Management Strategy Evaluation of Biomass Dynamic Management Procedures

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Introduction

Management Strategy Evaluation (MSE) compares the ability of different combinations of data collection schemes, methods of analysis and regulations, i.e. a Management Procedure (MP), to achieve management objectives. This is done this by simulating a plausible range of uncertainty in the resource dynamics using an Operating Model (OM), that is used to generate the type of observations that are available from the fishery and stock using an Observation Error Model (OEM). This allows the "best" option from a set of candidate strategies to be identified, or to determine how well an existing strategy performs.

To conduct an MSE requires six steps; namely i) identification of management objectives; ii) selection of hypotheses for the OM; iii) conditioning the OM based on data and knowledge; iv) identifying candidate management strategies and coding these as an MP; v) running the MP as feedback control in order to simulate the long-term impact of management; and vi) identifying the MP that robustly meets the management objectives.

mpb

The mpb package provides methods for conducting stock assessments and simulation testing management advice based on biomass stock assessments. It is part of FLR Kell et al. (2007) which has a variety of packages and methods for data analysis, modelling MPs and conditioning OMs.

```
library(FLCore)
library(mpb)
library(ggplotFL)
```

Management objectives

THE PERFORMANCE of alternative stategies are compared with respect to their ability to robustly deliver a range of management objectives, e.g. high catch, high catch rate, low variability in catches, high fishery and population resilience to environmental and other shocks, low catches of nominated by-catch or by- product species.

Biological reference points are modelled by the `FLBRP` package, while management objectives can be summarised by the `kobe` package.

```
library(FLBRP)
library(kobe)
```

Operating Model

The OM represents simulated versions of reality for a range of hypotheses, that represent the main uncertainties, about resource dynamics. There are many alternative ways to do this (e.g. **?**), for example a stock assessment paridigm could be used to develop the OM, or an OM could be conditioned on range of ecological and economic hypotheses about the factors that drive the system Punt et al. (2014). For example the `readMFCL` in `FLCore` can be used to read in output from Multifan-CL.

The use of an assessment model as an OM implies that assessment models describe nature almost perfectly, however, if a Management Procedure (MP) cannot perform well when reality is as simple as implied by an assessment model it is unlikely to perform adequately for more realistic representations of uncertainty about resource dynamics.

There are many important processes, however, that are not modelled in stock assessments and affect the robustness of control systems. Therefore to ensure a control system is robust also requires OMs to be conditioned based on expert beliefs and other apriori information about the processes that may affect the behaviour of management systems in the future. I.e. the focus is on the future, not on fitting historical data as when conditioning an OM on a stock assessment. This is a less data, and more hypothesis-orientated approach. The `FLife` package is designed to allow a variety of biological and ecological processes to be modelled.

Two example datasets are provided in `mpb`, derived from theMultifan-CL assessment of North Atlantic albacore, that can be used to build an OM based on a stock assessment model

```
data(eql)
data(om)
```

`om` is an `FLStock` object that models the age based dynamics

```
library(FLBRP)

ggplot(as.data.frame(FLQuants(eql,"stock.wt","m","mat","catch.sel"
  geom_line(aes(age,data))+
  facet_wrap(~qname,scale="free")+
  theme_bw()+
  theme(legend.position="bottom")
```

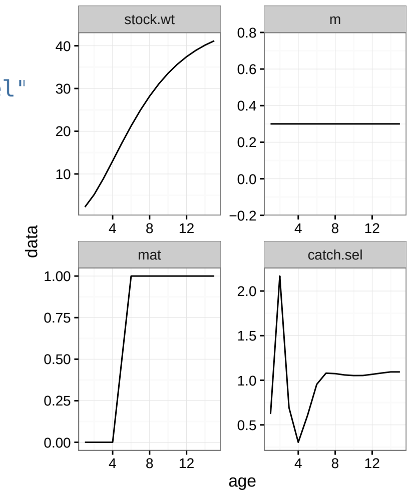


Figure 1: Biological Parameters

While FLBRP models the life history parameters, expected dynamics and biological reference points

```
plot(eql)+
  theme_bw()+
  theme(legend.position="bottom")
```

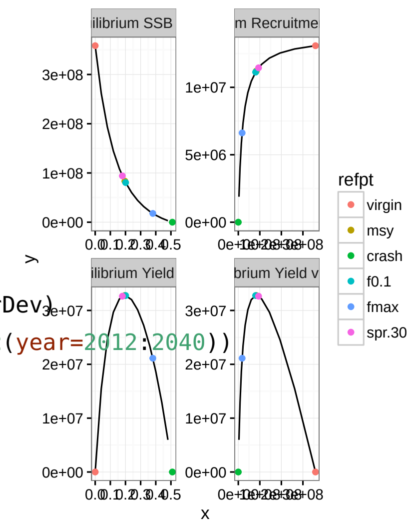


Figure 2: Expected Dynamics

Stochasticity can be added to the time series, e.g. in recent and future recruitment

```
om=propagate(om,100)
srDev=FLQuant(0,dimnames=list(year=2000:2040))
srDev=rlnorm(100,srDev,0.3)
```

and the stock object extended into the future

```
om=fwd(om,catch=catch(om)[,ac(2000:2011)],sr=eql,sr.residuals=srDev)
harvest=as.FLQuant(c(refpts(eql)["msy","harvest"]),dimnames=list(year=2012:2040))

om=fwdWindow(om,eql,end=2040)
om=fwd(om,f=harvest,sr=eql,sr.residuals=srDev)
plot(om)+
  theme_bw()


plot(om)+
  scale_x_continuous(limits=c(1930,2010))+
  theme_bw()
```

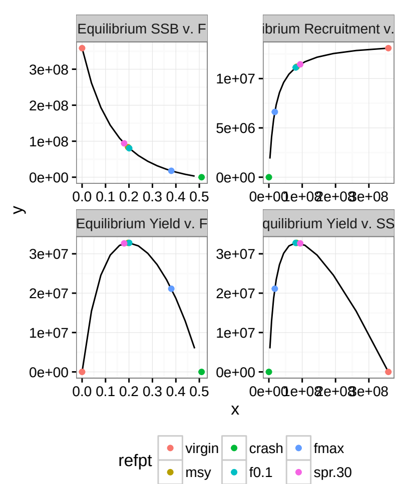
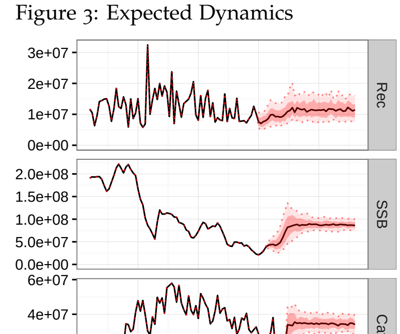


Figure 3: Expected Dynamics

Alternative hypotheses about the dynamics can be modelled by FLife package, e.g. diferent functional forms for processes like natural mortality and density dependence in processes other than stock recruitment.

```
options(warn=-1)
library(FLife)
```

Observation Error Model



PSUEDO DATA are simulated using the OEM, e.g. for catch per unit effort (CPUE)

```
uDev=FLQuant(0,dimnames=list(year=ac(dims(eql)["minyear"]):ac(dims(eql)["maxyear"])))
uDev=rlnorm(100,uDev,0.3)

cpue=oem(om)
plot(cpue)

#geom_path(aes(year,data),data=as.data.frame(iter(cpue,11)))
```

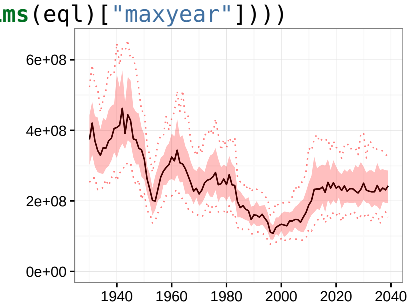


Figure 6: Simulated CPUE series

Management strategies

MANANGEMENT PROCEDURES based on a stock assessment reference points, and a HCR can be used to set preagreed management regulations such as a total allowable catch (TAC). This is done using the `biodyn` class. First a object has to be created, the easiest way to do this is coerce the `eql` object holding the age based population parameters

```
mp=FLBRP2biodyn(eql,"biodyn")
```

Initial guesses need to be provided for the production function and the nuisance parameters catchability (q) and (σ)

```
modelParams=mpb:::modelParams
setParams(mp)=cpue
```

The `control` slot providesthe initial guesses, upper and lower bounds (`min` and `max`), and the `phase` for each parameter.

```
setControl(mp)=params(mp)
```

Running

The Management Procedure (MP) is then run as

FEEDBACK CONTROL in order to simulate the long-term impact of management.

This can be done by the `mseBiodyn` method.

Example

OM

```
load("/home/laurie/Desktop/tmp/mpb-mse.RData")
source('~/Desktop/flr/mpb/R/biodyn-msy.R')
```

```
srDev=FLQuant(0,dimnames=list(year=2000:2040))
srDev=rlnorm(100,srDev,0.3)
```

OEM

```
uDev=FLQuant(0,dimnames=list(year=ac(dims(eql)["minyear"]):ac(dims(eql)["maxyear"])))
uDev=rlnorm(100,uDev,0.3)

omega =1
refB  =1
qTrend=0
```

MP

```
hcrPar=function(mp,ftar=0.70,btrig=0.60,fmin=0-01,blim=0.001)
          hcrParam(ftar =ftar *fmsy(mp),
                   btrig=btrig*bmsy(mp),
                   fmin =fmin *fmsy(mp),
                   blim =blim *bmsy(mp))
bndF=NULL
bndTac=NULL
maxF=1.0
```

Running

```
end=range(om)["maxyear"]
start=end-30
interval=3

## Get number of iterations in OM
nits=c(om=dims(om)$iter, eql=dims(params(eql))$iter, rsdl=dims(srDev)$iter)
if (length(unique(nits))>=2 & !(1 %in% nits)) ("Stop, iters not '1 or n' in OM")
if (nits['om']==1) stock(om)=propagate(stock(om),max(nits))

## Cut in capacity
maxF=mean(apply(fbar(window(om,end=start)),6,max)*maxF)

#### Observation Error (OEM) setup #######################
## Random variation for CPUE
cpue=oem(window(om,end=start),cv=uDev,fishDepend=TRUE)
if (!("FLQuant"%in%is(qTrend)))
  qTrend=FLQuant(cumprod(rep(1+qTrend,(end+interval-as.numeric(dims(cpue)["minyear"])+1))),
                 dimnames=list(year=range(om)["minyear"]:(end+interval)))
cpue=cpue*qTrend[,dimnames(cpue)$year]
```

```
plot(cpue)

iYr = seq(start,range(om,'maxyear'),interval)[1]

#### OEM
## use data from last year
catch(mp)=window(catch(om),end=iYr-1)
cpue=window(cpue,end=iYr-1)
cpue[,ac(iYr-(interval:1))]=oem(om[,ac(iYr-(interval:0))],uDev,fishDepend=TRUE)
cpue[,ac(iYr-(interval:1))]=cpue[,ac(iYr-(interval:1))]*qTrend[,ac(iYr-(interval:1))]

#### Management Procedure
## fit
mp =fit(mp,cpue)
mp =mpb:::fwd(mp,catch=catch(om)[,ac(iYr)])

## HCR
hcrP=hcrPar(mp)
tac=mpb:::hcr(mp,yr=iYr-1,hyr=(iYr+1):end,tac=TRUE)[,-1]

#### Operating Model feedforward
om=fwd(om,catch=tac,maxF=maxF,sr=eql,sr.residuals=srDev)

plot(om)
```

Identifying the MPs that robustly meet management objectives.

Summary stats

```
library(kobe)
```

Running an MSE

References

Kell, L.T., I. Mosqueira, P. Grosjean, J.M. Fromentin, D. Garcia, R. Hillary, E. Jardim, et al. 2007. "FLR: An Open-Source Framework for the Evaluation and Development of Management Strategies." *ICES J. Mar. Sci.* 64 (4): 640.

Punt, Andr?? E., Teresa A'mar, Nicholas A. Bond, Douglas S. Butterworth, Carryn L. de Moor, Jos?? A. A. De Oliveira, Melissa A. Haltuch, Anne B. Hollowed, and Cody Szuwalski. 2014. "Fisheries Management Under Climate and Environmental Uncertainty: Control

Rules and Performance Simulation." *ICES Journal of Marine Science: Journal Du Conseil* 71 (8): 2208–20. doi:10.1093/icesjms/fst057.