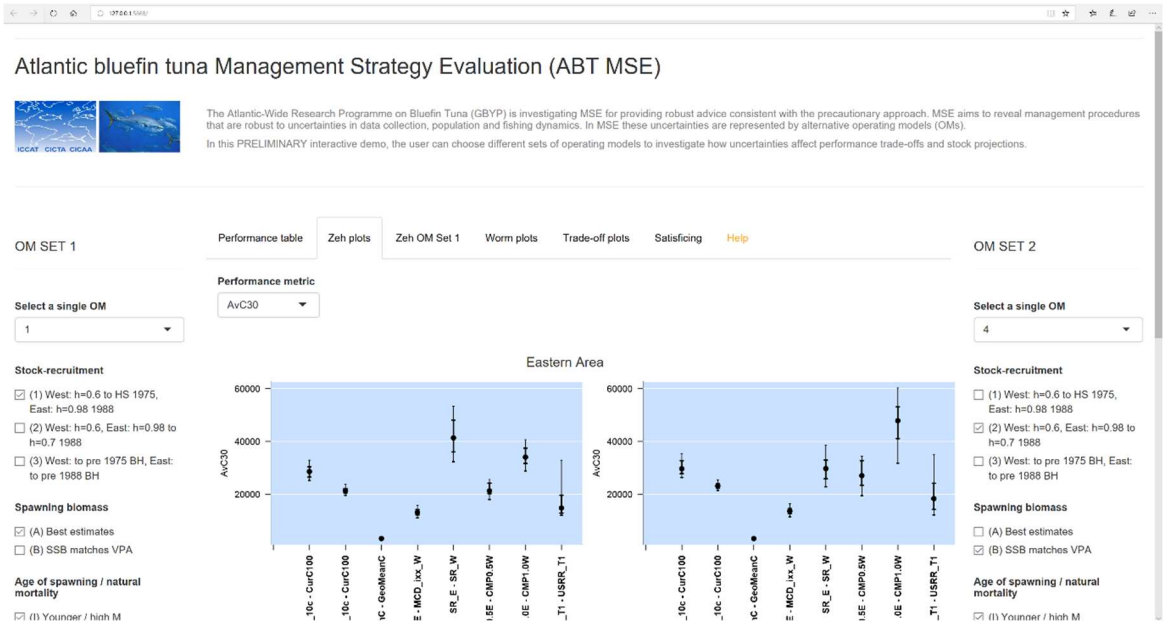
Evaluating Management Strategies for Atlantic Bluefin Tuna

Report 6: Updated operating model, MSE package, CMPs.

February 19th 2019

SHORT-TERM CONTRACT FOR MODELLING APPROACHES: SUPPORT TO BFT ASSESSMENT (GBYP 07/2018) OF THE ATLANTIC-WIDE RESEARCH PROGRAMME ON BLUEFIN TUNA (ICCAT-GBYP – Phase 8)



Preliminary Shiny App, Sept 2018

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Executive Summary

The focus of this contract was to take the first fully documented MSE framework (ABT-MSE v2.3.0) and refine it to account for feedback from the April 2018 swordfish and bluefin tuna MSE meeting and the September 2018 bluefin working group meeting.

Tasks

- Refine the software package following feedback from users at the 2018 ICCAT Bluefin Tuna and North Atlantic Swordfish MSE Meeting. Operating models have been updated considerably to include, for example, multiple phases of recruitment estimation and time-varying future movement (now version v4.4.5).
- Maintain the meta-data base. This has been updated to v3.0 (February 2019)
- Continue to develop help-documentation and tutorials to assist stakeholders in CMP development. A dedicated CMP developers guide is now available.
- Work with stakeholders to assist them to develop CMPs, and also the Contractor himself is to develop a CMP. A multi-stock mixing CMP, 'MPx' was presented to the group and is included in the latest R package (Carruthers 2018, Appendix 1). In the September 2018 and February 2019 meetings, more than 30 CMPs were integrated into the R package.
- Produce MSE visualization tools such as a revised Shiny App and Bayesian Belief network. Reference set operating models were not finalized during this contract and visualization tools could therefore not be updated. However, computer code was written to largely automate this process given an agreed set of operating models.
- Produce a scientific manuscript on a multi-stock management procedure to be presented as scientific communication to the ICCAT SCRS Species Groups 2018 meeting (as above the development of 'MPx', Carruthers 2018, Appendix 1).
- Produce a scientific manuscript on 'Strategies and Tactics in the Campaign for Sustainability of Atlantic Bluefin Tuna to be presented as scientific communication to ICCAT SCRS Species Groups 2018 meeting. Although the scope of the paper and tentative authorship has been proposed, without an agreed set of operating models it was not possible to finalize the methods or obtain results. However, with the exception of the data-rich VPA MP all MPs of this paper (Table 1 of the linked Google document) are now coded and available for testing once the reference operating models are finalized.
- Assist in documenting the deliberations of meetings taking this MSE process forward in a manner that records developments in some detail. The latest Trial Specifications document (Appendix 2) has expanded considerably in scope to include comprehensive detail on all operating model aspects and now includes version numbering to record the evolution of decisions regarding operating model structure and assumptions.

Other products

- A mixture modelling approach was developed to more accurately process stock-of-origin data such as otolith microchemistry and genetics data (Carruthers and Butterworth 2018a, Appendix 3).
- A full account of ABT-MSE operating models was submitted (Carruthers & Butterworth 2018b, Appendix 4)
- Following the identification of missing age-0 catches in the Mediterranean, a post-hoc analysis of impact on the Eastern VPA was conducted (Carruthers and Butterworth 2018c, Appendix 5).
- A meta analytic evaluation of bluefin tuna life-history assumptions (Carruthers and Hordyk 2018, Appendix 6)
- An automatic report is now available in the ABTMSE R package (v4.x.x +) that standardizes MSE results.

Contents

1 Review of contract activities 2018 - 2019

1.1 Swordfish – Bluefin MSE meeting (April 2018)

The swordfish-bluefin tuna MSE meeting was convened to start the process of Candidate Management Procedure (CMP) development, agree on a standard for presenting results among CMPs, develop CMP tuning specifications, and discuss aspects where input from stakeholders will assist in future CMP development.

The meeting generated a large number of appropriate requests for changes to both the operating model (M3) and R MSE framework (a detailed breakdown of these requests is including in Table 1b), including the calculation of dynamic B0 and MSY reference points and the inclusion of explicit stock-recruitment relationships in the OM conditioning (e.g. Beverton-Holt and Hockey Stick stock-recruitment models). There were a number of additional requests to overhaul the standard operating model report to show estimates of stock mixing, spatial distribution and fits to the various spatial data (e.g. electronic tagging and stock of origin data).

1.2 Bluefin Working Group meeting (September 2018).

The Bluefin Working Group convened to evaluate the progress on OM development, review approaches to interpret mixing data, establish terms for accepting / rejecting operating models, revise spatial OM structure if necessary and investigate the performance of existing CMPs. The meeting also included an initial discussion of OM plausibility weighting.

Two papers were presented on the mixture model interpretation of stock-of-origin data (Carruthers and Butterworth 2018a Appendix 3) and summarizing the current set of operating models (Carruthers and Butterworth 2018b, Appendix 4).

As with the previous meeting in April, there were a large number of requests for changes to model structure and the R MSE framework (for a detailed break-down see item after September 2018 in Table 1c). The most significant of these were a change to a 2-phase stock-recruitment model for both East and West stocks, requiring estimation of unfished recruitment (R0) in two historical time periods (which is challenging for even a single area, annual, single stock model).

1.3 MSE Technical Team (Core Modelling Group) and Working Group meeting (February 2019).

The 2019 meeting of the MSE technical team was intended to review the reference set of operating models and review the results of preliminary CMPs.

While all changes to the M3 estimation model were implemented correctly and OM fitting could be reviewed, these changes had been implemented but not thoroughly tested for the R MSE framework and discrepancies in the historical stock reconstructions prevented the interpretation of preliminary CMP results.

A number of requests for model verification were suggested to allow users to have confidence that operating models fitted by M3 are correctly implemented in the R software (a ‘check mode’ for any MSE run). Other additions to the R framework were suggested that would allow various stakeholders to have confidence in the implementation of CMPs for example by outputting the assumed selectivity and spatio-temporal distribution of catches for each fleet.

2 Progress with respect to deliverables

All deliverables were completed with the exception of those contingent on agreement on reference set operating models (Table 1). Both the preliminary Shiny App and the Bayesian Belief network rely on an agreed set of OMs and are therefore not final. For example, the initial shiny App has a Factor 2 for 'abundance' (A: best estimates, B: matching the current VPA assessments) that no longer exists in the current Trial Specifications document and has been replaced by the factor 'stock mixing' (A: best estimates, B: no western mixing – half eastern mixing). These may change again and until this can be finalized changes to the down-steam visualization tools may involve wasted development time.

Similarly, while the various management options have now been coded into the ABT-MSE R package (the majority of the methodological work of the paper) it was not possible to write up the methods and compute the results of the 'SCRS Strategies and Tactics' paper. As soon as reference operating models are available this scientific product can be finalized.

Table 1. Status of 2018/2019 contract deliverables (as with all progress tables in this document: green denotes completed, yellow are preliminary but not finalized, red are not completed).

Deliverable	Date	Status
1. Work-plan outlining the actions required to complete the final deliverables.	1 May 2018	
2. Comprehensive technical report on 2018 ICCAT Bluefin tuna MSE meeting	3 May 2018	
3. Preliminary refined version of the MSE software package	15 July 2018	
4. First progress report	15 July 2018	
5. MSE visualization tools (preliminary Shiny App completed, Appendix B)	5 Sept 2018	
6. SCRS communication on multi-stock MP (Appendix C)	15 Sept 2018	
7. SCRS communication on Strategies and tactics for ABFT (google doc)	22 Sept 2018	
8. Second progress report	15 Nov 2018	
9. Comprehensive technical report of CMG MSE meeting & updated TS doc.	31 Oct 2018	
10. Draft final report	13 Feb 2019	
11. Definitive final report	20 Feb 2019	

3 Progress with respect to April 2019 meeting requests

With three exceptions, all requests of the April 2018 swordfish-bluefin MSE workshop (Table 2) were completed before the September 2018 working group meeting.

The request to codify a scenario for increasing gravity in the Gulf of St Lawrence (GSL) was not completed since the request was too vague for reproduction, and in any case has been subsequently retracted and is no longer a robustness trial of the Trial Specifications document.

Diagnostics for quantifying 'cryptic biomass' (biomass that is neither available or vulnerable to fishing) have not been developed since it is not clear how to calculate this quantity for a seasonal-spatial model (but this request is ongoing and may be developed in future contracts).

Given that operating models were not finalized it was not possible to update the Bayesian Belief Network for evaluating MP performance.

Table 2. Additional requests arising from MSE intersessional. Red items have yet to be included, yellow items have been included but not tested, green items have been included and fully tested

FEATURE	Feb 2019
Data	
Reinterpretation of genetics and otolith microchemistry data	
Split French aerial survey index	
Add US RR > 177 index	
Include JPN LL GOM 1974-1981	
Remove Canada combined index, replace with SWNS and GSL	
All indices start in 1975	
Indices provided to MPs for years before 1975	
Observation model	
Indices are y-2 lagged, Catches are y-3, Catches in TAC y-2/y-1 are the TAC	
Include Canada acoustic index as a western projected index	
OM calculations	
Revisit BMSY calculation in light of R0 estimation and stock-recruit models	
Dynamic B0 calculation	
Dynamic BMSY calculation	
Dynamics B0/BMSY plots	
Add update interval to OM object	
Beverton-holt stock recruitment model included	
Hockey-stick stock recruitment model included	
Stock recruitment shift model (BH – HS, BH(low) – BH(high))	
OM fitting	
Move final year to 2016 or 2017	
Investigate 7-area model	
Correctly account for autocorrelation in index fitting	
Robustness OMs	
Split Med larval	
2% fishing efficiency gain for CPUE indices	
Increasing gravity in GSL	
Automatic reports / plotting	
Index fit – AC report	
Stock mixing plot	
Historical SSB depletions (ie including the SRA phase)	
Dynamic B0-BMSY plots	
Like-with-like length composition plots	
Cryptic biomass diagnostics	
Create an automatic Candidate MP performance report	
Various OM report scale and labelling bugs (e.g. Shuya y-axis scale issues)	
Average annual yield – negative only edition	
Trial specifications document	
Update to reflect MSE intersessional changes	
MSE Visualization tools	
Shiny App included in ABT MSE package	
Updated Bayesian Belief network	

4 Progress with respect to extra-contract 2018-2019 requests

A range of other research products and tasks were completed following requests from the September 2018 working group meeting and informal ad-hoc discussions over email (see Table 3 for a detailed breakdown). These requests included a new modelling approach for interpreting stock-of-origin (otolith microchemistry and genetics) data (Carruthers and Butterworth 2018a), a review of operating models (Carruthers and Butterworth 2018b) and an analysis of the impact of missing age-0 Mediterranean catches on recruitment estimates from the Eastern VPA stock assessment (Carruthers and Butterworth 2018c).

Also developed were new standardized operating model reports, operating model comparison reports and a preliminary MSE results report (essentially standardizing CMP developer results).

Table 3. Other requests arising from correspondence and meetings during the 2018-2019 contract.

June	
Mixture model approach developed for interpreting genetics and otolith microchemistry assignment data (Carruthers and Butterworth 2018a)	
July	
Post hoc Investigation of the impact of missing age-0 catches on the Eastern VPA assessment (Carruthers and Butterworth 2018c)	
August	
Hockey-stick post hoc fitting added to OMs	
SCRS paper on OM conditioning (Carruthers and Butterworth 2018b).	
SCRS paper on Bluefin Life-History parameters (Carruthers and Hordyk 2018)	
October	
More than 400 test OMs were conditioned to iteratively reweight the new 2-phase R0 model given earlier starting year, an extra year of data and new stock of origin / electronic tagging data	
November	
M3 model recoded to include a prior on the difference in the early and later periods of the two-phase R0 estimation	
Individual OM reports revised	
OM comparison reports revised	
December	
Time varying movement coded into operating model objects and MSE projection code	
Recoded M3 model to allow fitting to user-specified stock mixing	
Streamline CMP developers guide produced.	
12 new Robustness operating models coded and conditioned based on changes in mixing, Brazilian catch allocation and seasonal GOM abundance	
January '19	
Performance metrics change to dynamic B0 and dynamic BMSY versions	
Reference OMs refitted to prevent various 'red face' conditions of BFT WG	
Package documentation updated to reflect new robustness OMs.	
All package example objects (MSEs, simulated data, OMs) remade with new version.	
Allocation system changed to fleet-area following 2020 Allocation updates from Ai.	
February '19	
Multi-stock model-based 'learning' CMP developed that estimates changing stock productivity.	

5 Current status of objectives

The broad objectives of the contract have been met (Table 4).

Table 4. The status of contract objectives.

Objective			Tasks
	i 100 %	To ensure the OM scenarios agreed by the CMG in 2016 and 2017 can be run	OM scenarios are up-to-date and a set of revisions have been suggested for 2019.
	ii 100 %	That third parties can use the OM to evaluate candidate MPs (CMPs) of their own specifications	The R package has been updated (v4.4.5) to include the latest (February 2019) set of operating models.
	iii 100 %	To provide/output a set of agreed summary statistics that can be used by decision makers to identify the MP, including data and knowledge requirements, that robustly meets the management objectives.	Performance metrics are up to date in the latest R package (v4.4.5) and include a very wide range of possible quantities (14 metrics relating to long and short-term yield, variation in yield and stock biomass)

6 MSE development priorities

The MSE framework is complete but all components downstream of the Management Procedures and the Management Objectives are currently not finalized (Figure 1).

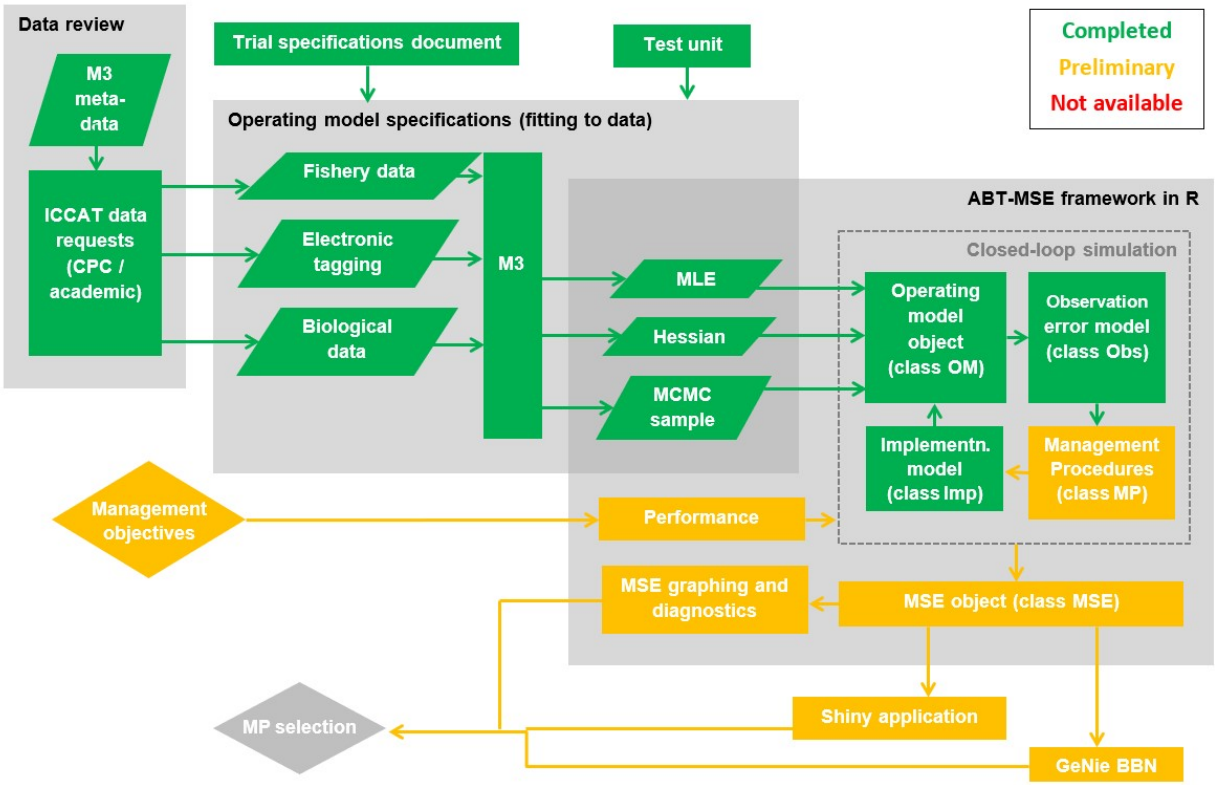


Figure 1. Current status of the components of the ABT MSE framework showing the preliminary nature of Management Procedures and Management objectives (and hence all components downstream).

6.1 Current data

An immediate priority is that all data providers are given the opportunity to check that the most recent version of their data are included in the modelling and that where applicable, data processing has been carried out correctly (for example electronic tagging data, historical catch observations and the mixture model interpretation of stock-of-origin data).

6.2 Trial Specifications update

Prior to the July 2019 MSE meeting (and as soon as possible) the trial specifications document should be updated to comprehensively address all outstanding issues in version D19-4.

6.3 Operating model adaptation

The M3 operating model should be revised to include annual, regional and seasonal deviations from the fishing mortality rates predicted by the master index. This update will allow the influence of the master index to be determined (compared to other sources of data) and potentially removed altogether.

The estimation model should not attempt to estimate recent recruitment deviations.

6.4 Alternative master indices

A range of alternative master indices should be developed to demonstrate the relative impact of this assumption on the estimates arising from the operating model.

6.5 R package checks

All operating models should pass the M3 estimated numbers at age to the MSE allowing for a comprehensive range of checks by which users can have confidence that the M3 model estimates are exactly reproduced in the ABT-MSE R package.

6.6 R package

The R package should be updated to reflect the current changes to the OM. Specific additions include:

- Dynamic B0 estimates of performance metrics should be added
- Integrate the Shiny App into the R package
- Cryptic biomass estimates in OM reporting
- Diagnostics for fleet allocation in future years

Acknowledgments

Many thanks in particular to Ai Kimoto for technical support, Francisco Alemany for directing the project, Nick Duprey for advancing the Trial Specifications document and Doug Butterworth for organizing all aspects of MSE framework development.

This work was carried out under the provision of the ICCAT Atlantic-Wide Research Programme for Bluefin Tuna (GBYP), funded by the European Union, by several ICCAT CPCs, the ICCAT Secretariat and by other entities (see: http ://www.iccat.int/GBYP/en/Budget.htm). The content of this report does not necessarily reflect the point of view of ICCAT or of the other funders, which have no responsibility for it, neither does it necessarily reflect the views of the funders and in no way anticipates the Commission's future policy in this area.

7 References

Carruthers, T.R. 2018. Designing and testing a multi-stock spatial management procedure for Atlantic Bluefin tuna. SCRS/2018/XXX. [Appendix 1].

Carruthers, T.R., Butterworth, D.S. 2018a. A mixture model interpretation of stock of origin data for Atlantic Bluefin tuna. SCRS/2018/133. [Appendix 3].

Carruthers, T.R., Butterworth, D.S. 2018b. Updated summary of operating models for Atlantic bluefin tuna. SCRS/2018/134. [Appendix 4].

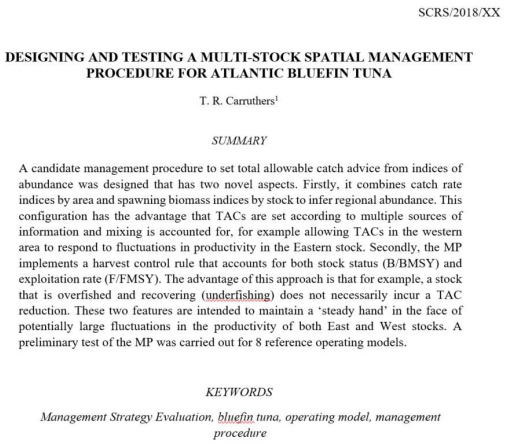
Carruthers, T.R., Butterworth, D.S. 2018c. Quantifying the impact on estimates of recruitment trends on previously unreported catches of age-0 bluefin tuna in the Mediterranean. SCRS/2018/XXX. [Appendix 5].

Carruthers, T.R., Hordyk, A.R. 2018. Are life-history parameters for bluefin tuna anomalous? SCRS/2018/156. [Appendix 6]

8 Appendices

8.1 Appendix 1: Designing and testing a multi-stock spatial MP

The theory and data types behind a new multi-stock management procedures using multiple indices and providing advice to both stocks.



SCRS/2018/XX

DESIGNING AND TESTING A MULTI-STOCK SPATIAL MANAGEMENT PROCEDURE FOR ATLANTIC BLUEFIN TUNA

T. R. Carruthers[1]

SUMMARY

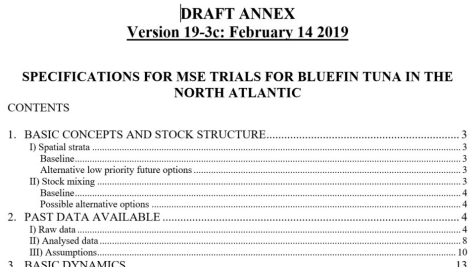
A candidate management procedure to set total allowable catch advice from indices of abundance was designed that has two novel aspects. Firstly, it combines catch rate indices by area and spawning biomass indices by stock to infer regional abundance. This configuration has the advantage that TACs are set according to multiple sources of information and mixing is accounted for, for example allowing TACs in the western area to respond to fluctuations in productivity in the Eastern stock. Secondly, the MP implements a harvest control rule that accounts for both stock status (B/BMSY) and exploitation rate (F/FMSY). The advantage of this approach is that for example, a stock that is overfished and recovering (underfishing) does not necessarily incur a TAC reduction. These two features are intended to maintain a 'steady hand' in the face of potentially large fluctuations in the productivity of both East and West stocks. A preliminary test of the MP was carried out for 8 reference operating models.

KEYWORDS

Management Strategy Evaluation, bluefin tuna, operating model, management procedure

8.2 Appendix 2: Trial Specifications Document 19-3

Now with version control, the latest trial specification document is appended:



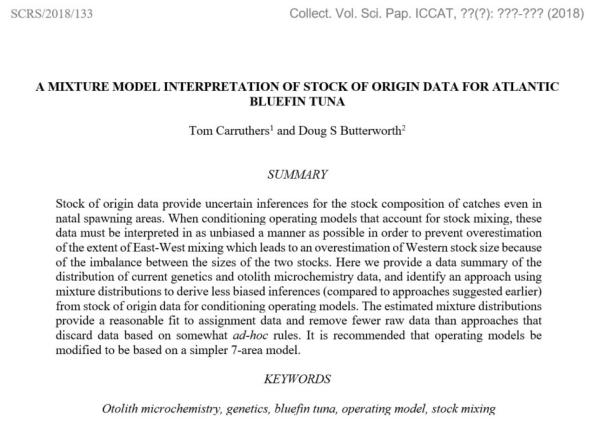
DRAFT ANNEX
Version 19-3c: February 14 2019

SPECIFICATIONS FOR MSE TRIALS FOR BLUEFIN TUNA IN THE NORTH ATLANTIC

CONTENTS

8.3 Appendix 3. A novel mixture-modelling approach for interpreting stock-of-origin data.

Both genetics and otolith microchemistry 'signatures' from the GOM and Mediterranean natal areas are used to interpret the fraction of east-west fish residing in mixed areas of the Atlantic (by season and age-class).



SCRS/2018/133 Collect. Vol. Sci. Pap. ICCAT, ??(?): ???-??? (2018)

A MIXTURE MODEL INTERPRETATION OF STOCK OF ORIGIN DATA FOR ATLANTIC BLUEFIN TUNA

Tom Carruthers[1] and Doug S Butterworth[2]

SUMMARY

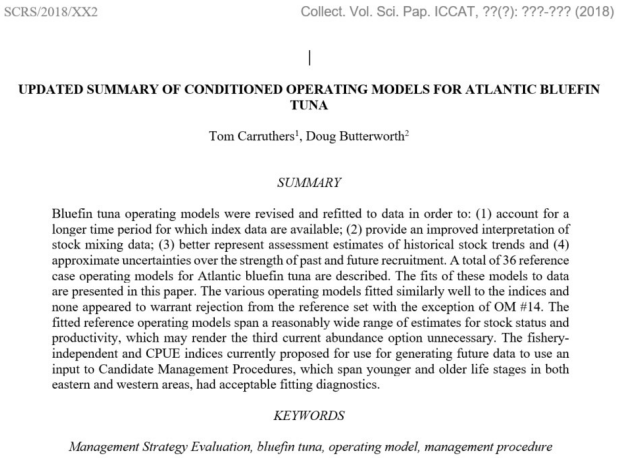
Stock of origin data provide uncertain inferences for the stock composition of catches even in natal spawning areas. When conditioning operating models that account for stock mixing, these data must be interpreted in as unbiased a manner as possible in order to prevent overestimation of the extent of East-West mixing which leads to an overestimation of Western stock size because of the imbalance between the sizes of the two stocks. Here we provide a data summary of the distribution of current genetics and otolith microchemistry data, and identify an approach using mixture distributions to derive less biased inferences (compared to approaches suggested earlier) from stock of origin data for conditioning operating models. The estimated mixture distributions provide a reasonable fit to assignment data and remove fewer raw data than approaches that discard data based on somewhat *ad-hoc* rules. It is recommended that operating models be modified to be based on a simpler 7-area model.

KEYWORDS

Otolith microchemistry, genetics, bluefin tuna, operating model, stock mixing

8.4 Appendix 4: A summary of current operating models

The estimates of a range of operating models were summarized and consistencies / inconsistencies were highlighted:



SCRS/2018/XX2 Collect. Vol. Sci. Pap. ICCAT, ??(?): ???-??? (2018)

UPDATED SUMMARY OF CONDITIONED OPERATING MODELS FOR ATLANTIC BLUEFIN TUNA

Tom Carruthers[1], Doug Butterworth[2]

SUMMARY

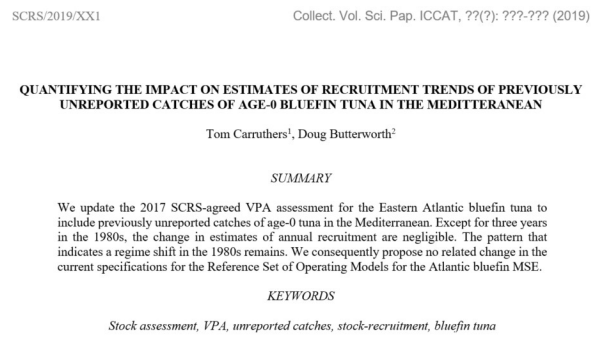
Bluefin tuna operating models were revised and refitted to data in order to: (1) account for a longer time period for which index data are available; (2) provide an improved interpretation of stock mixing data; (3) better represent assessment estimates of historical stock trends and (4) approximate uncertainties over the strength of past and future recruitment. A total of 36 reference case operating models for Atlantic bluefin tuna are described. The fits of these models to data are presented in this paper. The various operating models fitted similarly well to the indices and none appeared to warrant rejection from the reference set with the exception of OM #14. The fitted reference operating models span a reasonably wide range of estimates for stock status and productivity, which may render the third current abundance option unnecessary. The fishery-independent and CPUE indices currently proposed for use for generating future data to use an input to Candidate Management Procedures, which span younger and older life stages in both eastern and western areas, had acceptable fitting diagnostics.

KEYWORDS

Management Strategy Evaluation, bluefin tuna, operating model, management procedure

8.5 Appendix 5: Impact of missing age-0 catches

The Eastern VPA assessment estimates of recruitment were recalculated to include missing age-0 catches in the Mediterranean:



SCRS/2019/XX1 Collect. Vol. Sci. Pap. ICCAT, ??(?): ???-??? (2019)

QUANTIFYING THE IMPACT ON ESTIMATES OF RECRUITMENT TRENDS OF PREVIOUSLY UNREPORTED CATCHES OF AGE-0 BLUEFIN TUNA IN THE MEDITTERANEAN

Tom Carruthers[1], Doug Butterworth[2]

SUMMARY

We update the 2017 SCRS-agreed VPA assessment for the Eastern Atlantic bluefin tuna to include previously unreported catches of age-0 tuna in the Mediterranean. Except for three years in the 1980s, the change in estimates of annual recruitment are negligible. The pattern that indicates a regime shift in the 1980s remains. We consequently propose no related change in the current specifications for the Reference Set of Operating Models for the Atlantic bluefin MSE.

KEYWORDS

Stock assessment, VPA, unreported catches, stock-recruitment, bluefin tuna

8.6 Appendix 6: Are bluefin life-history parameter anomalous?

The assumed range of natural mortality rate, maturity and growth parameters for Atlantic bluefin tuna were evaluated using meta-analysis and with respect to other bluefin stocks:

SCRS/2018/156 Collect. Vol. Sci. Pap. ICCAT, ??(?): ???-??? (2018)

ARE LIFE-HISTORY PARAMETERS FOR BLUEFIN TUNA ANOMALOUS?

Tom Carruthers[1], Adrian Hordyk[2]

SUMMARY

The natural mortality rate, length at maturity, somatic growth rate that are assumed in current stock assessments and operating models for bluefin tunas are presented with reference to a range of fish species. In the context of the wider order of *perciforms*, Atlantic bluefin tuna parameters are consistent with many other species. When compared with the data for *scombrids*, bluefin tuna have similar ratios of natural mortality rate to somatic growth rate. Maturity schedules for Atlantic bluefin were not inconsistent with those that may be predicted according to basic life-history analysis. Compared to Atlantic bluefin life-history parameters, those for Pacific bluefin were more comparable to other taxonomically related species. Southern bluefin tuna length at 50% maturity relative to asymptotic length, was amongst the highest recorded for any fish in the various datasets. There was no conclusive evidence to suggest that the current set of parameters for Atlantic bluefin tuna are anomalous.

KEYWORDS

Life-history analysis, bluefin tuna, stock assessment, parameter

8.7 Appendix 7: Technical report of the April MSE meeting

The technical discussions, findings and recommendations arising from the April 2018 swordfish-bluefin MSE workshop were summarized:

Technical Report of the 2018 ICCAT Bluefin Tuna and North Atlantic Swordfish MSE Meeting

Tom Carruthers (bluemattersci@gmail.com)

2nd July 2018

1 Introduction

The Atlantic Bluefin Tuna Management Strategy Evaluation (ABT-MSE) process has entered a phase where various SCRS scientists and managers are developing candidate management procedures (CMPs) based on a proposed set of relative abundance indices. The 2018 ICCAT bluefin tuna and North Atlantic swordfish MSE meeting was convened to facilitate this process by providing a venue to engage with developers of CMPs and receive feedback on the current MSE software package.

The meeting covered various subject areas relating to these goals including: technical feedback on the current MSE software; a review of the current suite of CMPs; agreement on tuning specifications to facilitate comparison of future results; input from stakeholders on performance metrics and CMPs;