**Evaluating Management Strategies for Atlantic Bluefin Tuna**

***Report 4: An MSE R package for investigating custom operating models, performance metrics and management procedures.***

January 2017

SHORT-TERM CONTRACT FOR MODELLING APPROACHES: SUPPORT TO BFT

ASSESSMENT (GBYP 02/2016) OF THE ATLANTIC-WIDE RESEARCH PROGRAMME ON

BLUEFIN TUNA (ICCAT-GBYP – Phase 6)

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UBC

**Executive Summary**

The focus of this contract was finalizing the technical aspects of the operating modelling and producing a user friendly and fully functional MSE framework that could provide a basis for feedback and collaboration from a wider group of stakeholders.

In this regard, a number of major milestones were achieved in this contract:

Data

- Following the data preparatory meeting the fleet structure and data formats were finalized and the meta-database was updated.

- All fishery, survey, tagging and stock of origin data were formatted for use with the operating model

- A draft SCRS paper was written that provides a full account of the derivation of the ‘master index’ that is central to the operational modelling (Appendix 1)

- The online meta-data summary was linked to the corresponding sources of data in the GitHub repository.

Operational modelling

- A final operating model structure was designed following feedback from the Core Modelling Group including a new model initialization by stock reduction analysis to account for catches before 1960

- The new operating model was simulation tested to check for coding errors, identifiability and to establish suitable data weightings

- The trial specifications document was updated following feedback from the core modelling group (Appendix 2)

MSE development

- The 18 reference operating models were fitted to data and reproducible R scripts are available that describe this process.

- A standard operating model fitting report was developed in R markdown and were generated for each reference operating model.

- A comprehensive set of R functions were developed to allow for the simple and rapid design of operating models, fitting of operating models to data, design of management procedures, specification of performance metrics and the running of Management Strategy Evaluation

- All of the R code, data and objects were compiled into a single R package (ABTMSE) with complete documentation for all functions, objects and data to be used in MSE analyses (Appendix 3)

- The raw data, R scripts, Reports, help documentation and the R package were assembled in a single directory which can be downloaded from the ICCAT GitHub repository.

Documentation

- An extensive user guide was developed in R markdown that describes the file structure, the project and guides users through the various functions of the R package including worked examples of the 7 steps of MSE development (of Punt and Donovan, 2007)(Appendix 4).

- A fully documented website was produced using ‘pkgdown’ that can act as the front page of the ICCAT abft-mse repository and has links to various documentation including all the functions and objects of the R package (Appendix 5)

Created new surplus production assessments and other catch based methods

Help users develop MPs, PMs and OMs

**Future additions:**

Finalization of operating model fits (development of robustness set)

Better value of information analysis

Updating of the shiny app

Updating of the BBN

Update the automatic report to include Doug’s residual plots for index fits

Code up robustness OMs

Add convergence diagnostics for performance metrics

Create Rcpp code for calculating historical fishing mortality rate at length

Standard MSE report

Develop new MPs

Performance metric convergence diagnostics

Pencil plots

Better characterization of observation processes, for example what is an appropriate / credible degree of bias in age at maturity BMSY/B0, FMSY/M etc.

**Coding additions**

Update iALK in future years (don’t simply assume nyears matrix)

May need iALK that is stock specific for CAA predictions if growth is different among stocks (makeCAL2, makeCAL3)

Free up recruitment switching per stock (robustness sets)

**House keeping:**

Clean up code,

Copy over cov files

Add references to vignette

Build package and reference it in installation section

tidy up the software design document for 2.1

Example allocation

Do an MSE

Plot results

Create an MSE report

Update readme to reflect new file structure changes and possibly an order of operations

Update the test unit

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# Review of contract activities 2016 - 2017

At the July (24th – 29th) data preparatory meeting, two papers were presented demonstrating the successful simulation testing of the multi-stock operating model (SCRS/2016/144) and another highlighting the outstanding issues pertinent to the conditioning of operating models on real data (SCRS/2016/145).

Following the data-preparatory meeting (July 24-29) all data for fitting operating models were made available to the core modelling group (CMG). This allowed for an update in the meta-data summary, the preliminary fitting of operating models to real data and an overhaul of the Trial Specifications document, for example the definition of fleets and the start / end dates of the operational modelling.

The update in the Trial Specifications document and the provision of data allowed for the fitting of preliminary operating models (large grey shaded box ‘Operating model specifications’ of Figure 1). Code was developed to link these outputs to the ABTMSE R package (the linkages through MLE, Hessian and MCMC sample boxes of Figure 1 below).

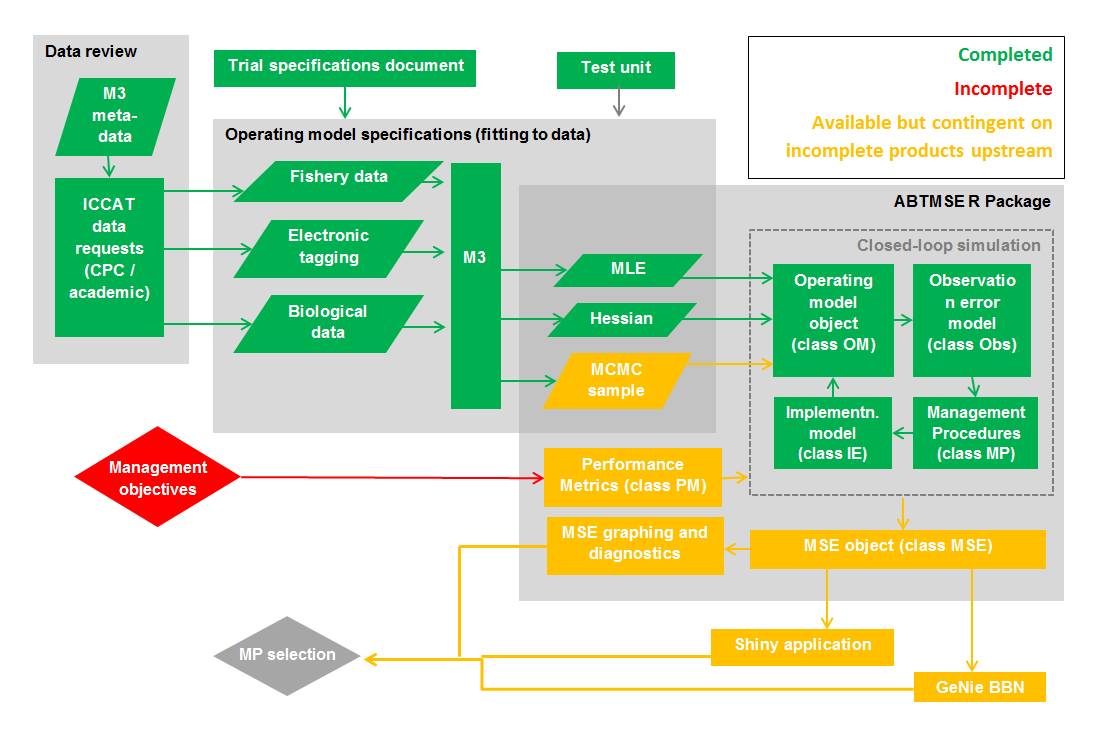


Figure 1. Current status of the ABT-MSE project.

At the September (26th -30th) species working group meetings a pair of papers were presented highlighting opportunities for operational modelling (SCRS/2016/204) and a new approach for imputing stock of origin to electronic tags using their spatial fingerprint (SCRS/2016/205). Following feedback from members of the CMG the R ABTMSE framework was updated as was the [meta-data base](https://docs.google.com/spreadsheets/d/%2013pFaM3BTnzQ1BNQGoYn4O2n1IeD18V3VTbN9Hv7139U/edit) which is now linked to the real data on the [ICCAT/abft-mse](https://github.com/ICCAT/abft-mse) GitHub page.

The 18 reference operating models were fitted to data and a standardized report was designed using R markdown, which allows any user to rapidly produce model diagnostics and estimates of management reference points. These fitted operating models were presented to the CMG in November (5th -6th) following the Tuna MSE working group meeting. Feedback from the CMG focused on finalizing the Trial Specifications document and reconfiguring the operating models. A substantial change in operating model structure was proposed relating to model initialization. Rather than assuming an stable rate of fishing mortality rate prior to 1960 the model is now initialized by stock reduction analysis (SRA, the removal of catches) accounting for catches from 1860 to 1959.

As requested by the CMG, an SCRS paper was drafted describing in detail the derivation of the ‘master index’ that is used to condition the operating models (Appendix 1). The paper discusses the advantages and disadvantages of the approach and highlights future priorities for research.

Since the CMG meeting at the start of November, the Trial Specifications document (latest version is attached in Appendix 2), operating model and R ABTMSE framework were reconfigured to incorporate this change in model structure.

A series of improvements to the R MSE framework were implemented. These include custom classes for operating model inputs, performance metrics, observation models and management procedures. The observation model was updated to generate future indices based on the statistical properties of model fit to prospective indices (e.g. the real Mediterranean larval survey). A range of new management procedures were added that make use of these indices including new surplus production, delay difference and catch-based MPs (there are now 23 example MPs).

The R MSE framework was consolidated into a single R package (ABTMSE) in which all functions and objects have documentation and worked examples (Appendix 3). MSE diagnostics were produced that match those of the Trial Specifications document including performance metrics, performance summary tables and projection plots.

A user guide was produced in R markdown (Appendix 4) that describes and demonstrates the package functionality including the ‘7 steps of MSE’ as described by Punt and Donovan (2007):

(1) qualitative specification and prioritization of the management objectives, as derived from legislation, legal decisions, and international standards and agreements;

(2) quantification of the qualitative management objectives in the form of performance measures;

(3) development and parameterization of a set of “operating models” that represent different plausible alternatives to the dynamics of the “true” resource and fishery being managed;

(4) identification of candidate management procedures, including monitoring strategies;

(5) simulation of the future use of each candidate management procedure, involving for each time-step during the projection period: (a) generation of assessment data; (b) determination of the management action (i.e. assessment and application of some HCR); and (c) evaluation of the biological implications of the management action by removing the catch from the population as represented in the operating model;

(6) summary of the performance of the candidate management procedures in terms of values for the performance measures; and

(7) selection of the management procedure that best meets the specified objectives.

Using a pre-release R package [pkgdown](https://github.com/hadley/pkgdown) a website was produced for the ABTMSE package. This allows for automated online documentation each time the package is updated. It can also serve as a splash page for the ICCAT/abft-mse repository (Appendix 5).

# Progress with respect to deliverables

|  |  |  |
| --- | --- | --- |
| **Deliverable 1 July 20, 2016 (100%)** | | |
|  | i | Workplan outlining the actions required to complete the 5 components of deliverable 3 |
|  | ii | Presentation and short report summarizing current status of deliverables and actions required to achieve them |
|  |  |  |

This deliverable was addressed in Progress Report 4 and accompanying presentations. The workplan (deliverable i) was presented in Progress Report 5 (Section 5).

|  |  |  |
| --- | --- | --- |
| **Deliverable 2 September 23, 2016 (100%)** | | |
|  | i | Updated presentations and short report summarizing current status of deliverables and actions required to achieve them (100%) |
|  | ii | Demonstrator showing the MSE running, should include examples of the 6 steps of developing an MSE (100%) |
|  | iii | Draft papers on applications (100%) |
|  |  |  |

Report 5 deliverable i.

A summary demonstration of MSE results will be set up in a shiny app (e.g. [**http://rscloud.iccat.int:3838/gbyp-mse/**](http://rscloud.iccat.int:3838/gbyp-mse/)**)** following feedback from the bluefin WG, CMG and stakeholders on the design of this graphical tool.

A review paper discussing the potential future applications of bluefin tuna operating models has been drafted and will be presented to the SCRS at the September 2016 species group meeting (Carruthers and Kell 2016, /Submissions/SCRS\_2016\_XX2 Carruthers Applications…docx). Feedback is being sought at the meeting regarding appropriate peer-reviewed papers based on the MSE and operating models.

|  |  |  |
| --- | --- | --- |
| **Deliverable 3 Draft: February 13, 2017 Final: February 21, 2017 (100%)** | | |
|  | i | Repository with version control for software development <http://github.com/ICCAT/abt-mse> containing the OM (~100%) |
|  | ii | SDP (Software Development Plan) that will be reviewed by external experts, as agreed at Monterey meeting (~100%) |
|  | iii | Test Unit so that code can be validated (100%) |
|  | iv | Meta Database summarizing all parameters and assumptions used <http://github.com/ICCAT/GBYP-MetaDB> (100%) |
|  | v | Management Procedures Support the implementation of 3rd parties. Written up as SCRS paper and code available in repository (100%) |
|  |  |  |

(i) Following the completion of version 1.0 of the M3 operating model, the ICCAT MSE GitHub site will now be subject to regular (weekly) updates following developments to code and software documentation. Branching, merging, pulls, commits etc. may be managed either by me the Technical Assistant or ICCAT staff.

(ii) The software development plan is a current task. Updated software design documents and manuals are available for the M3 operating model (v1.0). Following feedback from the bluefin working group (BFT WG), core modelling group (CMG) and SCRS the SDP for the ABT-MSE R framework can be finalized and a manual and software design document can be wrapped up before November 2016.

(iii) A test unit has been developed that matches the new features of the latest M3 model (v1.0). The simulator is built into the R ABT-MSE framework and uses streamlined operating model objects (OM definition objects) to generate simulations and calculate reference points. The test unit (and M3 model) must both be updated to reflect recommendations of the CMG, BFT WG and SCRS following the 2016 data preparatory meeting. The simulation testing framework (test unit) will be updated to simulate data from the dynamics of the fitted operating models (noting that simulation testing of the full operating model (55 years, 4 seasons, 10 areas, 14 fleets) will be considerably more computationally intensive than previous simulation tests.

(iv) The meta-database is now available as a publically editable google worksheet

[https://docs.google.com/spreadsheets/d/ 13pFaM3BTnzQ1BNQGoYn4O2n1IeD18V3VTbN9Hv7139U/edit#gid=1352276725](https://docs.google.com/spreadsheets/d/%2013pFaM3BTnzQ1BNQGoYn4O2n1IeD18V3VTbN9Hv7139U/edit#gid=1352276725)

The meta database has been updated following the provision

# Current status of objectives

|  |  |  |
| --- | --- | --- |
| **Objective** | | **Tasks (bold are completed)** |
| **a**  (100%) | Continue the development of the OM based on the MSE trial specifications document (TS) | **Added (M3 v1.0):**  **age-based movement, plus group, model initialization at equilibrium estimated F, recruitment predicted from SSB in previous year, a prior for depletion to allow the model to fit specified depletion.** |
| **b**  (100%) | Develop a test unit to validate the age-based movement model | **Test unit updated to match developments in the operating model above (a)** |
| **c**  (0%) | Work with third parties to add MPs to the MSE framework including empirical control rules and simple stock assessment methods | Reach out to national scientists, members of the BFT WG (possibly leverage the chairs of Eastern and Western WGs) and the CMG to develop new MPs or to incorporate existing MPs (e.g. CCSBT) |
| **d**  (0%) | Run the MSE in collaboration with BFT Species group | Requires a dedicated meeting following finalization of the TS, fitting of the appropriate OMs and integration of these into the R ABT-MSE framework. |
| **e**  (100%) | Collaborate with the SCRS to develop interactive graphics (e.g. Shiny apps) to communicate MSE results to stakeholders based on the performance metrics of the trial specifications document | **A preliminary Shiny App is now available at:** [**http://rscloud.iccat.int:3838/gbyp-mse/**](http://rscloud.iccat.int:3838/gbyp-mse/)  The App should be modified following feedback from the BFT WG and stakeholders.  The App should include sufficient flexibility to allow users to define their own OMs. |
| **f**  (100%) | Work with other to update and maintain the meta database of the available bluefin data and knowledge https://github.com/ICCAT/GBYP-MetaDB | **The meta database has been made publically available and editable** [https://docs.google.com/spreadsheets/d/ 13pFaM3BTnzQ1BNQGoYn4O2n1IeD18V3VTbN9Hv7139U/ edit#gid=1352276725](https://docs.google.com/spreadsheets/d/%2013pFaM3BTnzQ1BNQGoYn4O2n1IeD18V3VTbN9Hv7139U/%20edit#gid=1352276725)  The google sheet has been updated by myself and H. Arrizabalaga to reflect the latest status of BFT data. |
| **g**  (100%) | Work with SCRS to help develop 3 prototype examples |  |

# Priorties

Implement the max / min TAC changes of the Trial specifications document

# Addressing critical issues for MSE adoption

## Stakeholder specification of OMs

There are two levels at which stakeholders may specify OMs. The first is at the ground level in the description of the trial specifications document (TS). This determines the range of scenarios that the OM (M3) will be fitted to data.

The second level is post-hoc and may be achieve through various combinations of the OM conditions identified in the TS. For example a stakeholder may select a unique combination of mortality rate, stock depletion, stock-recruitment relationship, bias in reported catches and test MP robustness to this particular reference case. The creation of the OMI (Operating Model Input) class object greatly simplifies the process of custom OM specification as it contains a slot for all of the M3 model inputs in the correct format (for example the maturity schedule for each stock). The second level of stakeholder specification may be achieved through graphical MSE summary tools such as a shiny app. An online interactive table may be updated to allow for various OM types to be added by stakeholders.

## User-specified MPs

The ABT-MSE R framework is designed specifically to allow user defined MPs to be easily incorporated. The central obstacles for successfully engaging with stakeholders on MP development are materials (tutorials, examples, demos) that clearly explain this functionality. An example MP (http://iccat.int/Documents/CVSP/CV071\_2015/n\_6/CV071062790.pdf) will be coded into the package as part of a tutorial on custom MPs. It may be necessary to organize a dedicated MSE workshop once a working MSE framework is established.

## Custom performance metrics

The process of establishing management objectives (e.g. biomass above BMSY) and target performance metrics (probability of being above 50% BMSY after 10 years) relies on engagement with stakeholders. Typically this is an iterative approach and stakeholder require working MSE results to begin an informed decision about types of performance (short term yield, long term yield, stability in yield, biomass levels) targets and limits for these and probabilities of exceeding these. Interactive tools such a shiny apps and Bayesian belief networks offer a possible means of making MSE outputs accessible to stakeholders with a wide range of backgrounds and abilities.

# Workplan for achieving deliverable 3

Following the data preparatory meeting, it was clear that the data for the operating models would become available earlier than scheduled under the previous workplan of report 4 (see Figure 2 for the latest workplan and changes from previous version). The meta-database update was completed in light of the data preparatory meeting however it is subject to ongoing updates as data become available or are refined (finalization of maturity, growth model and inverse age-length key derivation).

A demonstration MSE is a part of deliverable 3 and should include user-specified MPs, and performance metrics that have been subject to review by stakeholders. However, the previous workplan did not acknowledge a prior, more cursory demonstration MSE that is part of deliverable 2 which is now reflected in the updated Gantt chart (Demonstration MSEs 1 and 2).

## Repository with version control (Complete, August 2016)

The most recent version of the M3 model is the first to be simulation tested and fitted to the operating models of the trial specifications document. This constitutes a first beta, a working example that is fit for purpose (v1.0). The ICCAT MSE GitHub repository is now linked with local repositories and will be updated on a regular basis to reflect changes in code and software documentation moving forwards.

## Software development plan (October 2016)

A manual and software design document are available for the latest version of the M3 operating model (/Manuals and design documents/). A software design document and manual is currently being drafted for ABT-MSE R framework.

## Test unit (Complete, Jul 2016)

The test unit is essentially complete for v1.0 of the M3 operating model but requires more sophisticated observation error models, potentially for new sources of information such as close-kin genetics analysis and standard gene tagging.

## Meta database (TBD depending on feedback, simple Excel version September 2016 following data preparatory meeting)

Carruthers (2015c) describe a cursory attempt to develop a meta database describing the types, availability and ownership of various data for condition OMs. This simple excel worksheet may not provide sufficient detail and flexibility to accommodate all data. The current version has been updated and is available as a public (and editable) google document at: [https://docs.google.com/spreadsheets/d/13pFaM3BTnzQ1BNQGoYn4O2n1IeD18V3VTbN9Hv7139U/edit#gid=1352276725](https://docs.google.com/spreadsheets/d/13pFaM3BTnzQ1BNQGoYn4O2n1IeD18V3VTbN9Hv7139U/edit%23gid=1352276725)

There are two options: continue to update and expand the current google worksheet. The other option is a wholesale overhaul and redevelopment to a more dedicated and powerful data base engine. This should be a topic for discussion of the CMG members at the September species group meeting.

## User-defined MPs (Prior to Jan 2017)

The current ABT-MSE R framework allows for rapid design and incorporation of user-specified MPs. The precursor to this is clear documentation (the ABT-MSE R framework manual is under development and will be finalized once OM and TS have been finalized). Additionally a tutorial and potential a demo video could also help prospective MP designers become acquainted with the simulation framework and outputs.

# Other outstanding issues

## Provision of electronic tagging data in requirement format

A large number of potentially informative electronic tags were provided by the Stanford lab, but without covariate length / age data with which to assign tags to age classes (e.g. age class one: 0-3 years, age class 2: 3-8 years, age class 3: 9+ years). These data are currently not used in the conditioning of operating models despite their potential value.

## Development of inverse age-length keys

Inverse age-length keys (probability of a fish being of length class L given age class A) were derived by me using a very naïve approach (i.e. superimposing a 10% coefficient of variation around the maximum likelihood fit of the Richards growth curve following Allioud et al.). Time – varying iALKs are accepted by the M3 operating model that may be better derived empirically from the raw age-length data.

## Changes to operating model structure

The modelling and estimation of recruitment deviations prior to the initial model year was deemed of secondary importance following the guidance of the core modelling group in Monterey (January 2016). However on examining the fit of the M3 model to the master abundance indices it is apparent that without the estimation of historical recruitment the model cannot fit initial ‘bumps’ in abundance that are inferred by indices. Incorporating these changes is reasonably trivial (a few days) and a priority following the September species group meeting.

## Derivation of a master relative abundance index

Currently a master relative abundance index is derived in an ad-hoc manner using coarse task II catch and effort data by me the technical assistant. This index is very important to the conditioning of operating models because it infers the temporal trajectory and spatial distribution of both stocks combined. Given its importance, this index should be derived by more detailed data (trip level data) and subject to careful review by a range of stakeholders.

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