**A summary of reference operating models for Atlantic bluefin tuna management strategy evaluation**

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*SUMMARY*

To do last

*KEYWORDS*

*Population dynamics, migration, movement, bluefin*

# Introduction

Management Strategy Evaluation (MSE) uses operating models whcih represent credible hypotheses for population and fishery dynamics to test the performance of prospective management procedures. These management procedures may encompass a wide range of complexity from conventional stock assessments linked to harvest control rules (Hilborn 2003) through to simple empirical management procedures that calculate catch limits directly from resource monitoring data indices (Geromont and Butterworth 2014a;b, Kell et al. 2015).

MSE applications generally develop operating models from stock assessments that are fitted to data in order to ensure that model assumptions and estimated parameters are empirically credible (Punt et al. 2014, e.g. CCSBT 2011). In the case of Atlantic bluefin tuna, such a model requires enough complexity to capture the core uncertainties regarding Atlantic bluefin tuna dynamics (Fromentin et al. 2014, Leach et al. 2014). These include stock structure (Kell et al. 2012), stock mixing, migration (Fromentin and Lopuszanski 2014) and biases in observed data (e.g. annual catch data). Additionally the model should be able to accommodate the wide range of data that have been collected for Atlantic bluefin tuna including catch rate indices (Abid et al. 2015, Hanke et al. 2015, Kimoto et al. 2015, Lauretta and Brown 2015, Santiago et al. 2015, and Walter 2015), aerial surveys (Bonhommeau et al. 2010), length composition data, larval surveys (Ingram et al. 2015), electronic tagging data (Block et al. 2005) and stock of origin data (Rooker et al. 2014).

A custom operating model known as M3 (Carruthers et al. 2015a) was designed for Atlantic bluefin tuna that could simultaneously estimate the size, trajectory, spatio-temporal seasonal distribution and movement of both the Western and Eastern Atlantic stocks. The M3 model uses a range of data including seasonal / spatial catches, effort, electronic tagging, stock of origin, stock assessment CPUE indices and fishery independent indices (see Carruthers et al. 2015b for summary). In this paper I summarize conditioned M3 models (v1.4) that represent the reference operating models of the propose MSE for Atlantic bluefin tuna.

# Methods

## Data

Data description from Matt

## Reference operating models

## Preliminary MSE results

# Results

## Base operating model predictions

## Variability among reference operating models

## MSE projections

# Discussion

In many stock assessment settings estimation is complicated by model overparameterization, uninformative data and conflicting data. These problems persist even for the ‘typical assessment’ which has a single area, a single stock and has annual time steps. Fitting seasonal, spatial, multistock operating models for bluefin tuna is particularly challenging because it includes all of the difficulties associated with estimation of the ‘typical assessment’ but these are multiplied by a host of new challenges arising from the additional complexities of movement estimation and multiple stock structure.

A very common problem with typical assessments is that there is poor contrast among

Multstock contrast

Conflicting indices

Crypitic biomass

# Acknowledgements

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# References

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Carruthers, T. R., Powers, J. E., Lauretta, M.V., di Natale, A., Kell, L. 2015b. A summary of data to inform operating models in management strategy evaluation of Atlantic bluefin tuna. SCRS/2015/180.

## Table 1. The frequency of movement types of electronic and conventional tags originating from the Atlantic and Strait of Gibraltar. Note that multistage movement types (e.g. ‘To central Med via Balearic’) cannot be determined from conventional tag release and recapture information.

**Figure 1.**  Areas defined for studying the distribution of tags for Bluefin tunas tagged in the Atlantic which popped-off or were recovered in the various parts of the Mediterranean Sea.

**Figure 2.** Electronic tag tracks for all tags entering the Mediterranean originating in the Atlantic organized by movement type.

**Figure 3.** Electronic tag tracks for all tags entering the Mediterranean originating from the Strait of Gibraltar organized by movement type.

**Figure 4**. Heat map of daily electronic tag density.

Figure 5. Origin (western areas) of electronic and conventional tags entering the Mediterranean

Figure 6. Origin (Eastern areas) of electronic and conventional tags entering the Mediterranean

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