y requieren un tiempo de procesamiento informático considerable. Por tanto, se utilizó una técnica más simple, un análisis de elasticidad que se utiliza a menudo en economía y gestión de la conservación, aunque hasta la fecha no ha sido muy utilizado en lo que concierne a la ordenación pesquera. Se evaluó la importancia de parámetros biológicos para la matriz de estrategia de Kobe II y se halló que la mortalidad natural era 3 órdenes de magnitud más importante que el siguiente parámetro importante, a saber la inclinación de la relación stock-reclutamiento.

KEYWORDS

Growth, Natural mortality, Recruitment, Elasticity, Evaluation, Yellowfin, MSY, Reference points, Stock assessment

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1. Introduction

The main management objective of ICCAT is to maintain the populations of tuna and tuna-like fishes at levels which will permit the maximum sustainable catch. Scientific advice within ICCAT is therefore based on maximum sustainable yield (MSY) and associated reference points; i.e. the biomass or spawning stock biomass (B_{MSY}) and fishing mortality (F_{MSY}) that will provide MSY. While $_{MSY}$ has traditionally been considered a target fishing at F_{MSY} will mean that 50% of the time biomass will be below B_{MSY} and so F_{MSY} can also be thought of as a limit. Advice in order to achieve MSY is provided in the form of the Kobe II strategy matrix (K2SM), where the probability of being above B_{MSY} and below F_{MSY} is summarized for different catch levels (or other management options) by year.

In order to develop a management framework based on best science KOBE III recommended:

(1) *Emphasizing the potential of the Kobe II Strategy Matrix (K2SM) to communicate efficiently among all stakeholders and to assist in the decision-making process according to different levels of risk, but also recognizing that substantial uncertainties still remain in the assessments, Kobe III participants recommended that the Scientific Committees and Bodies of the tRFMOs develop research activities to better quantify the uncertainty and understand how this uncertainty is reflected in the risk assessment inherent in the K2SM.*

(2) *Recognizing that a Management Strategy Evaluation (MSE) process needs to be widely implemented in the tRFMOs in the line of implementing a precautionary approach for tuna fisheries management, it is recommended that a Joint MSE Technical Working Group be created and that this Joint Working Group work electronically, in the first instance, in order to minimize the cost of its work.*

The Commission has recommended that a statement is included describing the robustness and uncertainty of the models and assumptions on which the K2SM is based. Stock assessment groups routinely run several stock assessment programmes when assessing a single stock and consider different options when running these programmes. Selected runs are then used to construct the K2SM. While there is a need to better quantify the uncertainty and understand how this uncertainty is reflected in the risk assessment inherent in the K2SM and MSE is an important tool for doing this. However, MSE is a complex and time consuming process and there is a need for simpler methods that can be used to quantify risk and uncertainty. Therefore in this study we show how elasticity analysis can be used to evaluate the relative importance of uncertainty, we do this for the biological processes in age based dynamics.

The K2SM for yellowfin was based on a virtual population analysis (VPA) and a biomass dynamic assessment model. In this study we evaluate the importance of the biological assumptions of the VPA.

In the yellowfin assessment the biological assumptions with the virtual population analysis (VPA) assumed that there was no model uncertainty and alternative runs were limited to assumptions about catch and effort. Therefore in this study we evaluate the relative importance of the assumed biological parameters for advice using an elasticity analysis. An elasticity analysis differs from a sensitivities analysis. In the latter measures absolute change while the former measures relative change.

2. Elasticity

Elasticity is an important tool in economics and population ecology; it measures the relative change of a dependent variable with respect to change in an independent variable. In this study we calculate the elasticities of the ratios of SSB to B_{MSY} and fishing mortality to F_{MSY} with respect to the assumed biological parameters.

Often the absolute value operator is used for simplicity although the elasticity can also be defined without the absolute value operator when the direction of change is important, e.g. to evaluate if a reduction in natural mortality increases or decreases MSY reference points,

The elasticities are calculated for every level of F used in the projections and therefore show how the current state of the stock and exploitation rate affect the relative importance of the different life history parameters, i.e.,where the most important source of uncertainty is.

3. Materials and Methods

The analysis was based on the biological assumptions made for the virtual population analysis (VPA)conduct for the 2011 assessment i.e.,

- Plus group ages 5 and older
- Natural mortality was assumed to be age-dependent with ages 0 and 1 = 0.8 and 0.6 for ages greater and equal to 2.
- Spawning Reproductive Potential Maturity was assumed to be knife-edged, with 100% of fish being mature at age 3 and older and SRP was calculated as the product of maturity and weight-at-age at the peak of the spawning season.
- Growth was based upon the two-stanza growth curve of Gascuel and parameters for condition factor and the allometric scaling factor,
    - $L_t = L_\infty (1 - \exp(-k(t - t_0))$
    -

where K is the rate at which the rate of growth in length declines as length approaches the asymptotic length L_∞ and t_0 is the time at which an individual is of zero length.

- Length is converted to mass using the condition factor, and an allometric growth coefficient, b.
- Stock recruitment was modeled by a Beverton and Holt stock recruitment relationship reformulated in terms of steepness (h), virgin biomass (v) and $S/R_{F=0}$, where steepness is the ratio of recruitment at 20% of virgin biomass to virgin recruitment (R_0). Steepness is difficult to estimate from stock assessment data sets and there is often insufficient range in biomass levels that is required for its estimation. Steepness and virgin biomass were set to 0.9 and 1000 t respectively.
- Selection pattern The selection pattern was a long-term average derived from the VPA results

4. Results

Using the relationships described above we generate a fully specified age-structured stock. The stock is projected forward through time at different levels of constant fishing pressure ranging from no fishing (F =0) to over exploited The management measures of interest are the equilibrium SSB relative to B_{MSY} and fishing mortality relative to F_{MSY})

The assumed mass, natural mortality, proportion mature and selection pattern-at-age are **Figure 1.** The equilibrium (i.e., expected) values of SSB and yield verses fishing mortality and recruitment and yield verses SSB are plotted in **Figure 2;** points correspond to MSY. The simulated values of SSB relative to B_{MSY} and F relative to F_{MSY} are shown in **Figure 3.**

Plots of elasticities are shown in **Figures 4** and **5**, these show SSB relative to B_{MSY} and F relative to F_{MSY} for the biological parameters by process, (note the y-axis all have different scales). For SSB relative to B_{MSY} the parameter that has the biggest effect is M2 (i.e., the natural mortality of fish 1). The next most important parameter is steepness, which changes sign as the stock increases, i.e., for a depleted stock reducing steepness results in an increase in the stock relative to B_{MSY}. However the difference between the relative important of M2 and steepness is 3 orders of magnitude. All other parameters have only a small effect. Similar effects were seen for F relative to F_{MSY}.

5. Discussion and Conclusions

Elasticity analysis is a useful tool for evaluating the relative importance of the model assumptions and parameters. It is relatively quick and simple method compared to other ways of evaluating uncertainty. This means that it can be done be conducting as part of a stock assessment to identify scenarios to run that capture the important sources of uncertainty within an assessment.

It was shown that the most important parameter was the natural mortality of mature fish; this was 3 orders of magnitude more important than the steepness of the stock recruitment relationship. The relative importance of

SSB relative to B_{MSY} changed in magnitude and sign i.e. for a depleted stock reducing steepness results in an increase in the stock relative to B_{MSY}. For F relative to F_{MSY} elasticities were independent of F.

The elasticity analysis has identified that yellowfin management advice based on age is sensitive to the assumed value of natural mortality of fish age 2 and older; the elasticity being 3 orders of magnitude greater than for steepness. Although in the stock assessment the parameters for M are assumed fixed, i.e. they do not vary over time, either randomly or following a trend. The effect of both forms of variation needs to be evaluated.

The values of M used in the yellowfin assessment are assumed to decline with age (Fonteneau 2005; Labelle 2003) and different functional forms have been proposed based on different assumptions and other authors indicate that it may be more realistic to consider a U-shaped or bath tub mortality vector due to M increasing as individuals age (Hampton 2000). An elasticity analysis could be conducted with the relationship of Gislason to identify for example is it more important to know how M changes with age or what the mean level of M is. Comparing different functional forms requires an appropriate sensitivity analysis.

If it is not possible to provide appropriate estimates of M then an alternative is to provide robust advice that does not depend upon assuming that M is known without error, for example, using a biomass dynamic model. However, in biomass dynamic models the population growth rate and the shape of the production function becomes the key parameters, which are often difficult to estimate and so priors are developed for them using aged based assumptions about M, growth and maturity.

Management strategy evaluation (MSE) can be conducted to choose estimation methods, reference points and harvest control rules that are robust to uncertainty about M. However conducting MSE is a time consuming and complex process. In contrast elasticity analysis is relatively quick and simple and can be used as a screening process to identify scenarios for simulation testing.

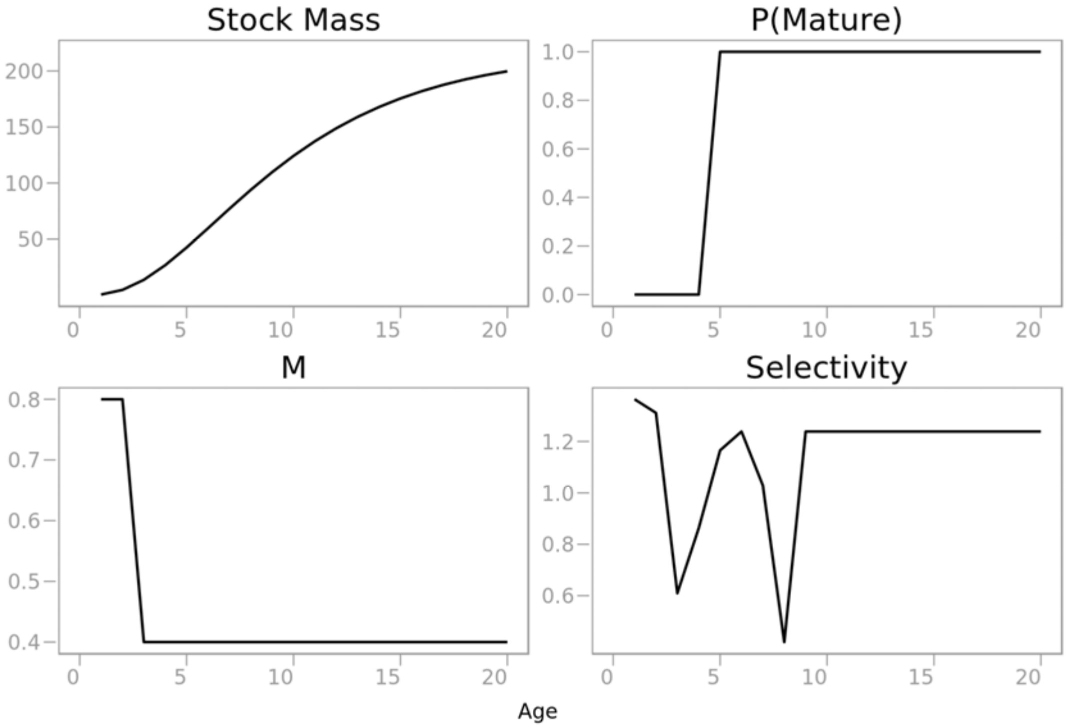

Figure 1. Mass, natural mortality, proportion mature and selection pattern-at-age.

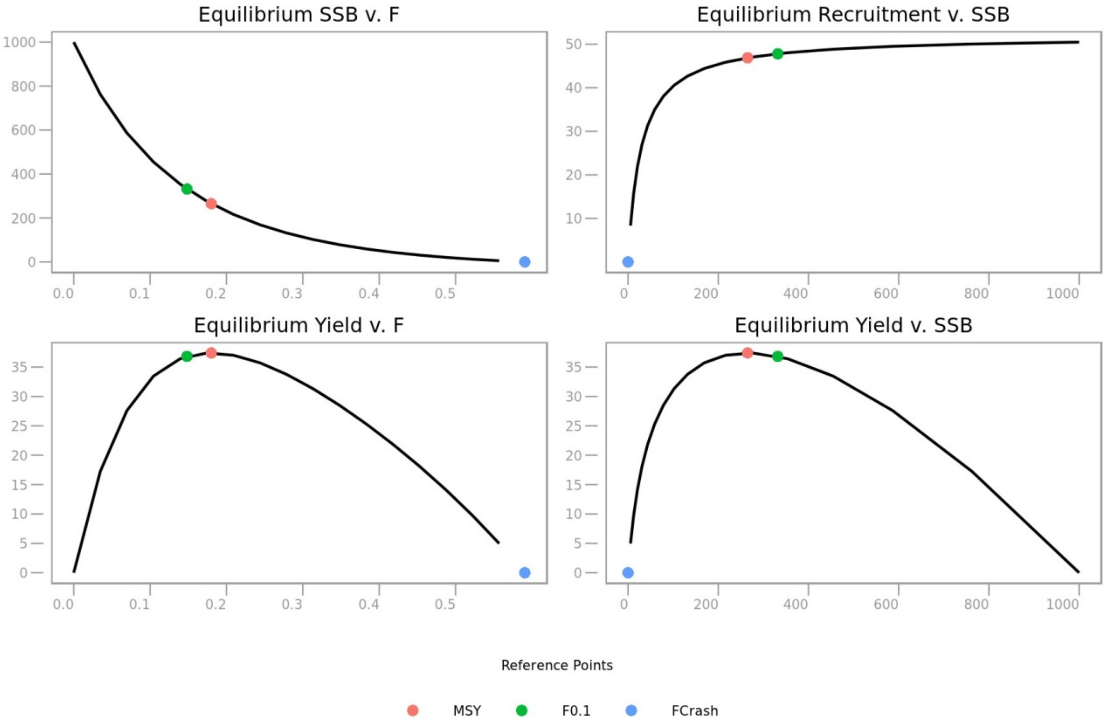

Figure 2: Equilibrium (i.e. expected) values of SSB and yield verses fishing mortality and recruitment and yield verses SSB; points correspond to MSY, F0.1 and F_{crash} reference points.

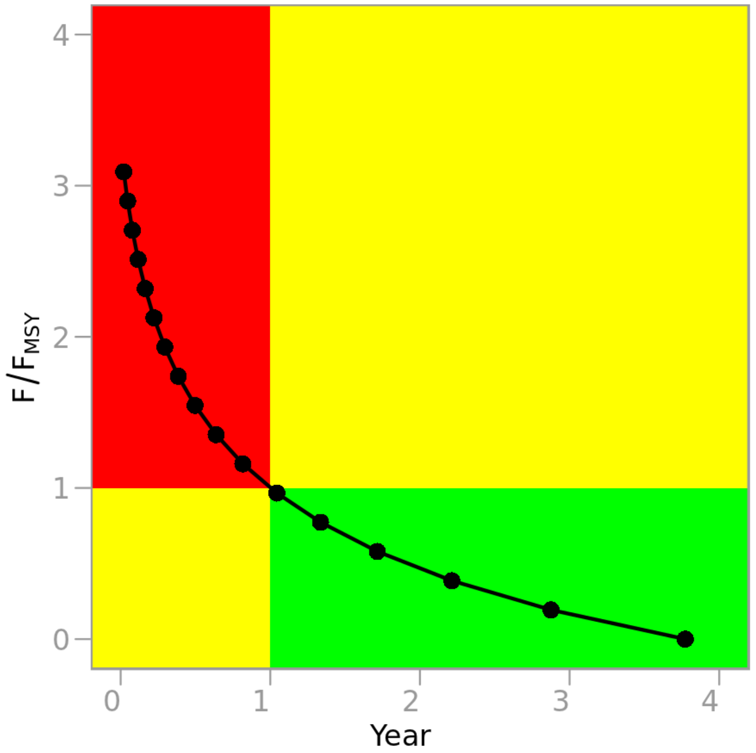

Figure 3. SSB and F relative to MSY reference points for the simulated equilibrium values**.**

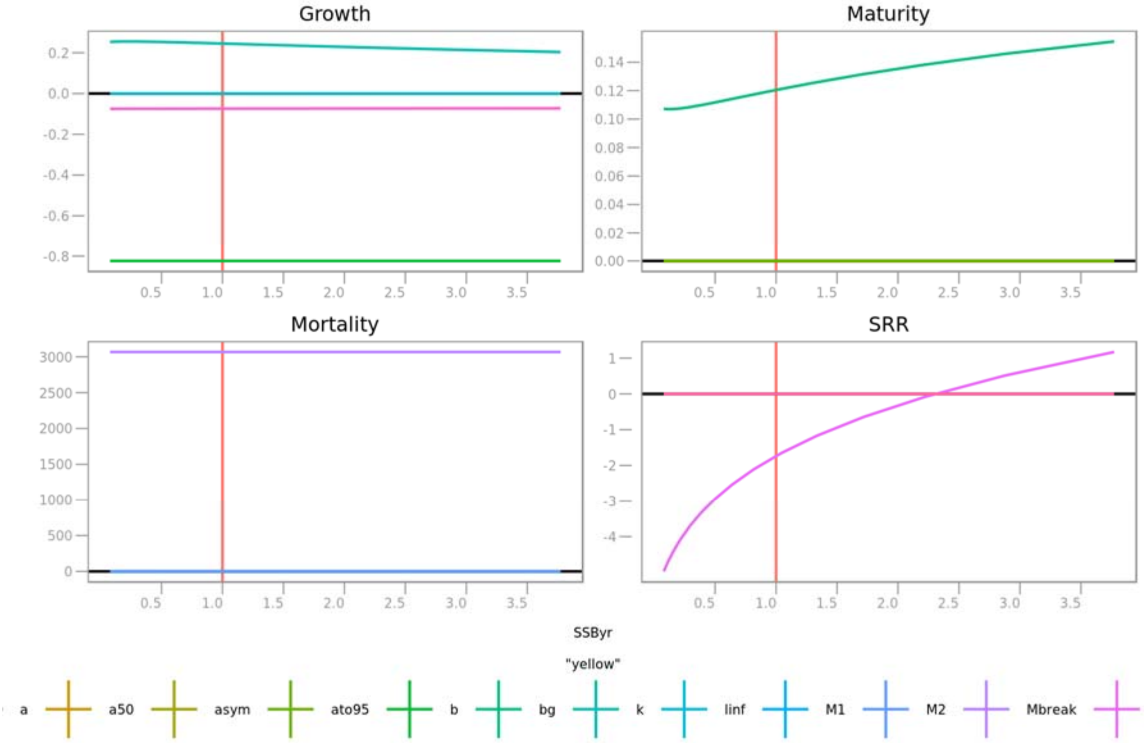

Figure 4. Plots of elasticities of SSB relative to B_{MSY}.

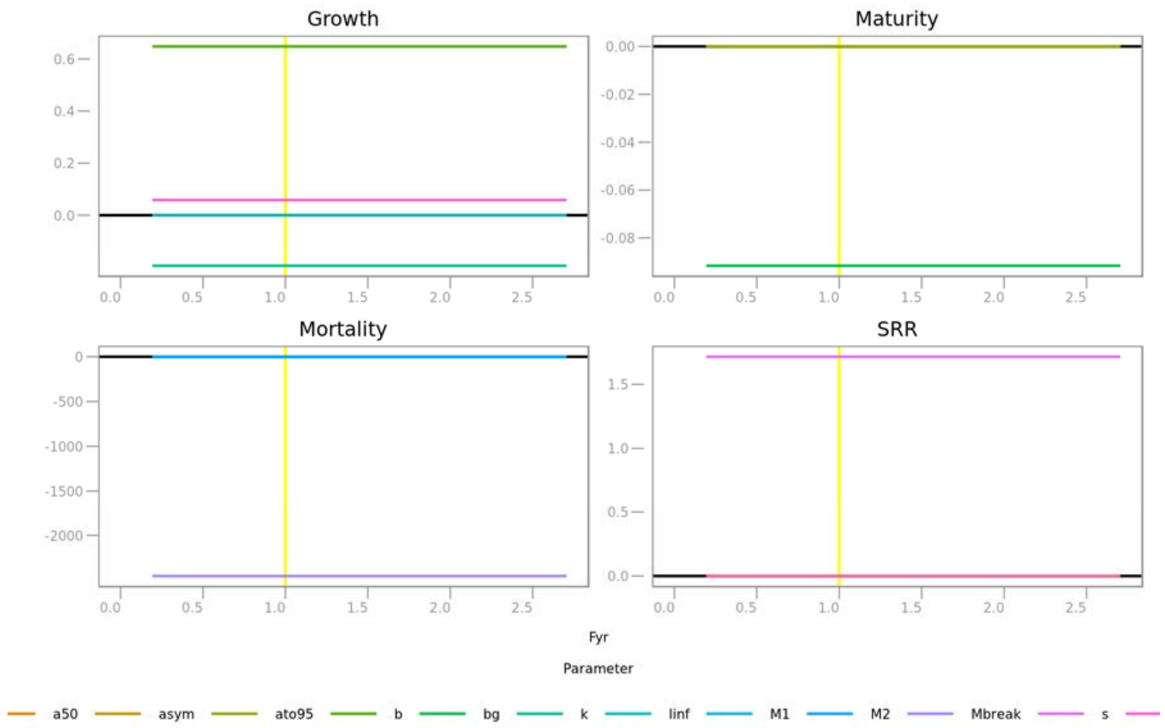

Figure 5. Plots of elasticities of F relative to F_{MSY}.