**ABT-MSE: an R package for Atlantic bluefin tuna management strategy evaluation**

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*SUMMARY*

To do last

*KEYWORDS*

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

# Introduction

A Management Strategy Evaluation (MSE, Butterworth 1999, Cochrane 1998) approach has been proposed for Atlantic bluefin tuna as a suitable framework for providing robust management advice consistent with the precautionary approach (GBYP 2017a).

A critical step in MSE is the development of candidate management procedures (MPs) which can provide management advice from fishery data. The success of past MSE applications has depended on the ability of stakeholders to design and test their own custom management procedures.

In this paper we provide an overview of an R MSE package designed to enable rapid design and testing of MPs for Atlantic bluefin tuna. A comprehensive user guide (Carruthers 2017) is available from a GitHub repository where all code and data are also freely available. A brief installation guide and example use of the package in included in the Appendix of this document.

In this paper we focus on a description of the software and its functionality. For a full description of operating model equations and parameters we refer users to the Trial specifications document (CMG 2017) and other supporting papers (Carruthers et al. 2015). See GBYP (2017b) for a summary of the data used by the operating models.

# Methods

***Aims and Objectives***

The ABT-MSE software was designed to be: (1) open-source with straightforward distribution and installation; (2) well documented with an intuitive system for accessing documentation; (3) as concise as possible; (4) easy to use, yet hard to misuse; (5) extensible, allowing for users to specify operating models and easily develop and test new MPs; and (6) sufficiently flexible in design to respond to feedback from stakeholders or member of the GBYP core modelling group. These objectives determined the environment, programming language and programming paradigm, all of which are described in more detail below.

***Open Source***

ABT-MSE freely available online from a dedicated GitHub code repository ([www.github.com/iccat/abft-mse](http://www.github.com/iccat/abft-mse)) which contains all data, code and documentation. The GitHub repository allows users to request software features, report bugs, and track software updates. GitHub also supports continuous integration of code from multiple developers and feature ‘branching’ a form of version control where additions can be coded in parallel and merged with the master branch. The principal challenge of developing MSE for bluefin was adopting a language and a programming paradigm that was sufficiently flexible to allow for increasingly complex additions.

***Environment, Programming Language and Software Dependencies***

ABT-MSE was developed in the statistical environment R (R Core Team 2017) and is primarily coded in the R language. There are important reasons for using R in this context. It is arguably the most widely used and most flexible software for scientific and statistical analysis, and is commonly applied in quantitative fisheries science for the processing and analysis of data. R has proven popular with the scientific community due to a large and diverse range of freely available packages and the ability to produce well-designed publication-quality figures. It follows that R provides an ideal environment for specifying operating models and then interpreting MSE outputs.

R allows for the development of self-contained packages which offers the attractive possibility of distributing complex software in a single file. Installation of ABT-MSE is achieved in a single command from the R console. R packages provide users with a certain degree of confidence since they must meet CRAN policy (CRAN 2017), which includes error checking, installation size limits, compatibility among operating systems and documentation requirements. ABT-MSE makes use of integrated R help and includes detailed documentation including worked examples for all objects and functions. The ABT\_MSE manuals and training materials are automatically rebuilt from the latest software release using R markdown (Allaire et al. 2017).

A principal limitation of computing in R is that calculations can be slow compared with languages such as C++, Python and Java. This is particularly important in this context because MSE has relatively high computational requirements. To address this, ABT-MSE defaults to parallel processing using the package ‘parallel’ (R Core Team 2017) to distribute calculations over either multiple cores of a workstation or a larger cluster of many hundreds of virtual machines – ABT-MSE is compatible with online computing resources such as Amazon Web Services (2017) and Google Cloud (2017).

***Programming Paradigm and Design***

An important feature of R is that it supports Object-Oriented Programming (OOP) (Jacobsen et al. 1992) in which data, models and results are organized in standardized objects (classes) on which standardized functions (methods) may be applied. In general OOP is desirable because it allows for the reuse of code, can impose stricter requirements of object attributes (e.g. annual catches must be a vector of non-negative real numbers), it demands careful software planning from the outset and is generally more extensible and easy to maintain that non-OOP code. ABT-MSE adopts the OOP paradigm, and includes seven principal object classes that describe:

(1) Operating model inputs (*OMI*), that are the correctly formatted data used by the M3 operating model:

(2) Operating models (*OM*), that are fitted M3 operating models and all inputs required to run an MSE;

(3) Observation processes (*Obs*), such as bias and imprecision in annual catch data;

(4) Management implementation error (*IE*), such as overages of the catch limit;

(5) MSE outputs (*MSE*), such as projections of biomass and exploitation rate for each MP and

(6) fishery data (*dset*), such as observations of annual catches and size composition data

See Figure 1 for a diagram of the relationships among these object (each object has complete documentation in the package e.g. class?OMI from the R console).

The primary objective of adopting the OOP paradigm was to standardize the formatting of data and support rapid building of operating models. For example, evaluating the robustness of management procedures across a range of operating models (*OM*).

***The OM object***

The primary purpose of the operating model object *OM*, is to aggregate all the information required to run an MSE and reproduce its results exactly. The package contains an operating model object for each of the 36 operating models of the reference set (OM\_1, OM\_2, etc). An OM object contains a certain number of historical simulations including calculated MSY reference points for each. In the MSE, these historical simulations branch in the future projections, one branch for each MP. Each branch (each MP) is subjected to an identical pattern of simulation conditions including productivity, observation error etc. Since MPs are compared on a level playing field, it takes substantially fewer simulations to reveal differences in their performance.

***The Data object***

Probably the most important object class to document for MP development is the data class *dset.* This is the format for simulated fishery data on which an MP is applied. Dset is a list object with a slot for each type of data. Table 2

*Developing an MP*

*Useful methods*

# Results

# Discussion

# Acknowledgements

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**Appendix**

***Software installation***

Download and install the latest version of R:

<https://cran.r-project.org/bin/windows/base/>

Download and install the latest version of RStudio: <https://www.rstudio.com/products/rstudio/download/#download>

***Package installation***

Save the library file ‘ABTMSE\_2.1.0.tar.gz’ to disk and then install from the R prompt in RStudio

> install.packages("C:/Downloads/ABTMSE\_2.1.0.tar.gz", repos = NULL, type="source")

***Required at the start of each R session***

> library(ABTMSE) # load the ABT-MSE library

> loadABT() # load all of the data objects

> sfInit(parallel=TRUE, cpus=detectCores()) # setup multicore processing

***Check package installation***

> checkMSE=new(‘MSE’) # run a test MSE

> plot(checkMSE) # plot the results

***Getting help***

> readme() # open the user guide in your internet browser

> class?MSE # get help on a class of ABTMSE objects

> class?OM

***Finding objects***

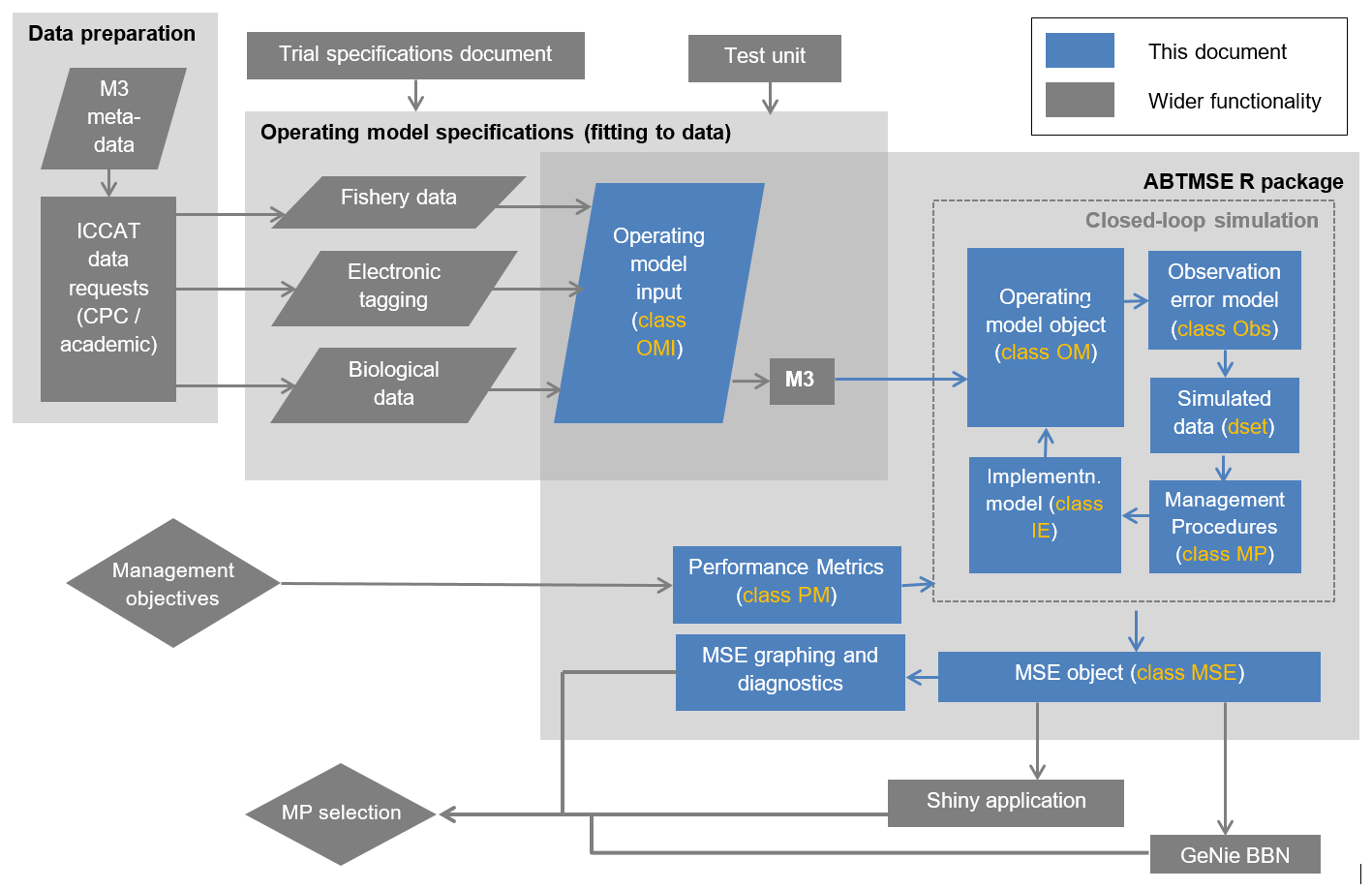
> avail(‘OM’) # list all of the available operating models

> Design # examine the design of the reference operating models

***Designing a new MP***

## Table 1. The format of the simulated data (object class dset) for use by management procedures.

|  |  |  |
| --- | --- | --- |
| **Slot** | **Description** | **Dimensions** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |



**Figure 1**. The design of the ABT-MSE software.

**Figure 1b**. Residuals for operation model fits (columns) to various assessment indices (rows)

**Figure 1c**. Residuals for operation model fits (columns) to various assessment indices (rows)

**Figure 1d**. Residuals for operation model fits (columns) to various assessment indices (rows)

**Figure 1e**. Residuals for operation model fits (columns) to various assessment indices (rows)

**Figure 2.** Predicted spawning biomass (East and West stocks) for each operating model (maximum posterior density estimates)

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