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CHARACTERIZATION OF STRUCTURAL UNCERTAINTY IN TROPICAL TUNA STOCKS' DYNAMICS

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SUMMARY

The MSE for the Atlantic tropical tuna stocks started in 2018 by developing a proposal on how to conduct this MSE in a series of phases. The present document aims at starting the second phase of the tropical tuna MSE by reviewing the main sources of uncertainty in the dynamics of tropical tuna fish and fisheries, including the uncertainty in the biological parameters of fish stocks, fishery exploitation patterns and information content of the data used in stock assessments. We will summarize the axes of uncertainty considered in the recent stock assessments of tropical tunas in ICCAT and other tuna RFMOs. It is expected that this document will facilitate discussions in the next dedicated Tropical Tuna MSE Technical Group meeting.

RÉSUMÉ

La MSE pour les stocks de thonidés tropicaux de l'Atlantique a débuté en 2018 par l'élaboration d'une proposition sur la manière de mener cette MSE en plusieurs phases. Le présent document vise à entamer la deuxième phase de la MSE pour les thonidés tropicaux en examinant les principales sources d'incertitude dans la dynamique des thonidés tropicaux et des pêcheries, y compris l'incertitude dans les paramètres biologiques des stocks de poissons, les modèles d'exploitation des pêcheries et le contenu informatif des données utilisées dans les évaluations des stocks. Les axes d'incertitude considérés dans les récentes évaluations des stocks de thonidés tropicaux de l'ICCAT et d'autres ORGP thonières sont résumés. Il est prévu que ce document facilite les discussions lors de la prochaine réunion du Groupe technique dédié à la MSE consacrée aux thonidés tropicaux.

RESUMEN

La MSE para los stocks de túnidos tropicales del Atlántico comenzó en 2018 desarrollando una propuesta sobre cómo llevar a cabo esta MSE en una serie de fases. El presente documento tiene como objetivo iniciar la segunda fase de la MSE para los túnidos tropicales revisando las principales fuentes de incertidumbre en la dinámica de los túnidos tropicales y en las pesquerías, incluyendo la incertidumbre en los parámetros biológicos de los stocks de peces, los patrones de explotación de las pesquerías y el contenido de información de los datos utilizados en las evaluaciones de stocks. Resumiremos los ejes de incertidumbre considerados en las recientes evaluaciones de stocks de túnidos tropicales en ICCAT y otras OROP de túnidos. Está previsto que este documento facilitará las discusiones en la próxima reunión del Grupo técnico sobre la MSE para los túnidos tropicales.

KEYWORDS

Management Strategy Evaluation, Operating Models, Uncertainty, tropical tunas, bigeye, yellowfin, skipjack

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1. Introduction

A model can never describe a system with certainty (Strong and Oakley, 2014), and thus, fish stock assessments are subject to uncertainty. When making predictions with computer models as done in fishery stock assessments, two types of uncertainties are encountered: structural uncertainty and statistical uncertainty (Matthies, 2007). *Structural uncertainty* is the result of *model uncertainty* and *input uncertainty*. *Model uncertainty* refers to uncertainty in the true relationship between inputs and outputs within a stock assessment model and is often characterized by using alternative models based on distinct principles (Strong and Oakley, 2014). *Input uncertainty* arises when there is no certainty about the input parameters or the quality of information. In fisheries science, it is attributed to the lack of knowledge about key biological processes and to inaccurate or incomplete data sources. This uncertainty is often characterized by developing alternative model configurations by using different model inputs (parameters and data), using ranges of values, weighting data streams etc.

In MSE, *structural uncertainty* is the basis for the developing axes of uncertainty and for conditioning Operating Models, which are plausible mathematical representations of the system being managed, including the biological components (fish stock dynamics) and the fishery which operates on the stock (Punt *et al.*, 2014a). In ICCAT's tropical tuna stock assessments *structural uncertainty* is characterized by combining alternative model results (*model uncertainty*) and different model configurations (*input uncertainty*). It is expected that the range of uncertainties considered in the MSE will go beyond the axes used for stock assessment. In this document we provide an overview of potential options for axes of uncertainty for the Atlantic tropical tunas MSE from the factors used to characterize the *structural uncertainty* in the stock assessments of ICCAT and other RFMOs.

This document has been developed using information from the tropical tuna stock assessments in ICCAT and elsewhere. We have used stock assessment meeting reports, SCRS (or other science providers') plenary reports and stock assessment model files.

2. Structural uncertainty in tropical tuna stocks'

2.1 Atlantic stocks' assessments

The stock assessments' uncertainty grids are a useful starting point for considering the range of uncertainty that should be included in the suite of OMs for the MSE analyses (Scott *et al.*, 2018). The latest stock assessments of Atlantic tropical tuna stocks were held in 2014 (skipjack), 2018 (bigeye) and 2019 (yellowfin). For skipjack, a number of stock assessment models were attempted but the increasing landings and increasing or stable CPUEs created a dynamic situation that made it very difficult for production models to reliably estimate recent stock trends and reference points (ICCAT, 2014). Thus, there is no axis of uncertainty defined for skipjack. However, as part of the phase 1 of the tropical tuna MSE project a prototype of Stock Synthesis model was developed (Harford W.J. *et al.*, 2018), which could potentially be used to condition Operating Models for the MSE.

For bigeye, one single stock assessment model was used to provide stock status and reference points' estimates (Stock Synthesis, (Methot Jr and Wetzel, 2013)). The characterization of structural uncertainty for bigeye consisted in the configuration of alternative models for Stock Synthesis. The final uncertainty grid consisted of 18 models developed using two alternative natural mortality vectors (base and high), three options for annual variability in recruitment (sigmaR: 0.2, 0.4 and 0.6) and three steepness values (0.7, 0.8, 0.9), (**Table 1**).

For yellowfin, the advice was built upon nine model runs developed from three different stock assessment models *(model uncertainty)*. 50% of the weight of the advice was given to biomass dynamic models (*JABBA* (Winker *et al.*, 2018*)* and *mpb* (Kell, 2016)) and 50% to the runs made with Stock Synthesis. For JABBA and Stock Synthesis two options for the CPUEs were used (1: Joint LL CPUE (Hoyle *et al.*, 2019) & EU Purse seine free school (Guéry L. *et al.*, 2019), and 2: Idem 1 + Buoy Abundance Index (Santiago *et al.*, 2019)). For JABBA, two options for the prior for the intrinsic growth rate *(r)* were used (based on Stock Synthesis results and based on FishLife). For Stock Synthesis two options for steepness were also contemplated (0.8 and 0.9). The summary of the scenarios used in the yellowfin assessment is provided in **Table 2**.

2.2 Pacific and Indian Ocean stocks' assessments

The stock assessments from other areas can also provide guidance on the ranges of uncertainty considered for tropical tunas in a more general way. The structural uncertainty considered in all RFMOs tropical tuna stock assessments is summarized in **Table 3**. The steepness parameter of the stock recruitment parameter is a common factor of uncertainty in all tropical tuna stocks' assessments. Additional parameters not considered in ICCAT assessments include tag mortality, tag mixing period, selectivity, recruitment regimes, catchability options, tag data overdispersion, effort creep for purse seine, uncertainty on length composition data and regional structure. Some of these factors of uncertainty stem from the use of information from regional tagging programs. In this regard, it seems reasonable to evaluate the potential of data from the Atlantic Ocean Tropical Tuna Tagging Program (AOTTP) in the MSE framework. Once it is incorporated the uncertainty on tagging data will be evaluated using different options. Also, tagging data provide information on the movement of fish stocks across oceanic regions. At this moment, the assessment of ICCAT tropical tuna stocks do not consider movement between regions and the inclusion of AOTTP data would support the exploration of explicitly modelling fish movement and the definition of regions. The other options could also be potentially included in the MSE, and possibly in the stock assessment grids too.

2.3 Western Central Pacific skipjack and Indian Ocean bigeye and yellowfin MSEs

The most advanced tropical tuna MSEs so far are the WCPFC skipjack and IOTC bigeye and yellowfin frameworks (Kolody, 2020a, Scott *et al.*, 2018, Kolody, 2020b). The three MSEs are developed from the structural uncertainty grids from their respective assessments by expanding options of parameters and data.

2.3.1. Bigeye IOTC

Starting from the grid of six models of the assessment, the uncertainty grid (Table 4) is expanded with options for natural mortality (seeking for values lower than those used in the assessment), catchability trends for the joint longline CPUE, method for scaling of the joint longline CPUE across regions (Hoyle *et al.*, 2018), size composition data (ESS=Effective sample size), and selectivity for longline fleets across areas. The total grid of Reference OMs accounts for 432 model options. Also, options for Robustness OMs have been preliminary evaluated, which include options for autocorrelation on CPUE, overcatch, implementation errors, additional catchability trend (3%) and one poor recruitment scenario (8 consecutive quarters of with recruitment being 55% of expected values in the early 2000s) (Kolody, 2020a).

2.3.2 Yellowfin IOTC

Starting from the grid of twenty four models of the assessment, the uncertainty grid (Table 5) is expanded with options for the spatial structure (two options), natural mortality scaling factors (also seeking for lower values), growth (2 equations), catchability trends for the joint longline CPUE, method for scaling of the joint longline CPUE across regions (Hoyle *et al.*, 2018), longline CPUE error assumption (two options), longline CPUE regional scaling factors (2 options) and tag mixing period (2 options). The total grid of OMs accounts for 3,456 model options, which then were reduced following plausibility criteria (Kolody, 2020b). Also, options for Robustness OMs have been designed (but not evaluated yet), which include options for autocorrelation on CPUE, overcatch, implementation errors, additional catchability trend (3%), one poor recruitment scenario (8 consecutive quarters of with recruitment being 55% of expected values in the early 2000s), and hyperdepletion for longline CPUE (Kolody, 2020b).

2.3.3 Skipjack WCPFC

The reference set of OMs for WCPFC skipjack (**Table 5**) is also built from the accepted stock assessment structural uncertainty grid (Scott *et al.*, 2018). The Reference OM grid accounts for 72 models with options for recruitment variability (2 options), catch and effort observation error (2 options), steepness (3 options), mixing period (2 options) and tag overdispersion (3 options). The Robustness test scenarios also include options for size composition data weighting, tag recapture options, environmentally driven movement (following ENSO oscillations), negative catchability trends and effort creep scenarios.

3. Defining axes of uncertainty for conditioning Operating Models

Operating Models are representations of the "true" dynamics of fish and fisheries, and must account for the major sources of uncertainties in the system (Punt *et al.*, 2014b). In this document we review the sources of uncertainty accounted for in the assessments and MSEs of tropical tunas in ICCAT and other tuna RFMOs. This review aims to facilitate the definition of the axes of uncertainty as a first step towards conditioning OMs for the Atlantic tropical tuna MSE. The grids shown in this document will be further discussed in the *intersessional meeting of the tropical tuna MSE technical group* (29-31 March 2021).

Using stock assessment model grids is only one option for developing uncertainty and OMs in MSE. This option is the path followed in many MSEs. For example, for Indian Ocean yellowfin, bigeye, swordfish and albacore, Western Pacific skipjack (and early development of other tropical stocks) and Pacific albacore, North Atlantic albacore and swordfish MSEs. In other cases, for example Atlantic bluefin, southern bluefin and Indian Ocean skipjack, one ad-hoc population dynamics model has been specifically built to condition OMs.

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Table 1. Natural mortality at age, steepness and sigmaR options included in the structural uncertainty grid of Atlantic bigeye (ICCAT, 2018).

Natural mortality options		Steepness options			SigmaR options		
Ma (ref)	Ma (alt)	0.7	0.8	0.9	0.2	0.4	0.6
0.727	0.909						
0.456	0.57						
0.358	0.447						
0.308	0.385						
0.279	0.348						
0.26	0.325						
0.248	0.31						
0.239	0.299						
0.233	0.291						
0.228	0.286						
0.221	0.276						

Table 2. Model runs used to characterize structural uncertainty in Atlantic yellowfin stock assessment (ICCAT, 2019).

CPUE options (SS3 & JABBA)		***Steepness options (SS3)***		***r prior (JABBA)***		***mpb***
Joint LL + EU PS FS	Joint LL + BAI	0.8	0.9	SS3	FishLife	Base case

		ICCAT		IOTC			WCPFC			IATTC	
		A-BET	**A-YFT**	**IO-BET**	**IO-YFT**	**IO-SKJ**	**P-BET**	**P-SKJ**	**P-YFT**	**EPO-BET**	**EPO-YFT**
Model	Software	1	3	1	1	1	1	1	1	1	1
Parameters	*Intrinsic growth*	-	2	-	-	-	-	-	-	-	-
	Steepness	3	2	3	3	3	3	3	3	4	4
	Growth	1	1	1	1	1	2	3	1	2	2
	sigmaR	3	1	1	1	1	1	1	1	1	1
	Natural mortality	2	1	1	1	1	1	1	1	2	1
	tag mortality	1	1	1	2	1	1	1	1	1	1
	tag mixing period	1	1	1	1	1	1	2	2	1	1
	Selectivity	1	1	1	1	1	1	1	1	2	2
	Recruitment regime	1	1	1	1	1	1	1	1	2	1
	Catchability	1	1	1	1	1	1	1	1	1	3
	tag data overdispersion	1	1	1	1	1	2	1	2	1	1
	effort creep for PS	1	1	1	1	2	1	1	1	1	1
	Length composition scalar	1	1	1	1	1	1	2	1	1	1
	Region structure	1	1	1	1	2	1	2	1	1	1
Data	*weight size data*	1	1	1	1	1	3	1	3	2	1
	weight tagging	1	1	2	2	2	1	1	1	1	1
	weight CPUE	1	2	1	2	1	1	1	1	2	1
	regional structure	1	1	1	1	1	2	1	2	1	1
Total		**18**	**9**	**6**	**24**	**24**	**72**	**108**	**72**	**44**	**48**

Table 4. Reference grid of Operating Models for Indian Ocean bigeye.

M scaling factors	1
	0.8
	0.6
Steepness options	0.7
	0.8
	0.9
Tagging data weight	0.0001
	0.1
	1
q trends	0
	1% year
Regional scaling factor	HBF
	Cluster
Size composition ESS	ess10
	Reweighted
Selectivity	Logistic
	Logistic for one area and double normal for others

Table 5. Reference grid of Operating Models for Indian Ocean yellowfin.

Spatial structure	4 regions
	2 regions
M scaling factors	1
	ICCAT yellowfin
	WCPFC yellowfin
Steepness options	0.7
	0.8
	0.9
Tagging data weight	0.0001
	0.1
	1
Growth curve	Dortel *et al.* (2015) - model2
	Dortel *et al.* (2015) - model3
q trends	0
	1% year
Regional scaling factor	HBF
	Cluster
Longline CPUE error assumption	0.3
	0.1
Longline COYE regional scaling factors	reference case
	alternate method
Tag mixing period	4 quarters
	8 quarters

Table 6. Reference grid of Operating Models for Western Pacific skipjack.

Recruitment variability	4 regions
	2 regions
Catch and effort observation error	20%
	30%
Steepness options	0.65
	0.8
	0.95
Mixing period	1
	2
Tag overdispersion	2.5
	4
	8

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