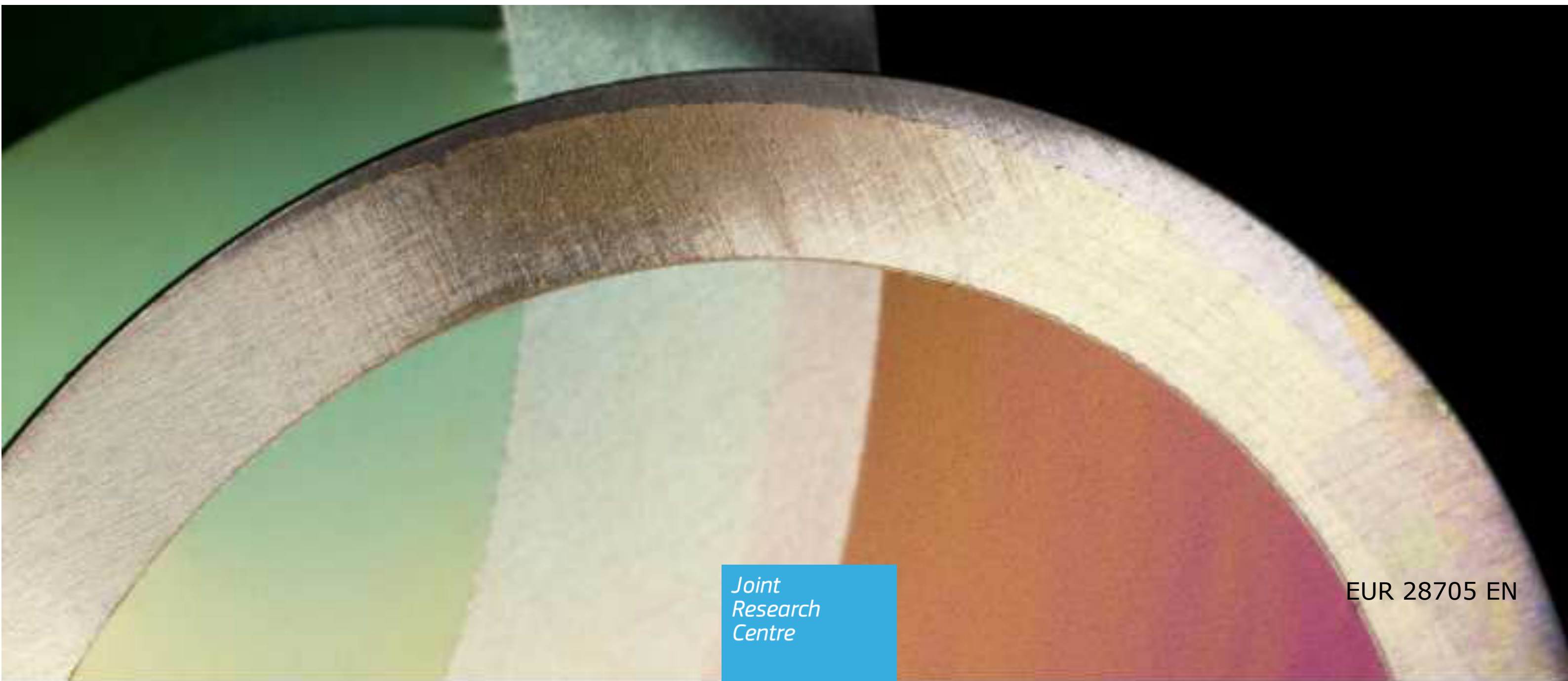
European Commission

JRC TECHNICAL REPORTS

Assessment for All initiative(a4a) Workshop on development of MSE algorithms with R/FLR/a4a

Ernesto Jardim, Finlay Scott, Iago Mosqueira, Leire Citores, Jennifer Devine, Simon Fischer, Leire Ibaibarriaga, Alessandro Mannini, Colin Millar, David Miller, Coilin Minto, Jose De Oliveira, Chato Osio, Agurtzane Urtizberea, Paris Vasilakopoulos, Laurie Kell



Joint Research Centre

EUR 28705 EN

Contact information

Name: Ernesto Jardim
Address: Joint Research Centre, Via Enrico Fermi 2749, TP 051, 21027 Ispra (VA), Italy
Email: ernesto.jardim@ec.europa.eu
Tel.: +39 0332 785311

JRC Science Hub
https://ec.europa.eu/jrc

JRC106750

EUR 28705 EN

PDF ISBN 978-92-79-71290-6 ISSN 1831-9424 doi:10.2760/18924

Luxembourg: Publications Office of the European Union, 2017

How to cite this report: Jardim, E., Scott, F., Mosqueira Sanchez, I., Citores, L., Devine, J., Fischer, S., Ibaibarriaga, L., Mannini, A., Millar, C., Miller, D., Minto, C., De Oliveira, J., Osio, G., Urtizberea, A., Vasilakopoulos, P. and Kell, L., *Assessment for All initiative(a4a) - Workshop on development of MSE algorithms with R/FLR/a4a,* EUR 28705 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-71290-6, doi:10.2760/18924, JRC106750

Assessment for All initiative(a4a) Workshop on development of MSE algorithms with R/FLR/a4a

Abstract: The a4a aims to develop a set of common methods and procedures to build a minimal standard MSE algorithm, which should allow the development of MSE simulations in an operational time frame. The JRC organized a workshop, 30/01-03/02 in Ispra, Italy, which was a mix of hands-on coding and discussion/implementation of concepts associated with MSEs.

Assessment for All initiative(a4a) Workshop on development of MSE algorithms with R/FLR/a4a

Ernesto Jardim, Finlay Scott, Iago Mosqueira, Leire Citores, Jennifer Devine, Simon Fischer, Leire Ibaibarriaga, Alessandro Mannini, Colin Millar, David Miller, Coilin Minto, Jose De Oliveira, Chato Osio, Agurtzane Urtizberea, Paris Vasilakopoulos, Laurie Kell

Contents

Abstract

The a4a approach to Management Strategies Evaluation (MSE) is to develop a set of common methods and procedures to build a minimal standard MSE algorithm. This has the most common elements of both uncertainty and management options. Such a tool set should allow for the development of MSE simulations for many fisheries in an operational time frame. Between the 30th of January and the 3rd of February, in Ispra, Italy, the JRC organized a workshop on development of MSE algorithms with R/FLR/a4a. The workshop was a mix of hands-on coding and discussion/implementation of concepts associated with MSEs. The participants used the most recent version of the a4a MSE code, modularized the most important processes and developed their own version of several processes so that the MSE could model and test alternative management procedures to the one initially coded.

1. Introduction

The a4a approach to Management Strategies Evaluation (MSE) is to develop a set of common methods and procedures to build a minimal standard MSE algorithm. This has the most common elements of both uncertainty and management options. Such a tool set should allow for the development of MSE simulations for many fisheries in an operational time frame.

The a4a MSE design uses a two step approach. The first step defines the 'standard' components of an MSE while the second step sets the details, for example the HCR or the OM conditioning.

The Workshop on development of MSE algorithms with R/FLR/a4a was a mix of hands-on coding and discussion/implementation of concepts associated with MSEs. The participants used the most recent version of the a4a MSE code, modularized the most important processes and developed their own version of several processes so that the MSE could model and test alternative management procedures to the one initially coded.

For background information on a4a check the website or the FLa4a introductory vignette[1].

2. Terms of Reference and agenda

2.1 Terms of Reference

Using as a basis the FLR/a4a MSE code:

- Discuss and revise the current design, in particular consider code modularization so that the distinct MSE elements can be "easily" changed/included,
- Implement/test suggested improvements as much as possible,
- Discuss and test strategies for parallelization,
- Discuss multi-species and/or multi-fleet analysis,
- Document code changes,
- Suggest future developments,

2.2 Agenda

The agenda of the meeting was:

- Monday
  - Welcome
  - Presentation of a4a MSE code
  - Presentation on tuna RFMOs MSE development
  - Discussion about MSE design
  - Discussion about implementation in the a4a MSE code
  - Discussion about parallelization and multi-species/multi-fleet analysis
  - Planning for next days work
- Tuesday - Coding and testing
- Wednesday - Coding and testing
- Thursday - Coding and testing
- Friday
  - Wrapping up and packing code snippets
  - Documentation
  - Close

[1] vignette("introduction", package="FLa4a")

3. MSE design and code development

The group of experts discussed the current design of the `a4a MSE` (Figure 1). The current design was considered to be generally correct. Several areas were identified for further improvement. For example, the distinction and interactions between the harvest control rule (function h()) and the management implementation (function k()) needs further consideration. Additionally, for management procedures based on indicators, the split between the observation error model (function o()) and the assessment/indicator estimation (function f()) was not always clear.

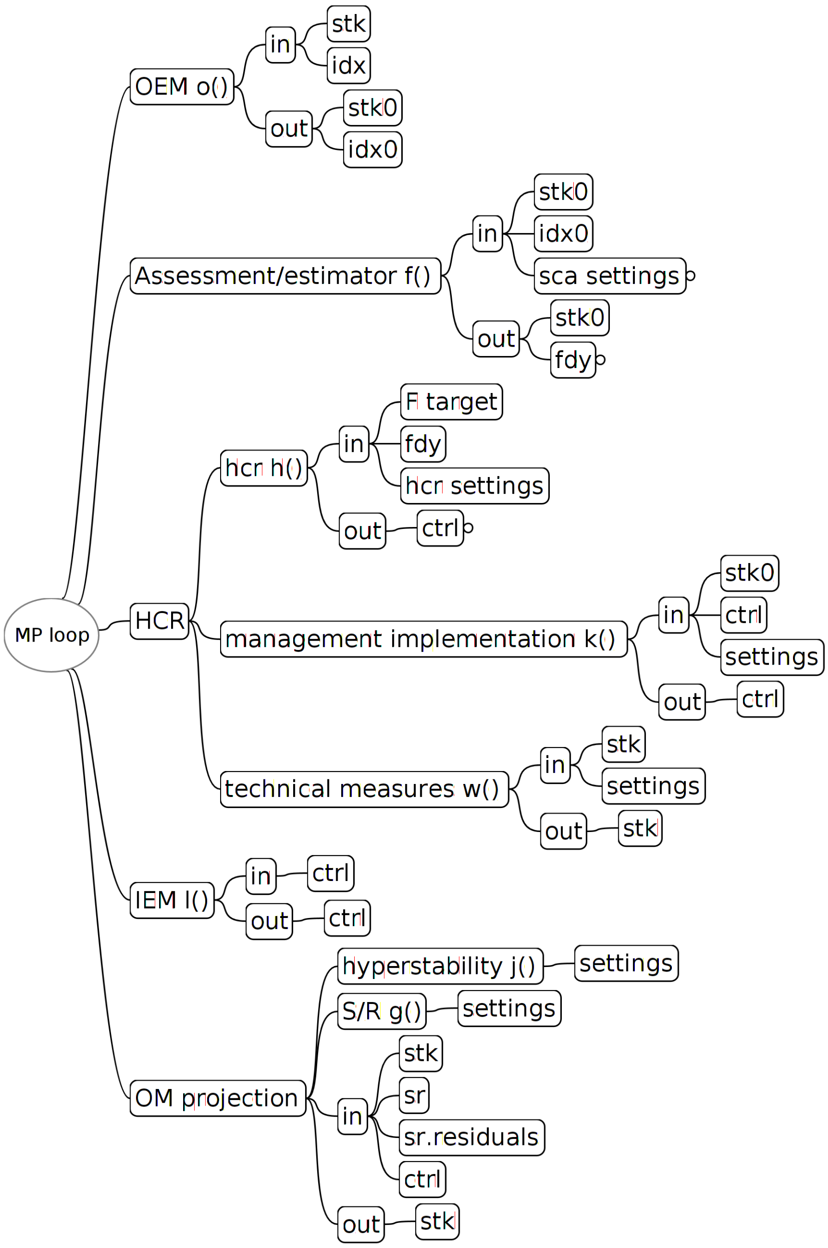


Figure 1: Management procedure loop implemented in the `a4a MSE` , including the input/output for each module. The functions in each module map with the functions described in the Annex.

From a generalization point of view, having these processes isolated makes the analysis clearer while providing flexibility. However, it's clear that documentation describing the analysis mut be available and each module must be well explained, including the mechanics of using each of them in the overall analysis and the interactions between them.

Several suggestions were lifted from the discussions and testing carried out.

- Use "wrapper" approach to mimic S4 dispatch. Explore the method used in function f() to allow the usage of several stock assessment methods, to introduce flexibility in each module. The most important advantage is to make it easy for users to develop their own functions. It may also reduce maintenance when compared with S4 methods. The disadvantage of this approach is that it's based on name matching, which makes it fragile.
- Scenarios and settings/control for each function. The process of passing settings to each module and defining scenarios requires development. It was set up for specific requests from DGMARE and STECF and requires generalization and flexibility.
- Control statistics. Need to develop the storage of control statistics, which are generated during the loop and provide information about each module. For example the convergence indicator of stock assessment models. This method will have to be flexible to allow the users to store the relevant information for each application.
- Performance statistics. To compute statistics to compare the different options being tested, a set of statistics are computed using the package "mse" of Iago Mosqueira (JRC). The list of statistics may require further discussion. However, the way this method is implemented is very flexible and can take all statistics which can be converted into an R formula.
- How to generate different indices. Management procedures may require abundance indices like CPUE, indices from acoustic survey, or even length-based indices. The generation of those indices in the observation error model is not trivial and require development of methods which can be quickly used.
- Methods to deal with non-convergence of some iterations. In some cases the stock assessment model does not converge, generating estimates which are not optimal and can be biased. Methods to deal which such cases automatically will have to be developed. It's not possible to interact with the code in each loop to manually deal with this problem.

4. Case studies

To test the current `a4a MSE` a set of case studies were developed using the same operating model. These cases studies implemented management procedures using:

- several stock assessment methods (including a dynamic biomass production model SPiCT, and XSA) and two different harvest control rules.
- indicators of stock status which are not based on a stock assessment, more in line with what is done for data-limited stocks; e.g. indicators based on biomass indices and mean individual length of large mature fish were tested.

The case studies were implemented by adapting the current `a4a MSE` code. This provided a good test of the generality of the current code as well as providing a guide to where improvements can be made. All changes were recorded and uploaded to the centralized repository.

Furthermore, a case study using a different operating model, based on the stock of Adriatic Anchovy, was also developed to test the use of stock assessment method SPICT.

5. Final comments

The testing and developing of code during the meeting constituted a hands-on revision of the current version of the MSE code, the FLa4a package and the FLR packages supporting it.

The results obtained showed that the code was already well prepared for the exercise of collaborative coding. In a short time frame (2 to 3 days) the group was able to implement 3 different management procedures, and explore expanding the separate processes to using several different stock assessment models, harvest control rules, etc.

The mathematical description of the management procedure (annex in section 6) was a key element to allow a common understanding of the model.

On the other hand several issues arose which require further consideration, namely the development and implementation of control statistics, scenarios and settings to be passed to each function, and the dispatching mechanism.

6. Annex - The a4a MSE algorithm

Assessment for All initiative(a4a)
The a4a Management Strategies Evaluation algorithm

Ernesto Jardim[1], Finlay Scott[1], and Iago Mosqueira[1]

[1]European Commission, Joint Research Centre, Sustainable resources directorate, Water and Marine Resources unit, 21027 Ispra (VA), Italy
*Corresponding author ernesto.jardim@jrc.ec.europa.eu

January 25, 2017

Abstract

This document presents the Management Strategies Evaluation algorithm developed in the JRC Assessment For All (a4a) initiative. Management Strategy Evaluation (MSE) is a complex simulation and forecasting procedure that takes into account structural and observational uncertainty on stock dynamics (growth, recruitment, maturity) and on its exploitation by fishing fleets (selectivity, effort). The MSE paradigm can lead to to the articulation of the central part of a decision making framework for fisheries management under uncertainty. The a4a approach to MSE is to develop a set of common methods and procedures to build a minimal standard MSE algorithm. This has the most common elements of both uncertainty and management options. Such a toolset should allow for the development of MSE simulations for many fisheries in an operational time frame. The a4a MSE design uses a two step approach. The first step defines the 'standard' components of an MSE while the second step sets the details, for example the HCR or the OM conditioning.

Contents

1 Introduction

Management Strategy Evaluation (MSE) is a complex simulation and forecasting procedure that takes into account structural and observational uncertainty on stock dynamics (growth, recruitment, maturity) and on its exploitation by fishing fleets (selectivity, effort). The MSE paradigm can lead to to the articulation of the central part of a decision making framework for fisheries management under uncertainty. The algorithms for development and application of MSE simulations are currently fairly diverse across different fora and fisheries, despite the obvious common elements and a shared overall structure.

Figure 1 shows the major components in the fisheries system, how they relate and interact, and their position in the the fisheries management cycle. The industry, in most cases comprising private companies, manage fleets of fishing vessels exploiting the public marine resources. Scientific institutions then collect data on both the activity of the industry and the biological resources, in order to build a model representing both fleets and stocks dynamics. These models form the basis for scientific advice to the corresponding management body on how distinct policy options will affect the whole system, fleets and stocks. This management body (government, international institution or RFMO) has the institutional responsibility of managing these public marine resources for the common good. This requires the setting of appropriate regulations to steer and limit the activity of fishing.

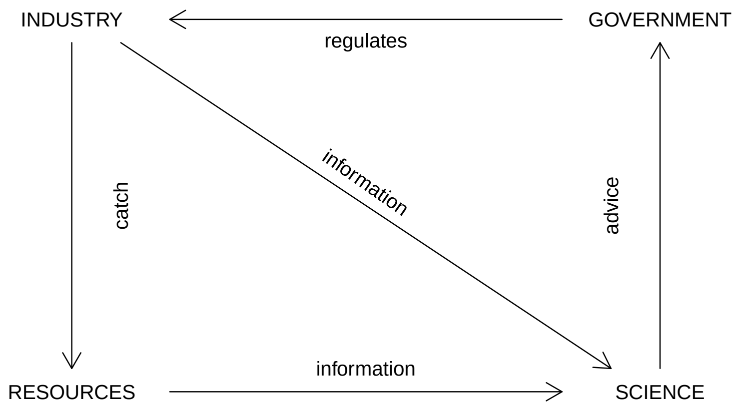


Figure 1: Management cycle

Figure 2 places the MSE components on top of the management cycle. The fleet and the stocks are embedded in an operating model, which is the representation of the natural and fishery systems. On the other side, the management procedure includes the stock assessment process, carried out by scientific institutions and experts, and the management process, carried out by the governmental institutions based on scientific advice. Two other important components are the observation error, which represents the process of collecting information for scientific purposes, and the implementation error, which accounts for differences between the intended results of the regulatory processes and the observed results, and incorporates the way the actors implement regulations and perceive the management objectives behind them.

The a4a approach to MSE is to develop a set of common methods and procedures to build a minimal standard MSE algorithm. This has the most common elements of both uncertainty and management options. Such a toolset should allow for the development of MSE simulations for many fisheries in an operational time frame.

The a4a MSE design uses a two step approach. The first step defines the 'standard' components of an MSE while the second step sets the details, for example the HCR or the OM conditioning.

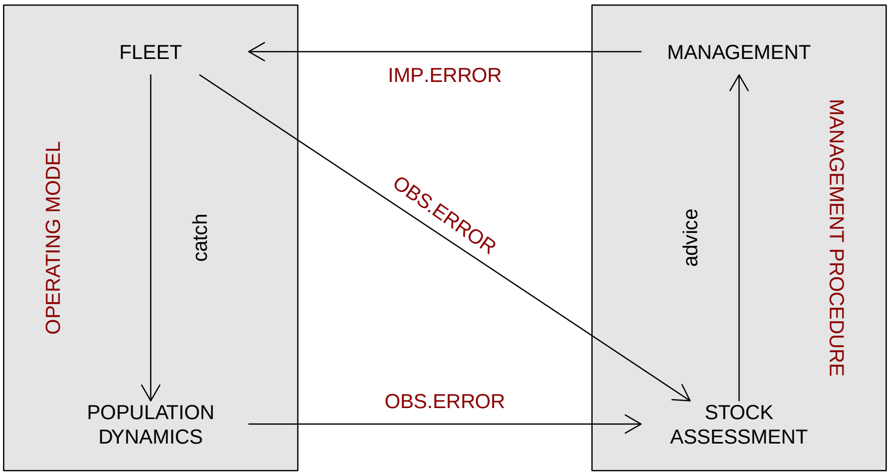


Figure 2: Management Strategies Evaluation

For background information on `a4a` check the `FLa4a` introductory vignette[1].

For more information on the `a4a` methodologies refer to Jardim, et.al, 2014, Millar, et.al, 2014 and Scott, et.al, 2016.

2 Notation and Definition of variables

The following notation will be used for the defined variables, functions and indices. Variables in the Operating Model (OM) are always uppercase, whiles variables in the Management Procedure (MP) are lowercase, *e.g.* catch C in OM c in the MP. Quantities estimated within the MP, *e.g.* fishing mortality by a stock assessment model, will use the uppercase with a hat, *e.g.* $\hat{F}$. The same will apply to functions which are estimated within the MP, *e.g.* the stock-recruitment function[2]. The target value that results from a decision process, *e.g.* the application of a harvest control rule, is identified by a tilde, $\tilde{F}$. Indices will always use lowercase, with their maximum value represented by the corresponding uppercase letter, *e.g.* ages as $a = 1 \ldots A$. Table 1 presents the variables used in this document.

[1] `vignette("introduction", package="FLa4a")`

[2] The S/R estimation means not only the parameters but also the choice of the functional form, which depends of the perception of the stock on that moment.

[3] Either in terms of catch-per-unit-effort and abundance or fishing mortality and effort.

Subject	Notation	Description
Variables		
	N	population abundance in number of individuals
	R	recruitment in number of individuals
	F	fishing mortality rate
	M	natural mortality rate
	B	mature biomass in weight
	W	individual mean weight
	P	percentage of mature fish
	C	catch in number of individuals
	Y	yield in weight
	Q	fleet catchability
	S	fleet selectivity
	E	fleet effort
	V	indicator of stock status
	D	abundance index
Functions		
	g	stock-recruitment function
	j	hyper(hypo)stability function [3]
	f	stock assessment model or indicator
	h	management decision function (aka harvest control rule)
	k	implementation function
	w	technical measures function
	l	implementation error function
	o	observation error function
Other		
	μ	expected value
	σ^2,Σ	variance or covariance matrix
	θ	set of parameters
	ϕ	median
	LN	lognormal probability density distribution
Indices		
	$a = 1 \ldots A$	age
	$t = 1 \ldots T$	years
	$i = 1 \ldots N$	iterations
	trg	target

Table 1: Variables, indices and function, and the notation used to refer to them in the text.

3 Operating model

The operating model includes the population dynamics of the stock

$$N_{a+1,t+1} = N_{a,t} \exp(-F_{a,t} - M_{a,t})$$

while for the first age, recruitment is estimated following some function of the adult biomass $G(B)$

$$N_{0,t} = R_t = g(B_t)$$

which is in turn dependent on the proportion of mature individuals at age (P_a) and the mean weight at age in the stock (W_a)

$$B_t = \sum_{a=1}^{A} W_{a,t} N_{a,t} P_{a,t}$$

Calculation of catch at age in numbers follows the standard Baranov equation

$$C_{a,t} = \frac{F_{a,t}}{F_{a,t} + M_{a,t}} N_{a,t}(1 - \exp(-F_{a,t} - M_{a,t}))$$

while total yield in weight is calculated as

$$Y_t = \sum_{a=1}^{A} W_{a,t} C_{a,t}$$

Fishing mortality at age is related to effort through selectivity-at-age, catchability and the (possibly non-linear) function (j)

$$F_{a,t} = S_{a,t} Q_t j(E_t)$$

4 Observation error model

4.1 Catch in number of individuals, $c_{a,t}$

Catch in numbers-at-age[4] are observed with error

$$c_{a,t} = C_{a,t} \exp \epsilon_c$$

where ϵ_c is log-normally distributed

$$\epsilon_c \sim LN(\mu_c, \sigma_c^2)$$

4.2 Index of abundance, $d_{a,t}$

The index of abundance is observed with error, through catchability, which defines its relationship with the stock abundance-at-age

$$d_{a,t} = N_{a,t} q_{a,t} \exp \epsilon_d$$

where ϵ_d is log-normally distributed

$$\epsilon_d \sim LN(\mu_d, \sigma_d^2)$$

5 Management procedure

5.1 Assessment/Estimator of stock statistics

Input into the decision rule includes the indicator of current status ($\hat{V}$), given the available information, in this case catches (c) and an index of abundance (d)

$$\hat{V} = f(c_{a,t}, d_{a,t} | \theta_f)$$

where

$$V =\sim LN(\mu_v, \Sigma_v)$$

transformed through some suitable function (f), for example a stock assessment. The precise inputs, and the elements in θ will depend on the precise form of the HCR. In an age based system, for example, these would be estimates of F_t, B_t and C_t[5].

The stock assessment component of the status estimator might include an stock-recruitment relationship

$$\hat{N}_{0,t} = \hat{g}(\hat{B}_t)$$

$\hat{g}$ is the stock recruitment relationship estimated within the MP and represents the perceived dynamics, which differs from G, included in the OM.

5.2 Management Decision/Harvest Control Rule

In this code it is assumed that management is carried out through changes in F, although the implementation of those changes can be done through a combination of systems: input control, output control and/or technical measures. A first decision is made about the target fishing mortality for next year. The result of this decision is afterwards translated into an *implementation variable*.

$$\tilde{F}_{a+1,t+1} = h(\hat{F}_{a-1,t-1}, \hat{F}_{trg}, t_{trg})$$

[4] Generally derived from sampling of numbers-at-length and a growth model or age-length key

[5] Which in our notation would be represented by $\hat{F}_t$, $\hat{B}_t$ and $\hat{C}_t$.

5.3 Management system

This process translates the management decision into a regulation, for example fishing opportunities, or days at sea. It mimics the process used to formulate the advice from the scientific estimates of likely effects of different fishing mortality levels.

5.3.1 Input/effort management

$$\tilde{E}_{t+1} = k(\tilde{F}_{a+1,t+1}|\theta_k) \exp \epsilon_{\tilde{E}}$$

$$\epsilon_{\tilde{E}} \sim LN(\mu_{\tilde{E}}, \sigma^2_{\tilde{E}})$$

5.3.2 Output/TAC management

$$\tilde{C}_{t+1} = k(\tilde{F}_{a+1,t+1}|\theta_k) \exp \epsilon_{\tilde{C}}$$

$$\epsilon_{\tilde{C}} \sim LN(\mu_{\tilde{C}}, \sigma^2_{\tilde{C}})$$

5.3.3 Technical measures

Technical measures affect the exploitation by imposing a shift in the age structure of the catch. Both gear selectivity or availability can be mimicked using shifts in the age structure of the exploitation. The overall level of exploitation is dealt by the input or output controls and technical measures are seen as a complement.

$$\tilde{S}_{a,t+1} = w(\hat{S}_{a,t}|\theta_w) \exp \epsilon_{\tilde{S}}$$

$$\epsilon_{\tilde{S}} \sim LN(\mu_{\tilde{S}}, \sigma^2_{\tilde{S}})$$

6 Implementation error model

$$F_{a,t+1} = l(\{\tilde{E}_{t+1}, \tilde{C}_{t+1}\}, \tilde{S}_{a,t+1}|\theta_l) \exp \epsilon_F$$

$$\epsilon_F \sim LN(\mu_F, \sigma^2_F)$$

7 Summary

Flexible framework to run single species MSE analysis. Each MSE element and process has a function that allows the user to set its own approach:

- Fleet dynamics - $j()$
- Stock-recruitment relationship - $g()$
- Observation error model - $o()$
- Stock assessment model or status indicator - $\{f(), \hat{g}()\}$
- Harvest control rule - $h()$
- Management system - $k()$
- Technical measures - $w()$
- Implementation error model - $l()$

7. Annex - The a4a generic MP R code

```
################################################################################
# EJ(20150519)
# NOTE: The first intermediate year must be the last on the assessment so that
#   the OM has information for the MPs assessment/intermediate year.
################################################################################

#===============================================================================
# data, libraries and auxiliary functions
#===============================================================================
rm(list=ls())
library(FLa4a)
library(FLash)
library(FLAssess)
library(FLXSA)
library(ggplotFL)
library(FLBRP)
library(parallel)
source("funs.R")
source("oemFun.R")
source("fFun.R")
source("hcrFun.R")
source("kFun.R")
source("jFun.R")
source("iemFun.R")
source("project_om.R")
source("wFun.R")
set.seed(0)
while("file:om.RData" %in% search()) detach("file:om.RData")
attach("om.RData")
# Skinny the FLIndices to just the first one to speed up
idx <- idcs[1]

#===============================================================================
# Variables and settings
#===============================================================================

it <- dim(stock(stk))[6] # iterations
# initial year
iy <- an(dimnames(catch(stk))$year[which(is.na(iter(catch(stk),1)))[1]]) - 1 #
last year of data before NA in catch - dodgy
fy <- range(stk)["maxyear"] # final year to project to
vy <- ac(iy:fy)
fmsy_year <- 2020
y0 <- range(stk)["minyear"] # initial data year
nsqy <- 3

## blank container for convergence diagnostics
converge <- NULL

#===============================================================================
# Run simulations
#===============================================================================

scenarios <- data.frame(
        id="test",
        management="Amendment",
        managementType=c("effort"),
        correction = FALSE,
        ftrgType = "fmsy",
        ftrg = c(refpts(brp)["msy","harvest"]),
        mxy = fmsy_year,
        techMeasures=FALSE,
        techMeasuresEffect=NA,
        techMeasuresEffectSD=NA,
        stk = "stk",
        stringsAsFactors=FALSE, # Probably not needed
        biomassRecovery=NA,
        refptsError=FALSE,
        iem=TRUE,
```

```
        multiplicative=TRUE,
        beta.om=1,
        bsafe = min(iterMedians(ssb(stk)), na.rm=TRUE)*qnorm(0.975),
        blim = min(iterMedians(ssb(stk)), na.rm=TRUE),
        runAssessment = TRUE,
        assessmentMethod = "xsa.wrapper", # "sca.wrapper",
        sr = "srbh",
        sr.res = "srbh.res", # or NA if no residuals
        sr.res.mult = TRUE # or NA if no residuals
)

dti <- date()
res3 <- mclapply(split(scenarios, 1:nrow(scenarios)), function(scn){
    set.seed(0)
    # Get the stock and sr objects
    stk <- get(scn$stk)
    name(stk) <- scn$id
    # Set list of SRR variables
    srr <- list(sr = get(scn$sr))
    if (!is.na(scn$sr.res)){
        srr$sr.res <- get(scn$sr.res)
        srr$sr.res.mult <- scn$sr.res.mult
    }

    # Fixed objects with intermediate year included
    TAC <- FLQuant(NA, dimnames=list(TAC="all", year=vy, iter=1:it))
    TAC[,ac(iy)] <- catch(stk)[,ac(iy)]
    # Target F
    EFF <- FLQuant(NA, dimnames=list(EFF="all", year=vy, iter=1:it))
    EFF[,ac(iy)] <- fbar(stk)[,ac(iy)]
    EFF0 <- EFF[rep(1,6)]

    # go fish
    for(i in vy[-length(vy)]){
        gc()
        ay <- an(i)
        cat(i, " > ")
        vy0 <- 1:(ay-y0) # data years (positions vector) - one less than current
year
        sqy <- (ay-y0-nsqy+1):(ay-y0) # status quo years (positions vector) - one
less than current year

        #==============================================================
        #----- OEM ------
        # function o()
        # Generating the 'perceived' stock from the 'true' stock
        # EJ, Jose
        #oem <- o(stk, idx, i, vy0)
        oem <- o(stk, idx)
        stk0 <- oem$stk
        idx0 <- oem$idx
        idx <- oem$idx.om

        #==============================================================
        #----- Assessment/Estimator of stock statistics ------
        # Is perceived stock based on an assessment?
        # function f()
        # Coilin, Agurtzane, Leire
        if (scn$runAssessment){
            out.assess <- f(assessmentMethod = scn$assessmentMethod, stk0 = stk0,
idx0 = idx0)
            stk0 <- out.assess$stk0
            converge <- rbind(converge, c(i, out.assess$converge))
        }

        fdy <- fbar(stk0)[,ac(ay-1)] # Perceived F is final perceived data year
        EFF0[1,ac(ay)] <- fdy

        #==============================================================
```

```
        #------ HCR ------
        # function h()
        # Colin, Simon
        # apply hcr
        res <- h(stk0 = stk0, scn = scn, fdy = fdy, ay = ay, EFF = EFF,
                 EFF0 = EFF0)
        # extract estimated F targets and control object
        EFF <- res$EFF
        EFF0 <- res$EFF0
        ctrl <- res$ctrl

        #============================================================
        # management implementation
        # function k()
        # David, Jennifer
        kRes <- k(stk0 = stk0, SCN = scn, TAC = TAC, EFF = EFF, EFF0 = EFF0, ctrl
= ctrl, assessmentYear = ay, SQy = sqy)
        stk0 <- kRes$stk0
        EFF <- kRes$EFF
        EFF0 <- kRes$EFF0
        TAC <- kRes$TAC
        ctrl <- kRes$ctrl

        #============================================================
        # Technical measures
        # function w()
        # Paris, Ale
        stk <- w(stk, scn, ay, vy, fy)

        #============================================================
        #--------- IEM --------------
        # function l()
        # iem parameters set at top: iemset
        # Puts random noise on top - mult or additive
        # EJ
        if(scn$iem) ctrl <- l(ctrl)
        EFF0[5,ac(ay+1)] <- ctrl@trgtArray[,"val",]

        #============================================================
        #--------- OM --------------
        # hyperstability or hyperdepletion
        # function j()
        ctrl <- j(ctrl, beta = scn$beta.om)
        EFF0[6,ac(ay+1)] <- ctrl@trgtArray[,"val",]
        # Project the OM
        # uses function g()
        # Note that sr is now a list of:
        # srr = FLSR (compulsory)
        # sr.res = residuals (if used)
        # sr.res.mult (if used)
        stk <- project_om(stk=stk, srr=srr, ctrl=ctrl)
    }
    cat("\n")
    attr(stk, "EFF") <- EFF0
    attr(stk, "converge") <- converge
    stk
}, mc.cores=1)

dtf <- date()

#q("yes")
```

List of figures

KJ-NA-28705-EN-N

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office

doi:10.2760/18924

ISBN 978-92-79-71290-6