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A PROPOSAL FOR A BIOMASS LIMIT REFERENCE POINT (B_{LIM}) FOR THE MSE FOR ATLANTIC BLUEFIN TUNA

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SUMMARY

B_{LIM}, or the biomass limit reference point, is usually defined as the stock size below which recruitment has a high likelihood of being impaired. LRPs can either be active triggers for reductions in fishing mortality, even to the extent of closing the fishery (F=0), or passive statistics. Given the nature of ABFT and the empirical form of the CMPs, we propose B_{LIM} as a passive performance statistic to evaluate CMP performance. We propose a B_{LIM} of 40% of dynamic SSB_{MSY} for the purposes of the ABFT MSE for CMP testing and performance tuning. This is calculated as the lowest depletion (spawning biomass relative to dynamic SSB_{MSY}) over years 11-30 of the first 30 years for which CMP is applied, as evaluated across the plausibility weighted Operating Models of the grid. Such a B_{LIM} reflects the individual production dynamics of each OM, reflects temporal variability in production dynamics, and provides the best representation of the potential consequences of stocks falling below it. Such a B_{LIM} is consistent with Panel 2 decisions for Northern Albacore and approaches in other RFMOs.

RÉSUMÉ

B_{lim}, ou le point de référence limite de la biomasse, est généralement défini comme la taille du stock en dessous de laquelle le recrutement a une forte probabilité d'être altéré. Les LRP peuvent être soit des déclencheurs actifs de réduction de la mortalité par pêche, allant jusqu'à la fermeture de la pêche (F=0), soit des statistiques passives. Compte tenu de la nature du thon rouge de l'Atlantique et la forme empirique des CMP, nous proposons la B_{lim} comme statistique passive pour évaluer la performance des CMP. Nous proposons un B_{lim} de 40% de la SSB_{PME} dynamique aux fins de la MSE pour le thon rouge de l'Atlantique pour les tests et le calibrage des performances des CMP. Cette valeur est calculée comme étant l'épuisement le plus faible (biomasse reproductrice par rapport à la SSB_{PME} dynamique) au cours des années 11 à 30 pendant lesquelles la CMP est appliquée, évaluée dans tous les modèles opérationnels de la grille pondérés par la plausibilité. Cette B_{lim} reflète la dynamique de production individuelle de chaque OM, reflète la variabilité temporelle de la dynamique de production et fournit la meilleure représentation des conséquences potentielles de la chute des stocks en dessous de ce niveau. Cette B_{lim} est conforme aux décisions de la Sous-commission 2 pour le stock de germon du Nord, le stock d'espadon du Nord et les approches d'autres ORGP.

RESUMEN

B_{LIM}, o punto de referencia límite de la biomasa, suele definirse como el tamaño del stock por debajo del cual el reclutamiento tiene una alta probabilidad de verse afectado. Los PRL pueden ser desencadenantes activos de reducciones de la mortalidad por pesca, incluso hasta el punto de cerrar la pesquería (F=0), o estadísticas pasivas. Dada la naturaleza del atún rojo del Atlántico y la forma empírica de los CMP, proponemos B_{LIM} como estadística de desempeño pasiva para evaluar el desempeño de los CMP. Proponemos una B_{LIM} del 40 % de la SSB_{RMS} dinámica a efectos de la MSE para el atún rojo del Atlántico para las pruebas de CMP y de la calibración del desempeño. Se calcula como la merma más baja (biomasa reproductora con respecto a SSB_{RMS} dinámica) durante los años 11-30 de los primeros 30 años para los que se aplica el CMP, evaluado mediante la ponderación de la plausibilidad de los modelos operativos de la matriz. B_{LIM} refleja la dinámica de producción individual de cada OM, refleja la variabilidad temporal de la dinámica de producción y proporciona la mejor representación de

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las consecuencias potenciales de que los stocks caigan por debajo de dicho nivel. B_{LIM} es coherente con las decisiones de la Subcomisión 2 para el atún blanco del norte y los enfoques de otras OROP.

KEYWORDS

Atlantic Bluefin Tuna, Management Strategy Evaluation, biomass limit reference point

Introduction

Biomass limit reference points provide lower bounds on stock biomass to which a management body would want a high probability of avoiding. B_{LIM} or the biomass limit reference point is usually taken as the stock size below which recruitment and yield has a high likelihood of being impaired. Fishery management strategies should then ensure that the risk of falling below biomass limit reference points is very low. Operational management objectives for Atlantic Bluefin tuna are in the process of being adopted by the Commission, for which the 'safety' objective states the following: ***"****There should be no more than a 15% chance of the stock falling below B_{LIM} at any point during the 30-year evaluation period. A definition of B_{LIM} should be recommended by SCRS."*

In this paper we propose a B_{LIM}, for the purposes of the current Atlantic Bluefin tuna management strategy evaluation. The translation of the B_{LIM} concept from the traditional best assessment to the MSE paradigm is not straightforward. This is because of the possibility of some Operating Models (OMs) starting the future management period with a biomass below the value being proposed for B_{LIM}, which leads to inappropriate inflation of the probability of the behavior of concern, viz. the resource dropping below this level of biomass. Here a pragmatic and ABFT-specific proposal is made to address this; such an approach would not necessarily prove appropriate for other MSE cases.

Methods

Types of biomass limit reference points

Biomass limit reference points can play several roles in management procedures (Sissenwine, *pers comm.*):

1. Active: Hard trigger in a catch control rule (e.g., Harley *et al.* 2009)
2. Passive: A performance statistic against which to evaluate management performance.

Given the nature of the Atlantic bluefin tuna, use of B_{LIM} as a hard trigger would be difficult, both because of the challenge which assessment models have in estimating biomass reference points, but also because the empirical management procedures being considered do not have a clear basis for evaluating biomass status. Hence, the current ABFT MSE can really use B_{LIM} only as a passive statistic to evaluate and eventually tune CMP performance so as to achieve desired safety objectives. This then clarifies the scope of the intended use of B_{LIM} as a passive performance statistic.

Similarly, Preece *et al.* 2011 outlines a hierarchy for specifying biomass limit reference points starting with:

1. X% estimated maximum sustainable yield, e.g., 30,40% SSB_{MSY}
2. X% Spawning potential ratio (SPR) based proxies for MSY; e.g., 30, 40%SPR
3. X% Fraction of virgin biomass, e.g., 10, 20%.

Preece *et al.* (2011) recommend that (1) or MSY-based reference points be used when estimable, that SPR proxies be used when uncertainty in steepness is high provided that key biological (natural mortality, maturity) and fishery (selectivity) variables are well estimated, and that the third option be used only when only a few of the key determinants of productivity are certain.

In the Atlantic bluefin tuna MSE, the productivity dynamics of each OM are known, and are specified to span the range of biological and fishery uncertainties. In this case, there are unique and known B_{MSY} reference points for each stock within each OM, and hence their use would be preferable to determining whether a CMP meets desired operational management objectives. Furthermore, specification of a common percentage of SSB_{MSY} better reflects the individual production dynamics of each OM than would the use of a common percentage of SSB_0; hence one would certainly prefer to use MSY-based reference points to evaluate CMPs. In a previous paper Walter and

Andonegi (2021) proposed limit reference points based on a fraction of virgin biomass; however, based on the Preece *et al.* (2011) prioritization, such reference points would be sub-optimal for explicit consideration of recruitment limitation within the grid of operation models.

Results

A number of authors have proposed various biomass limit reference points for tunas and tuna like stocks (Merino *et al.* 2016, Nakatasuka *et al.* 2017) and ICCAT panel 2 has defined interim limit reference points for Northern Albacore of 40% SSB_{MSY}. Given the above scope of use of B_{LIM}, and the fact that production dynamics are known for the OMs, we propose a B_{LIM} as defined below:

We propose a B_{LIM} of 40% of dynamic SSB_{MSY} for the purposes of the MSE for CMP testing and performance tuning. This would be calculated as the lowest depletion (spawning biomass relative to dynamic SSB_{MSY}) over years 11-30 for which the CMP is applied across the plausibility weighted operating models.

This is exactly (apart from the omission from consideration of years 1-10) the performance statistic LD (**Figure 1**) and, once evaluated across weighted OMs, the calculated LD statistics are analogous to B_{LIM} and their associated probabilities for not falling below (**Figure 2**). The calculation follows, with the set of all LD values, below:

$$LD = \left\{ \left\{ \min \left\{ \frac{SSB_i}{SSB_{MSY}} \right\}_{i=11}^{30} \right\}_1^j \right\}_1^k$$

Over *i* years 11-30 we get a single minimum SSB_i/SSB_{MSY}, over $j=48$ simulations of one operating model, and $k=48$ operating models this gives a set of 2304 values. Then, a weighted percentile is obtained using the OM plausibility weights using the R function wtd.quantile in the Hmisc package (Harrell 2021). This gives a probability across the weighted OMs of any CMP giving biomass below B_{LIM} in any year of the evaluation period.

The calculation is consistent with the Northern Albacore approach (ICCAT 2021) which has precedent for Panel 2, as probabilities are across the OMs not for every OM. The rationale for calculation over years 11-30 is that a few of OMs (for the western stock only) start the future 30-year management period below 40% of B_{MSY}, with most others well above such a value for B_{LIM}. Hence it would not be particularly meaningful to use these early years to evaluate CMP performance relative to B_{LIM} as SSB levels then are primarily determined by the starting conditions, rather than by CMP performance. For the OMs that start below B_{LIM}, these CMPs would require rebuilding that could reasonably occur only after several years of CMP application. For Atlantic bluefin tuna, it turns out that the first 10 years of management provide a reasonable opportunity for that rebuilding to occur – hence the proposal to consider years 11-30 only in evaluating performance in terms of avoiding the stock dropping below B_{LIM}.

Associated probability

As each value of B_{LIM} could be paired with an associated probability of not falling below that level, the choice of B_{LIM} is linked to its probability (Davies and Harley, 2010). Panel 2 has provided preliminary guidance of not greater than a 15% probability of the stock falling below B_{LIM}. While ICES (2017) and Preece *et al.* (2011) suggest that there should be a very low probability of falling below B_{LIM} (e.g., 5-10%), such low probabilities need to be balanced by practical considerations regarding the modeling and characterization of uncertainty. For Atlantic bluefin tuna, a probability lower than 15% would be more prone to poorly estimated tail behavior and could be unduly influenced by only a few of the OMs.

Conclusions

We propose the same approach for Atlantic bluefin tuna as for Northern albacore of 40% of SSB_{MSY} calculated across all OMs (here for years 11-30) when using dynamic SSB_{MSY} as the denominator. This has the benefit of scaling relative to dynamic SSB_{MSY}, and it uniquely and accurately reflects each OM's productivity dynamics.

The proposed reference point is similar to what is used in IOTC for skipjack and yellowfin tuna (40%SSB_{MSY}), though lower than that for bigeye tuna (50%SSB_{MSY}) (IOTC 2015), but different than in that we are proposing it to be used in a passive rather than active manner. Given the structure of the ABFT OMs with multiple levels of stock recruitment steepness, mortality, maturity, scale and fit to composition data, these OMs cover a range of hypotheses regarding bluefin productivity, spanning from high to low productivity. Hence specifying one common relative measure (40% of SSB_{MSY}) while entertaining diverse scenarios within the OMs, allows the comparison of performance of CMPs across a wide variation in productivity dynamics more appropriately and accurately.

Given the need to provide Panel 2 with a biologically-based B_{LIM} to define the 'safety' operational management objective, 40% of SSB_{MSY} represents a useful and achievable biomass limit reference point for most CMPs. Initial model results shown illustrate both achievement of (for the first two CMPs) and failure to achieve (for the 3rd) the safety criterion at the 15% level (**Figure 2**). Such a scenario could certainly be used as a means to remove lower performing CMPs. Furthermore, as both of upper two CMPs have some probability space to "spare", the process of 'performance' tuning to better achieve multiple objectives could decrease the tuning target to achieve higher yield while still meeting a safety criterion of not more than a 15% probability of falling below 40%SSB_{MSY}. While **Figure 2** shows what are only preliminary results, they illustrate a path forward for use of B_{LIM} as a key operational management objective in the ABFT MSE process.

In this ABFT case we have unique and known SSB_{MSY} reference points for each stock within each OM, and hence these would be preferable to determining whether a CMP meets desired operational management objectives. Furthermore, specification of a common percentage of SSB_{MSY} better reflects the individual production dynamics of each OM than the use of a common percent of SSB_0.

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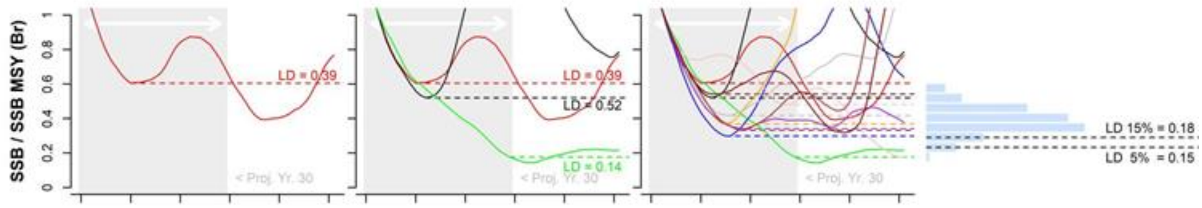

Figure 1. Visual descriptions of the calculation of B_{LIM} performance statistic illustrating one simulation (first column), three simulations (second column) and multiple simulations (3rd column) for one OM and one CMP. B_{LIM} is defined in relation to the performance statistic LD or Lowest depletion (i.e., SSB relative to dynamic SSB_{MSY}) over 30-year projection period. This figure shows LD for years 1-30 though we propose using years 11-30 only for B_{LIM} calculations for reasons explained in the text. LD is calculated as a weighted average across all OMs in the grid.

West	Br30 target	VarC (median)	AvC10 (median)	AvC30 (median)	LD (5th percentile)	LD (15th percentile)
CMP1	1.25	13.79	3.09	2.87	0.22	0.43
CMP2	1.25	11.36	2.05	2.21	0.26	0.48
CMP3	1.25	15.97	2.96	2.53	0.02	0.25
East	**Br30 target**	**VarC (median)**	**AvC10 (median)**	**AvC30 (median)**	**LD (5th percentile)**	**LD (15th percentile)**
CMP1	1.50	16.72	39.06	37.65	0.30	0.55
CMP2	1.50	11.41	34.74	28.50	0.33	0.52
CMP3	1.50	13.95	41.48	30.29	0.07	0.29

Figure 2. 'Quilt' plot for summarizing performance of candidate management procedures from development tuning. All CMPs are tuned to meet the same median Br30 value to elucidate relative performance across other statistics. This 'levels' the field to facilitate evaluating choices amongst top performing CMPs. Six key performance statistics are shown, which are defined above. The absolute value of the statistic is shown and the CMPs are ranked and color coded within a column. The colors are simply for visual representation of best (green) to worst (red) within a column. The right two columns illustrate the use of LD as B_{LIM}. Here the top two CMPs meet the B_{LIM} (40% dynamic SSB_{MSY}) criterion at the 15% level. In other words, two exhibit no greater than 15% chance of falling below B_{LIM} during the time period across the plausibility weighted average of the Operating Models. The 15th percentile for CMP3 is below the proposed B_{LIM} indicating a higher probability of the population falling below B_{LIM} during the time period and failure to meet a possible 'safety' threshold. Note that this figure uses preliminary results and is the same as the figure shown in the Ambassador materials.