

Package ‘MSEtool’

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Type Package

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Description Simulation tools for management strategy evaluation are provided for the 'DLMtool' operating model to inform data-rich fisheries.

'MSEtool' provides complementary assessment models of varying complexity with standardized reporting, diagnostic tools for evaluating assessment models within closed-loop simulation, and helper functions for building more complex operating models and model-based management procedures.

License GPL-3

Depends R (>= 3.3.0), DLMtool (>= 5.3.1)

Imports MASS, TMB, coda, corpcor, dplyr, gplots, grDevices, graphics, methods, mvtnorm, reshape2, snowfall, stats, utils, abind, rmarkdown

LinkingTo TMB, RcppEigen

LazyData yes

LazyLoad yes

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Suggests knitr, testthat, r4ss, shiny

VignetteBuilder knitr

URL <http://www.datalimitedtoolkit.org>

BugReports <https://github.com/tcarruth/MSEtool/issues>

NeedsCompilation yes

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Description

Simulation tools for management strategy evaluation are provided for the DLMtool operating model to inform data-rich fisheries. MSEtool provides complementary assessment models of varying complexity with standardized reporting, diagnostic tools for evaluating assessment models within closed-loop simulation, and helper functions for building more complex operating models and management procedures.

How to use MSEtool

The main features of MSEtool are the assessment models and the ability to make model-based management procedures by combining assessment models with harvest control rules. Such MPs can be used and tested in management strategy evaluation with DLMtool operating models. An overview of these features is available in the [MSEtool vignette](#).

The following assessment models are available:

- [Surplus production](#) (SP, SP_SS, SP_Fox, and spict)
- [Delay difference](#) (DD, cDD, DD_SS, and cDD_SS)
- [Statistical catch-at-age](#) (SCA, SCA2, and SCA_Pope)
- Simple Stock Synthesis (SSS which implements [SCA_Pope](#) with fixed depletion assumption)
- [Virtual population analysis](#) (VPA)

The [SRA_scope](#) model can be used to condition DLMtool operating models from real data. Information can be found [here](#).

MSEtool also contains [multiMSE](#), a platform for multi-stock and multi-fleet operating models based on components from DLMtool. An overview of multiMSE is available in the [multiMSE vignette](#).

All MSEtool vignettes can also be viewed by typing `browseVignettes("MSEtool")` into the R console or through the MSEtool webpage on [CRAN](#).

Additional links

See the [DLMtool User Guide](#) for a detailed description of how to use the DLMtool package.

See the [Data-Limited Toolkit Website](#) for more information on DLMtool, including an interactive demo of the main features of the toolkit, information on case studies where the toolkit has been applied, and more about the history and development of the DLMtool.

Author(s)

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References

Carruthers, T.R., Punt, A.E., Walters, C.J., MacCall, A., McAllister, M.K., Dick, E.J., Cope, J. 2014. Evaluating methods for setting catch limits in data-limited fisheries. *Fisheries Research*. 153: 48-68.

Carruthers, T.R., Kell, L.T., Butterworth, D.S., Maunder, M.N., Geromont, H.F., Walters, C., McAllister, M.K., Hillary, R., Levontin, P., Kitakado, T., Davies, C.R. Performance review of simple management procedures. *ICES Journal of Marine Science*. 73: 464-482.

Albacore_TwoFleet *A two-fleet Albacore operating model*

Description

A generic operating model for an albacore stock with two fishing fleets. The first fleet has dome-shaped selectivity (similar to a baitboat fleet) while the second fleet exhibits logistic selectivity (such as a longline fleet). With the CatchFrac slot, we generate a 30 ratio between the baitboat-longline fleets in the most recent historical year.

Usage

```
Albacore_TwoFleet
```

Format

An object of class [MOM](#).

Examples

```
## Plot historical effort and selectivity between the 2 fleets
plot(Albacore_TwoFleet)

## Generate data (e.g., catch, length comps) from the fleets
Hist <- multiMSE(Albacore_TwoFleet, Hist = TRUE)
DataList <- Hist$Data
```

Assessment-class	Class-Assessment
------------------	------------------

Description

An S4 class that contains assessment output. Created from a function of class Assess.

Slots

Model Name of the assessment model.

Name Name of Data object.

conv Logical. Whether the assessment model converged (defined by whether TMB returned a positive-definite covariance matrix for the model).

UMSY Estimate of exploitation at maximum sustainable yield.

FMSY Estimate of instantaneous fishing mortality rate at maximum sustainable yield.

MSY Estimate of maximum sustainable yield.

BMSY Biomass at maximum sustainable yield.

SSBMSY Spawning stock biomass at maximum sustainable yield.

VBMSY Vulnerable biomass at maximum sustainable yield.

B0 Biomass at unfished equilibrium.

R0 Recruitment at unfished equilibrium.

N0 Abundance at unfished equilibrium.

SSB0 Spawning stock biomass at unfished equilibrium.

VB0 Vulnerable biomass at unfished equilibrium.

h Steepness.

U Time series of exploitation.

U_UMSY Time series of relative exploitation.

FMort Time series of instantaneous fishing mortality.

F_FMSY Time series of fishing mortality relative to MSY.

B Time series of biomass.

B_BMSY Time series of biomass relative to MSY.

B_B0 Time series of depletion.

SSB Time series of spawning stock biomass.

SSB_SSBMSY Time series of spawning stock biomass relative to MSY.

SSB_SSB0 Time series of spawning stock depletion.

VB Time series of vulnerable biomass.

VB_VBMSY Time series of vulnerable biomass relative to MSY.

VB_VB0 Time series of vulnerable biomass depletion.

R Time series of recruitment.
N Time series of population abundance.
N_at_age Time series of numbers-at-age matrix.
Selectivity Selectivity-at-age matrix.
Obs_Catch Observed catch.
Obs_Index Observed index.
Obs_C_at_age Observed catch-at-age matrix.
Catch Predicted catch.
Index Predicted index.
C_at_age Predicted catch-at-age matrix.
Dev A vector of estimated deviation parameters.
Dev_type A description of the deviation parameters, e.g. "log recruitment deviations".
NLL Negative log-likelihood. A vector for the total likelihood, integrated across random effects if applicable, components, and penalty term (applied when $U > 0.975$ in any year).
SE_UMSY Standard error of UMSY estimate.
SE_FMSY Standard error of FMSY estimate.
SE_MSY Standard error of MSY estimate.
SE_U_UMSY_final Standard error of U/UMSY in the terminal year.
SE_F_FMSY_final Standard error of F/FMSY in the terminal year.
SE_B_BMSY_final Standard error of B/BMSY in the terminal year.
SE_B_B0_final Standard error of B/B0 in the terminal year.
SE_SSB_SSBMSY_final Standard error of SSB/SSBMSY in the terminal year.
SE_SSB_SSB0_final Standard error of SSB/SSB0 in the terminal year.
SE_VB_VBMSY_final Standard error of VB/VBMSY in the terminal year.
SE_VB_VB0_final Standard error of VB/VB0 in the terminal year.
SE_Dev A vector of standard errors of the deviation parameters.
info A list containing the data and starting values of estimated parameters for the assessment.
obj A list with components returned from [MakeADFun](#).
opt A list with components from calling [nlminb](#) to **obj**.
SD A list (class `sdreport`) with parameter estimates and their standard errors, obtained from [sdreport](#).
TMB_report A list of model output reported from the TMB executable, i.e. `obj$report()`, and derived quantities (e.g. MSY).
dependencies A character string of data types required for the assessment.

Author(s)

Q. Huynh

See Also

[plot.Assessment.summary.Assessment retrospective profile make_MP](#)

Examples

```
output <- DD_TMB(Data = DLMtool::Red_snapper)
class(output)
```

avail

What objects of this class are available

Description

Generic class finder

Usage

```
avail(classy, all_avail = TRUE)
```

Arguments

classy	A class of object (character string, e.g. 'Fleet')
all_avail	Logical. If TRUE, function will return all objects of class classy available to user. If FALSE, returns only those objects included in MSetool.

Details

Finds objects of the specified class in the global environment or in the MSetool and DLMtool packages. This function is an addendum to the [avail](#) function in DLMtool.

Author(s)

Q. Huynh

Examples

```
avail("Assess")
avail("HCR")
avail("Stock")
avail("MP")
avail("MP", all_avail = FALSE)
```

Awatea2OM	<i>Reads MCMC estimates from Awatea (Paul Starr) processed r file structure into an operating model</i>
-----------	---

Description

A function that uses the file location of a fitted Awatea model post-processed into a set of rmd files

Usage

```
Awatea2OM(
  AwateaDir,
  nsim = 48,
  proyears = 50,
  Name = NULL,
  Source = "No source provided",
  Author = "No author provided",
  verbose = T
)
```

Arguments

AwateaDir	A folder with Awatea files
nsim	The number of simulations to take for parameters with uncertainty (for OM@cpar custom parameters)
proyears	The number of projection years for MSE
Name	The name of the operating model
Source	Reference to assessment documentation e.g. a url
Author	Who did the assessment
verbose	Should the r4ss function SS_ouput return detailed messages?

Author(s)

T. Carruthers

CASAL2OM	<i>Reads MLE estimates from CASAL file structure into an operating model</i>
----------	--

Description

A (prototype) function that uses the file location of a fitted CASAL assessment model including input files to population the various slots of an operating model with MLE parameter estimates. The function mainly populates the Stock and Fleet portions of the operating model; the user still needs to parameterize most of the observation and implementation portions of the operating model.

Usage

```

CASAL2OM(
  CASALdir,
  Obs = DLMtool::Precise_Unbiased,
  Imp = DLMtool::Perfect_Imp,
  Name = NA,
  Agency = NA,
  Region = NA,
  Sponsor = NA,
  Latitude = NA,
  Longitude = NA,
  nsim = 48,
  proyears = 50,
  interval = 4,
  pstar = 0.5,
  maxF = 2,
  reps = 1,
  seed = 1,
  Common_Name = NA,
  Species = NA,
  Source = NA,
  Author = NA
)

```

Arguments

CASALdir	A folder with CASAL input and output files in it
Obs	The observation model (class Obs).
Imp	The implementation model (class Imp).
Name	The common name of the operating model
Agency	The fishery management agency
Region	The geographical location
Sponsor	Who funded the work
Latitude	In degrees north
Longitude	In degrees west
nsim	The number of simulations to take for parameters with uncertainty (for OM@cpar custom parameters).
proyears	The number of projection years for MSE
interval	The number of years between management updates
pstar	The quantile for TAC management given stochasticity
maxF	The maximum allowable F in the operating model.
reps	The number of stochastic replicates within each simulation in the operating model.
seed	The random seed for the operating model.

Common_Name	The name of the species
Species	The species latin name
Source	Reference to assessment documentation e.g. a url
Author	Who did the assessment

Value

An object of class OM.

Author(s)

T. Carruthers

See Also

[SS2OM](#)

CASALpars

Rips MLE estimates from CASAL file structure

Description

A function that uses the file location of a fitted CASAL assessment model including input files to extract data required to populate an OMx class operating model.

Usage

```
CASALpars(CASALdir)
```

Arguments

CASALdir A folder with Stock Synthesis input and output files in it

Value

A list.

Author(s)

T. Carruthers

See Also

[CASAL2OM](#)

cDD

*Continuous Delay-differential assessment model***Description**

A catch and index-based assessment model. Compared to the discrete delay-difference (annual time-step in production and fishing), the delay-differential model (cDD) is based on continuous recruitment and fishing mortality within a time-step. The continuous model works much better for populations with high turnover (e.g. high F or M, continuous reproduction). This model is conditioned on catch and fits to the observed index. In the state-space version (cDD_SS), recruitment deviations from the stock-recruit relationship are estimated.

Usage

```

cDD(
  x = 1,
  Data,
  AddInd = "B",
  SR = c("BH", "Ricker"),
  rescale = "mean1",
  start = NULL,
  fix_h = TRUE,
  dep = 1,
  LWT = NULL,
  n_itF = 5L,
  silent = TRUE,
  opt_hess = FALSE,
  n_restart = ifelse(opt_hess, 0, 1),
  control = list(iter.max = 5000, eval.max = 10000),
  ...
)

cDD_SS(
  x = 1,
  Data,
  AddInd = "B",
  SR = c("BH", "Ricker"),
  rescale = "mean1",
  start = NULL,
  fix_h = TRUE,
  fix_sigma = FALSE,
  fix_tau = TRUE,
  dep = 1,
  LWT = NULL,
  n_itF = 5L,
  integrate = FALSE,
  silent = TRUE,

```

```

    opt_hess = FALSE,
    n_restart = ifelse(opt_hess, 0, 1),
    control = list(iter.max = 5000, eval.max = 10000),
    inner.control = list(),
    ...
  )

```

Arguments

x	An index for the objects in Data when running in closed loop simulation. Otherwise, equals to 1 when running an assessment.
Data	An object of class Data .
AddInd	A vector of integers or character strings indicating the indices to be used in the model. Integers assign the index to the corresponding index in Data@AddInd, "B" (or 0) represents total biomass in Data@Ind, "VB" represents vulnerable biomass in Data@VInd, and "SSB" represents spawning stock biomass in Data@SpInd.
SR	Stock-recruit function (either "BH" for Beverton-Holt or "Ricker").
rescale	A multiplicative factor that rescales the catch in the assessment model, which can improve convergence. By default, "mean1" scales the catch so that time series mean is 1, otherwise a numeric. Output is re-converted back to original units.
start	Optional list of starting values. Entries can be expressions that are evaluated in the function. See details.
fix_h	Logical, whether to fix steepness to value in Data@steep in the assessment model.
dep	The initial depletion in the first year of the model. A tight prior is placed on the model objective function to estimate the equilibrium fishing mortality corresponding to the initial depletion. Due to this tight prior, this F should not be considered to be an independent model parameter.
LWT	A vector of likelihood weights for each survey.
n_itF	Integer, the number of iterations to solve F conditional on the observed catch.
silent	Logical, passed to MakeADFun , whether TMB will print trace information during optimization. Used for diagnostics for model convergence.
opt_hess	Logical, whether the hessian function will be passed to nlminb during optimization (this generally reduces the number of iterations to convergence, but is memory and time intensive and does not guarantee an increase in convergence rate). Ignored if <code>integrate = TRUE</code> .
n_restart	The number of restarts (calls to nlminb) in the optimization procedure, so long as the model hasn't converged. The optimization continues from the parameters from the previous (re)start.
control	A named list of parameters regarding optimization to be passed to nlminb .
...	Additional arguments (not currently used).
fix_sigma	Logical, whether the standard deviation of the index is fixed. If TRUE, sigma is fixed to value provided in start (if provided), otherwise, value based on Data@CV_Ind.

<code>fix_tau</code>	Logical, the standard deviation of the recruitment deviations is fixed. If TRUE, tau is fixed to value provided in <code>start</code> (if provided), otherwise, equal to 1.
<code>integrate</code>	Logical, whether the likelihood of the model integrates over the likelihood of the recruitment deviations (thus, treating it as a state-space variable). Otherwise, recruitment deviations are penalized parameters.
<code>inner.control</code>	A named list of arguments for optimization of the random effects, which is passed on to <code>newton</code> via <code>MakeADFun</code> .

Details

To provide starting values for `cDD`, a named list can be provided for R_0 (unfished recruitment) and h (steepness) via the `start` argument (see example).

For `cDD_SS`, additional start values can be provided for σ and τ , the standard deviation of the index and recruitment variability, respectively.

Value

An object of [Assessment](#) containing objects and output from TMB.

Required Data

- `cDD`: Cat, Ind, Mort, L50, vbK, vbLinf, vbt0, wla, wlb, MaxAge
- `cDD_SS`: Cat, Ind, Mort, L50, vbK, vbLinf, vbt0, wla, wlb, MaxAge

Optional Data

- `cDD`: steep
- `cDD_SS`: steep, CV_Ind, sigmaR

Author(s)

Q. Huynh

References

Hilborn, R., and Walters, C., 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. Chapman and Hall, New York.

See Also

[DD_TMB plot](#), [Assessment summary](#), [Assessment retrospective profile](#), [make_MP](#)

Examples

```
#### Observation-error delay difference model
res <- cDD(Data = DLMtool::Red_snapper)

# Provide starting values
start <- list(R0 = 1, h = 0.95)
```

```
res <- cDD(Data = DLMtool::Red_snapper, start = start)

summary(res@SD) # Parameter estimates

### State-space version
### Set recruitment variability SD = 0.6 (since fix_tau = TRUE)
res <- cDD_SS(Data = Red_snapper, start = list(tau = 0.6))
```

compare_models	<i>Compare output from several assessment models</i>
----------------	--

Description

Plot biomass, recruitment, and fishing mortality time series from several . This function can be used to compare outputs among different assessment models from the same Data object.

Usage

```
compare_models(..., label = NULL, color = NULL)
```

Arguments

...	Objects of class Assessment .
label	A character vector of the models for the legend.
color	A vector of colors for each assessment model.

Value

A set of figures of biomass, recruitment, and fishing mortality estimates among the models.

Author(s)

Q. Huynh

Examples

```
res <- cDD_SS(Data = DLMtool::SimulatedData)
res2 <- SCA(Data = DLMtool::SimulatedData)
res3 <- SCA2(Data = DLMtool::SimulatedData)
res4 <- VPA(Data = DLMtool::SimulatedData)

compare_models(res, res2, res3)
```

DD_TMB

*Delay - Difference Stock Assessment in TMB***Description**

A simple delay-difference assessment model using a time-series of catches and a relative abundance index and coded in TMB. The model can be conditioned on either (1) effort and estimates predicted catch or (2) catch and estimates a predicted index. In the state-space version, recruitment deviations from the stock-recruit relationship are estimated.

Usage

```
DD_TMB(
  x = 1,
  Data,
  condition = c("catch", "effort"),
  AddInd = "B",
  SR = c("BH", "Ricker"),
  rescale = "mean1",
  start = NULL,
  fix_h = TRUE,
  dep = 1,
  LWT = NULL,
  silent = TRUE,
  opt_hess = FALSE,
  n_restart = ifelse(opt_hess, 0, 1),
  control = list(iter.max = 5000, eval.max = 10000),
  ...
)

DD_SS(
  x = 1,
  Data,
  condition = c("catch", "effort"),
  AddInd = "B",
  SR = c("BH", "Ricker"),
  rescale = "mean1",
  start = NULL,
  fix_h = TRUE,
  fix_sd = FALSE,
  fix_tau = TRUE,
  dep = 1,
  LWT = NULL,
  integrate = FALSE,
  silent = TRUE,
  opt_hess = FALSE,
  n_restart = ifelse(opt_hess, 0, 1),
```



```

control = list(iter.max = 5000, eval.max = 10000),
inner.control = list(),
...
)

```

Arguments

x	An index for the objects in Data when running in closed loop simulation. Otherwise, equals to 1 when running an assessment.
Data	An object of class Data .
condition	A string to indicate whether to condition the model on catch or effort (ratio of catch and index).
AddInd	A vector of integers or character strings indicating the indices to be used in the model. Integers assign the index to the corresponding index in Data@AddInd, "B" (or 0) represents total biomass in Data@Ind, "VB" represents vulnerable biomass in Data@VInd, and "SSB" represents spawning stock biomass in Data@SpInd.
SR	Stock-recruit function (either "BH" for Beverton-Holt or "Ricker").
rescale	A multiplicative factor that rescales the catch in the assessment model, which can improve convergence. By default, "mean1" scales the catch so that time series mean is 1, otherwise a numeric. Output is re-converted back to original units.
start	Optional list of starting values. Entries can be expressions that are evaluated in the function. See details.
fix_h	Logical, whether to fix steepness to value in Data@steep in the assessment model.
dep	The initial depletion in the first year of the model. A tight prior is placed on the model objective function to estimate the equilibrium exploitation rate that corresponds to the initial depletion. Due to this tight prior, this F should not be considered to be an independent model parameter.
LWT	A vector of likelihood weights for each survey.
silent	Logical, passed to MakeADFun , whether TMB will print trace information during optimization. Used for diagnostics for model convergence.
opt_hess	Logical, whether the hessian function will be passed to nlminb during optimization (this generally reduces the number of iterations to convergence, but is memory and time intensive and does not guarantee an increase in convergence rate). Ignored if <code>integrate = TRUE</code> .
n_restart	The number of restarts (calls to nlminb) in the optimization procedure, so long as the model hasn't converged. The optimization continues from the parameters from the previous (re)start.
control	A named list of parameters regarding optimization to be passed to nlminb .
...	Additional arguments (not currently used).
fix_sd	Logical, whether the standard deviation of the data in the likelihood (index for conditioning on catch or catch for conditioning on effort). If TRUE, the SD is fixed to value provided in start (if provided), otherwise, value based on either Data@CV_Cat or Data@CV_Ind.

<code>fix_tau</code>	Logical, the standard deviation of the recruitment deviations is fixed. If TRUE, tau is fixed to value provided in <code>start</code> (if provided), otherwise, equal to 1.
<code>integrate</code>	Logical, whether the likelihood of the model integrates over the likelihood of the recruitment deviations (thus, treating it as a random effects/state-space variable). Otherwise, recruitment deviations are penalized parameters.
<code>inner.control</code>	A named list of arguments for optimization of the random effects, which is passed on to <code>newton</code> via <code>MakeADFun</code> .

Details

To provide starting values for DD_TMB, a named list can be provided for R_0 (virgin recruitment), h (steepness), and q (catchability coefficient) via the `start` argument (see example).

For DD_SS, additional start values can be provided for ω and τ , the standard deviation of the catch and recruitment variability, respectively.

Value

An object of `Assessment` containing objects and output from TMB.

Functions

- DD_TMB: Observation-error only model

Required Data

- DD_TMB: `Cat`, `Ind`, `Mort`, `L50`, `vbK`, `vbLinf`, `vbt0`, `wla`, `wlb`, `MaxAge`
- DD_SS: `Cat`, `Ind`, `Mort`, `L50`, `vbK`, `vbLinf`, `vbt0`, `wla`, `wlb`, `MaxAge`

Optional Data

- DD_TMB: `steep`
- DD_SS: `steep`, `CV_Cat`

Note

Similar to many other assessment models, the model depends on assumptions such as stationary productivity and proportionality between the abundance index and real abundance. Unsurprisingly the extent to which these assumptions are violated tends to be the biggest driver of performance for this method.

Author(s)

T. Carruthers & Z. Siders. Zach Siders coded the TMB function.

References

- Carruthers, T, Walters, C.J., and McAllister, M.K. 2012. Evaluating methods that classify fisheries stock status using only fisheries catch data. *Fisheries Research* 119-120:66-79.
- Hilborn, R., and Walters, C., 1992. *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*. Chapman and Hall, New York.

See Also

[plot.Assessment.summary.Assessment.retrospective.profile.make_MP](#)

Examples

```
#### Observation-error delay difference model
res <- DD_TMB(Data = DLMtool::Red_snapper)

# Provide starting values
start <- list(R0 = 1, h = 0.95)
res <- DD_TMB(Data = DLMtool::Red_snapper, start = start)

summary(res@SD) # Parameter estimates

### State-space version
### Set recruitment variability SD = 0.3 (since fix_tau = TRUE)
res <- DD_SS(Data = Red_snapper, start = list(tau = 0.3))
```

diagnostic_AM	<i>diagnostic_AM (diagnostic of Assessments in MSE): Did Assess models converge during MSE?</i>
---------------	---

Description

Diagnostic check for convergence of Assess models during MSE. Assess models write output to the DLMenv environment if the MP was created with [make_MP](#) with argument `diagnostic = TRUE`. This function summarizes and plots the diagnostic information.

Usage

```
diagnostic_AM(MSE, MP = NULL, gradient_threshold = 0.1, figure = TRUE)
```

Arguments

MSE	An object of class MSE created by runMSE . If no MSE object is available, use argument MP instead.
MP	A character vector of MPs with assessment models.
gradient_threshold	The maximum magnitude (absolute value) desired for the gradient of the likelihood.
figure	Logical, whether a figure will be drawn.

Value

A matrix with diagnostic performance of assessment models in the MSE. If `figure = TRUE`, a set of figures: traffic light (red/green) plots indicating whether the model converged (defined if a positive-definite Hessian matrix was obtained), the optimizer reached pre-specified iteration limits (as passed to `nlm`), and the maximum gradient of the likelihood in each assessment run. Also includes the number of optimization iterations function evaluations reported by `nlm` for each application of the assessment model.

Author(s)

Q. Huynh

See Also

[retrospective_AM](#)

Examples

```
## Not run:
DD_MSY <- make_MP(DD_TMB, HCR_MSY, diagnostic = "min")
show(DD_MSY)

##### Ensure that PPD = TRUE in runMSE function
myMSE <- runMSE(DLMtool::testOM, MPs = "DD_MSY", PPD = TRUE)
diagnostic_AM(myMSE)

## End(Not run)
```

expandHerm

Expand the Herm list in SexPars to a matrix of fractions at age

Description

Expand the Herm list in SexPars to a matrix of fractions at age

Usage

```
expandHerm(Herm, maxage, np, nsim)
```

Arguments

Herm	A list of Hermaphroditic fractions at age (starting age class 1)
maxage	The maximum age of stocks being simulated
np	The total number of stocks being simulated
nsim	The number of simulations

Author(s)

T. Carruthers

fetch.file.names	<i>Reads iSCAM Data, Control and Projection files</i>
------------------	---

Description

A function for returning the three types of iSCAM input and output files

Usage

```
fetch.file.names(path, filename)
```

Arguments

path	File path
filename	The filename

Author(s)

Chris Grandin (DFO PBS)

getinds	<i>Characterize posterior predictive data</i>
---------	---

Description

Characterize posterior predictive data

Usage

```
getinds(
  PPD,
  styr,
  res = 6,
  tsd = c("Cat", "Cat", "Cat", "Ind", "ML"),
  stat = c("slp", "AAV", "mu", "slp", "slp")
)
```

Arguments

PPD	An object of class Data stored in the Misc slot of an MSE object following a call of runMSE(PPD = TRUE).
styr	Positive integer, the starting year for calculation of quantities
res	Positive integer, the temporal resolution (chunks - normally years) over which to calculate quantities

tsd	Character vector of names of types of data: Cat = catch, Ind = relative abundance index, ML = mean length in catches
stat	Character vector of types of quantity to be calculated: slp = slope(log(x)), AAV = average annual variability, mu = mean(log(x))

Value

A 3D array of results (type of data/stat (e.g. mean catches),time period (chunk), simulation)

Author(s)

T. Carruthers

References

Carruthers and Hordyk 2018

getnIVs	<i>Count independent variables for a MICE relationship at position x in a Rel list</i>
---------	--

Description

Count independent variables for a MICE relationship at position x in a Rel list

Usage

```
getnIVs(x, Rel)
```

Arguments

x	Position of a MICE relationship in the list Rel (MOM@Rel)
Rel	The list of MICE relationships (MOM@Rel)

Author(s)

T.Carruthers

HCRlin

Generic linear harvest control rule based on biomass

Description

A general function used by HCR_ramp that adjusts the TAC by a linear ramp based on estimated biomass.

Usage

```
HCRlin(Brel, LRP, TRP, rel_min = 0, rel_max = 1)
```

Arguments

Brel	Improper fraction: An estimate of biomass (either absolute or relative, e.g. B/BMSY or B/B0).
LRP	Improper fraction: the Limit Reference Point, the biomass below which the adjustment is at its minimum, e.g. zero, no fishing. Same units as Brel.
TRP	Improper fraction: the Target Reference Point, the biomass above which the adjustment is at its maximum. Same units as Brel.
rel_min	The relative maximum value (e.g. a multiple of FMSY) if Brel < LRP.
rel_max	The relative maximum value (e.g. a multiple of FMSY) if Brel > TRP.

Value

a TAC or TAE adjustment factor.

Author(s)

T. Carruthers

Examples

```
#40-10 linear ramp
Brel <- seq(0, 1, length.out = 200)
plot(Brel, HCRlin(Brel, 0.1, 0.4), xlab = "Estimated B/B0", ylab = "Relative change in F",
main = "A 40-10 harvest control rule", type = 'l', col = 'blue')
abline(v = c(0.1,0.4), col = 'red', lty = 2)
```

HCR_FB	<i>A Harvest Control Rule using B/BMSY and F/FMSY to adjust TAC or TAE.</i>
--------	---

Description

A Harvest Control Rule using B/BMSY and F/FMSY to adjust TAC or TAE.

Usage

```
HCR_FB(Brel, Frel, Bpow = 2, Bgrad = 1, Fpow = 1, Fgrad = 1)
```

Arguments

Brel	improper fraction: an estimate of Biomass relative to BMSY
Frel	improper fraction: an estimate of Fishing mortality rate relative to FMSY
Bpow	non-negative real number: controls the shape of the biomass adjustment, when zero there is no adjustment
Bgrad	non-negative real number: controls the gradient of the biomass adjustment
Fpow	non-negative real number: controls the adjustment speed relative to F/FMSY. When set to 1, next recommendation is FMSY. When less than 1 next recommendation is between current F and FMSY.
Fgrad	improper fraction: target Fishing rate relative to FMSY

Value

a TAC or TAE adjustment factor.

Author(s)

T. Carruthers

References

Made up for this package

Examples

```
res <- 100
Frel <- seq(1/2, 2, length.out = res)
Brel <- seq(0.05, 2, length.out=res)
adj <- array(HCR_FB(Brel[rep(1:res, res)], Frel[rep(1:res, each = res)]),
             Bpow = 2, Bgrad = 1, Fpow = 1, Fgrad = 0.75), c(res, res))
contour(Brel, Frel, adj, nlevels = 20, xlab = "B/BMSY", ylab = "F/FMSY",
        main = "FBsurface TAC adjustment factor")
abline(h = 1, col = 'red', lty = 2)
abline(v = 1, col = 'red', lty = 2)
legend('topright', c("Bpow = 2", "Bgrad = 1", "Fpow = 1", "Fgrad = 0.75"), text.col = 'blue')
```

HCR_MSY	<i>Harvest control rule to fish at some fraction of maximum sustainable yield</i>
---------	---

Description

A simple control rule that specifies the total allowable catch (TAC) to be the product of current vulnerable biomass and UMSY.

Usage

```
HCR_MSY(Assessment, reps = 1, MSY_frac = 1, ...)
```

Arguments

Assessment	An object of class Assessment with estimates of FMSY or UMSY and vulnerable biomass in terminal year.
reps	The number of stochastic samples of the TAC recommendation.
MSY_frac	The fraction of FMSY or UMSY for calculating the TAC (e.g. MSY_frac = 0.75 fishes at 75% of FMSY).
...	Miscellaneous arguments.

Value

An object of class [Rec](#) with the TAC recommendation.

Author(s)

Q. Huynh

References

Punt, A. E, Dorn, M. W., and Haltuch, M. A. 2008. Evaluation of threshold management strategies for groundfish off the U.S. West Coast. *Fisheries Research* 94:251-266.

See Also

[make_MP HCR_ramp](#)

Examples

```
# create an MP to run in closed-loop MSE (fishes at UMSY)
DD_MSY <- make_MP(DD_TMB, HCR_MSY)
class(DD_MSY)

# The same MP which fishes at 75% of UMSY
DD_75MSY <- make_MP(DD_TMB, HCR_MSY, MSY_frac = 0.75)
class(DD_75MSY)
```

```
## Not run:
myOM <- DLMtool::runMSE(DLMtool::testOM, MPs = c("FMSYref", "DD_MSY"))

## End(Not run)
```

HCR_ramp

Linearly ramped harvest control rules

Description

An output control rule with a ramp that reduces the TAC recommendation linearly with respect to fishing mortality (F) or harvest rate (U) when the relative biomass (i.e., spawning depletion or spawning biomass relative to that at MSY) is less than the target reference point (TRP). The TAC reduction is linearly reduced with respect to F to a minimum value when the relative biomass is less than the limit reference point (LRP). For example, the TRP and LRP for spawning depletion is 0.4 and 0.1, respectively, in the 40-10 control rule. Class HCR objects are typically used with function [make_MP](#).

Usage

```
HCR_ramp(
  Assessment,
  reps = 1,
  LRP,
  TRP,
  rel_min = 0,
  rel_max = 1,
  RP_type = c("SSB_SSB0", "SSB_SSBMSY"),
  ...
)

HCR40_10(Assessment, reps = 1, ...)

HCR60_20(Assessment, reps = 1, ...)
```

Arguments

Assessment	An object of class Assessment with estimates of FMSY or UMSY, vulnerable biomass, and spawning biomass depletion in terminal year.
reps	The number of stochastic samples of the TAC recommendation.
LRP	Numeric, the limit reference point.
TRP	Numeric, the target reference point.
rel_min	The relative maximum value (e.g. a multiple of FMSY) if $B_{rel} < LRP$.
rel_max	The relative maximum value (e.g. a multiple of FMSY) if $B_{rel} > TRP$.
RP_type	The reference point metric for TRP and LRP ("SSB_SSB0" for spawning depletion by default, or "SSB_SSBMSY" for spawning biomass relative to MSY).
...	Miscellaneous arguments.

Details

HCR_ramp is the generic ramped-HCR function where user specifies LRP, TRP, and relative biomass metric, as well as minimum and maximum values for adjusting the fishing mortality.

HCR40_10 is a common U.S. west coast control rule (LRP and TRP of 0.1 and 0.4 spawning depletion, respectively), while HCR60_20 is more conservative than 40-10, with LRP and TRP of 0.2 and 0.6 spawning depletion, respectively).

Value

An object of class [Rec](#) with the TAC recommendation.

Author(s)

Q. Huynh & T. Carruthers

References

Deroba, J.J. and Bence, J.R. 2008. A review of harvest policies: Understanding relative performance of control rules. *Fisheries Research* 94:210-223.

Edwards, C.T.T. and Dankel, D.J. (eds.). 2016. *Management Science in Fisheries: an introduction to simulation methods*. Routledge, New York, NY. 460 pp.

Punt, A. E, Dorn, M. W., and Haltuch, M. A. 2008. Evaluation of threshold management strategies for groundfish off the U.S. West Coast. *Fisheries Research* 94:251-266.

Restrepo, V.R. and Power, J.E. 1999. Precautionary control rules in US fisheries management: specification and performance. *ICES Journal of Marine Science* 56:846-852.

See Also

[HCR_MSY](#) [HCRlin](#) [make_MP](#)

Examples

```
# 40-10 linear ramp
Brel <- seq(0, 1, length.out = 200)
plot(Brel, HCRlin(Brel, 0.1, 0.4), xlab = "Estimated SSB/SSB0",
      ylab = "Prescribed F relative to FMSY", main = "40-10 harvest control rule",
      type = "l", col = "blue")
abline(v = c(0.1, 0.4), col = "red", lty = 2)

# create a 40-10 MP to run in closed-loop MSE
DD_40_10 <- make_MP(DD_TMB, HCR40_10)

# Alternatively,
DD_40_10 <- make_MP(DD_TMB, HCR_ramp, LRP = 0.1, TRP = 0.4)

# An SCA with LRP and TRP at 0.4 and 0.8, respectively, of SSB/SSBMSY
SCA_80_40 <- make_MP(SCA, HCR_ramp, LRP = 0.4, TRP = 0.8, RP_type = "SSB_SSBMSY")

# A conservative HCR that fishes at 75% of FMSY at B > 80% BMSY but only reduces F
```

```

# to 10% of FMSY if B < 40% BMSY.
SCA_conservative <- make_MP(SCA, HCR_ramp, LRP = 0.4, TRP = 0.8, rel_max = 0.75,
rel_min = 0.1, RP_type = "SSB_SSBMSY")

# Figure of this conservative HCR
Brel <- seq(0, 1, length.out = 200)
Frel <- HCRlin(Brel, 0.4, 0.8, rel_max = 0.75, rel_min = 0.1)
plot(Brel, Frel, xlab = "Estimated SSB/SSB_MSY", ylab = "Prescribed F relative to FMSY",
type = "l", col = "blue")
abline(v = c(0.4, 0.8), col = "red", lty = 2)

## Not run:
myOM <- DLMtool::runMSE(DLMtool::testOM, MPs = c("FMSYref", "DD_40_10"))

## End(Not run)

```

iSCAM2Data

Reads data from iSCAM file structure into a DLMtool Data object

Description

A function that uses the file location of a fitted iSCAM model including input files to population the various slots of an data object. iSCAM2OM relies on several functions written by Chris Grandin (DFO PBS).

Usage

```

iSCAM2Data(
  iSCAMdir,
  Name = NULL,
  Source = "No source provided",
  length_timestep = 1,
  Author = "No author provided"
)

```

Arguments

iSCAMdir	A folder with iSCAM input and output files in it
Name	The name of the operating model
Source	Reference to assessment documentation e.g. a url
length_timestep	How long is a model time step in years (e.g. a quarterly model is 0.25, a monthly model 1/12)
Author	Who did the assessment

Author(s)

T. Carruthers

iSCAM2OM	<i>Reads MLE estimates from iSCAM file structure into an operating model</i>
----------	--

Description

A function that uses the file location of a fitted iSCAM model including input files to population the various slots of an operating model parameter estimates. iSCAM2OM relies on several functions written by Chris Grandin (DFO PBS).

Usage

```
iSCAM2OM(
  iSCAMdir,
  nsim = 48,
  proyears = 50,
  mcmc = F,
  Name = NULL,
  Source = "No source provided",
  length_timestep = 1,
  Author = "No author provided"
)
```

Arguments

iSCAMdir	A folder with iSCAM input and output files in it
nsim	The number of simulations to take for parameters with uncertainty (for OM@cpar custom parameters)
proyears	The number of MSE projection years
mcmc	Whether to use mcmc samples to create custom parameters cpar
Name	The name of the operating model
Source	Reference to assessment documentation e.g. a url
length_timestep	How long is a model time step in years (e.g. a quarterly model is 0.25, a monthly model 1/12)
Author	Who did the assessment

Author(s)

T. Carruthers

iSCAMcomps	<i>Combines all iSCAM age composition data across fleets</i>
------------	--

Description

iSCAM assessments are often fitted to numerous fleets that have differing age selectivities. iSCAMcomps is a simple way of providing the aggregate catch at age data. It should be noted that this process is important and in a real application would require due diligence (ie peer reviewed data workshop).

Usage

```
iSCAMcomps(replist, Year)
```

Arguments

replist	S3 class object: the output from a read from an iSCAM data folder
Year	Integer vector: the years of the DLMtool data object ie Data@Year

Author(s)

T. Carruthers

iSCAMinds	<i>Combines indices into a single index using linear modelling</i>
-----------	--

Description

iSCAM assessments often make use of multiple indices of abundance. The DLMtool data object and MPs currently only make use of a single index. combiSCAMinds is a function that creates a single index from many using linear modelling. It is a simple way of providing initial calculations of management recommendations and it should be noted that this process is important and in a real application would require due diligence (ie peer reviewed data workshop).

Usage

```
iSCAMinds(idata, Year, fleeteffect = T)
```

Arguments

idata	List: the indices recorded in a read from an iSCAM data folder, e.g. replist\$data\$indices
Year	Integer vector: the years of the DLMtool data object ie Data@Year
fleeteffect	Logical: should a fleet effect be added to the linear model?

Author(s)

T. Carruthers

ldim	<i>Dimensions of a hierarchical list object</i>
------	---

Description

Dimensions of a hierarchical list object

Usage

```
ldim(x)
```

Arguments

x	A list
---	--------

Author(s)

T. Carruthers

load.iscam.files	<i>Reads iSCAM files into a hierarchical R list object</i>
------------------	--

Description

A function for reading iSCAM input and output files into R

Usage

```
load.iscam.files(model.dir, burnin = 1000, thin = 1, verbose = FALSE)
```

Arguments

model.dir	An iSCAM directory
burnin	The initial mcmc samples to be discarded
thin	The degree of chain thinning 1 in every thin iterations is kept
verbose	Should detailed outputs be provided.

Author(s)

Chris Grandin (DFO PBS)

mahplot	<i>Plot statistical power of the indicator with increasing time blocks</i>
---------	--

Description

Plot statistical power of the indicator with increasing time blocks

Usage

```
mahplot(outlist, res = 6, maxups = 5, MPs)
```

Arguments

outlist	A list object produced by the function PRBcalc
res	Integer, the resolution (time blocking) for the calculation of PPD
maxups	Integer, the maximum number of update time blocks to plot
MPs	Character vector of MP names

Author(s)

T. Carruthers

References

Carruthers and Hordyk 2018

makemov	<i>Calculates movement matrices from user inputs for fraction in each area (fracs) and probability of staying in areas (prob)</i>
---------	---

Description

A function for calculating a movement matrix from user specified unfished stock biomass fraction in each area. Used by [simmov](#) to generate movement matrices for a DLMtool operating model.

Usage

```
makemov(frac = c(0.1, 0.2, 0.3, 0.4), prob = c(0.5, 0.8, 0.9, 0.95))
```

Arguments

fracs	A vector nareas long of fractions of unfished stock biomass in each area
prob	A vector of the probability of individuals staying in each area or a single value for the mean probability of staying among all areas

Author(s)

T. Carruthers

See Also[simmov](#)

`make_MP`*Make a custom management procedure (MP)*

Description

Function operator that combines a function of class `Assess` and a function of class `HCR` to create a management procedure (MP). The resulting function can then be tested in closed-loop simulation via [runMSE](#).

Usage

```
make_MP(.Assess, .HCR, diagnostic = c("none", "min", "full"), ...)
```

Arguments

<code>.Assess</code>	A function of class <code>Assess</code> .
<code>.HCR</code>	A function of class <code>HCR</code> .
<code>diagnostic</code>	A character string describing if any additional diagnostic information from the assessment models will be collected during a call with runMSE ("none" is the default). "min" (minimal) will collect information on convergence and "full" will also collect the Assessment object generated by the <code>.Assess</code> . This information will be written to the <code>Misc</code> slot in the MSE object. See example.
<code>...</code>	Additional arguments to be passed to <code>.Assess</code> and <code>.HCR</code> .

Value

A function of class `MP`.

See Also

[HCR_ramp](#) [HCR_MSY](#) [diagnostic_AM](#) [retrospective_AM](#)

Examples

```

# A delay-difference model with a 40-10 control rule
DD_40_10 <- make_MP(DD_TMB, HCR40_10)

# A delay difference model that will produce convergence diagnostics
DD_40_10 <- make_MP(DD_TMB, HCR40_10, diagnostic = "min")

# MP that uses a Delay-Difference which assumes a Ricker stock-recruit function.
DD_Ricker <- make_MP(DD_TMB, HCR_MSY, SR = "Ricker")

## Not run:
myMSE <- DLMtool::runMSE(DLMtool::testOM, MPs = c("FMSYref", "DD_40_10"), PPD = TRUE)

str(myMSE@Misc)
diagnostic_AM(myMSE)

## End(Not run)

```

MMSE-class

*Class 'MMSE'***Description**

A Multi Management Strategy Evaluation object that contains information about simulation conditions and performance of MPs for a multi-stock, multi-fleet operating model.

Slots

Name Name of the MMSE object. Single value. Character string

nyears The number of years for the historical simulation. Single value. Positive integer

proyears The number of years for the projections - closed loop simulations. Single value. Positive integer

nMPs Number of management procedures simulation tested. Single value. Positive integer.

MPs The names of the MPs that were tested. Vector of length nMPs. Character strings.

MPcond The MP condition. Character ('bystock': an MP per stock, 'byfleet' and MP per stock and fleet, 'MMP' an MP for all stocks and fleets)

MPrefs The names of the MPs applied for each stock (row) and fleet (column). An array.

nsim Number of simulations. Single value. Positive integer

nstocks Number of stocks. Single value. Positive integer

nfleets Number of fleets. Single value. Positive integer

Snames Names of the stocks

Fnames Names of the fleets (matrix nstocks x nfleets)

Stocks The stock operating model objects. List of Stocks

Fleets The fleet operating model objects. Hierarchical list, fleets nested in stocks.

Obs The fleet specific observation error operating model objects. Hierarchical list, fleets nested in stocks.

Imps The fleet soecific implementation error operating model objects. Hierarchical list, fleets nested in stocks.

OM A table of sampled parameters of the operating model. Data frame of nsim rows.

Obs A table of sampled parameters of the observation model. Data frame of nsim rows.

B_BMSY Simulated biomass relative to BMSY over the projection. An array with dimensions: nsim, nMPs, proyears. Non-negative real numbers

F_FMSY Simulated fishing mortality rate relative to FMSY over the projection. An array with dimensions: nsim, nMPs, proyears. Non-negative real numbers

B Simulated stock biomass over the projection. An array with dimensions: nsim, nMPs, proyears. Non-negative real numbers

SSB Simulated spawning stock biomass over the projection. An array with dimensions: nsim, nMPs, proyears. Non-negative real numbers

VB Simulated vulnerable biomass over the projection. An array with dimensions: nsim, nMPs, proyears. Non-negative real numbers

FM Simulated fishing mortality rate over the projection. An array with dimensions: nsim, nMPs, proyears. Non-negative real numbers

C Simulated catches (taken) over the projection. An array with dimensions: nsim, nMPs, proyears. Non-negative real numbers

TAC Simulated Total Allowable Catch (prescribed) over the projection (this is NA for input controls). An array with dimensions: nsim, nMPs, proyears. Non-negative real numbers

SSB_hist Simulated historical spawning stock biomass. An array with dimensions: nsim, nages, nyears, nareas. Non-negative real numbers

CB_hist Simulated historical catches in weight. An array with dimensions: nsim, nages, nyears, nareas. Non-negative real numbers

FM_hist Simulated historical fishing mortality rate. An array with dimensions: nsim, nages, nyears, nareas. Non-negative real numbers

Effort Simulated relative fishing effort in the projection years. An array with dimensions: nsim, nMPs, proyears. Non-negative real numbers

PAA Population at age in last projection year. An array with dimensions: nsim, nMPs, nages. Non-negative real numbers

CAA Catch at age in last projection year. An array with dimensions: nsim, nMPs, nages. Non-negative real numbers

CAL Catch at length in last projection year. An array with dimensions: nsim, nMPs, nCALbins. Non-negative real numbers

CALbins Mid-points of the catch-at-length bins. Vector of length nCALbins. Positive real numbers.

MSY_P Array of projected MSY by year with dimensions: nsim, nstock, nMP, proyears.

FMSY_P Array of projected FMSY by year with dimensions: nsim, nstock, nMP, proyears.

SSBMSY_P Array of projected Spawning Stock Biomass at MSY by year with dimensions: nsim, nstock, nMP, proyears.

Misc Miscellanenous output such as posterior predictive data

Objects from the Class

Objects can be created by calls of the form `new('MMSE', Name, nyears, proyears, nMPs, MPs, nsim, OMtable, Obs, B_BMSYa,`

Author(s)

T. Carruthers

Model-based-MP

Model-based management procedures

Description

A suite of model-based management procedures (MPs) included in the package. Additional MPs, with specific model configurations (e.g., stock-recruit function or fixing certain parameters) or alternative ramped harvest control rules can be created with [make_MP](#) and the available Assess and HCR objects.

Usage

`SCA_MSY(x, Data, reps = 1)`

`SCA_75MSY(x, Data, reps = 1)`

`SCA_4010(x, Data, reps = 1)`

`DDSS_MSY(x, Data, reps = 1)`

`DDSS_75MSY(x, Data, reps = 1)`

`DDSS_4010(x, Data, reps = 1)`

`SP_MSY(x, Data, reps = 1)`

`SP_75MSY(x, Data, reps = 1)`

`SP_4010(x, Data, reps = 1)`

`SSS_MSY(x, Data, reps = 1)`

`SSS_75MSY(x, Data, reps = 1)`

`SSS_4010(x, Data, reps = 1)`

Arguments

<code>x</code>	A position in the Data object.
<code>Data</code>	An object of class Data
<code>reps</code>	Numeric, the number of stochastic replicates for the management advice.

Value

An object of class [Rec](#) which contains the management recommendation.

Functions

- SCA_MSY: A statistical catch-at-age model with a TAC recommendation based on fishing at FMSY, and default arguments for configuring [SCA](#).
- SCA_75MSY: An SCA with a TAC recommendation based on fishing at 75% of FMSY.
- SCA_4010: An SCA with a 40-10 control rule.
- DDSS_MSY: A state-space delay difference model with a TAC recommendation based on fishing at FMSY, and default arguments for configuring [DD_SS](#).
- DDSS_75MSY: A state-space delay difference model with a TAC recommendation based on fishing at 75% of FMSY.
- DDSS_4010: A state-space delay difference model with a 40-10 control rule.
- SP_MSY: A surplus production model with a TAC recommendation based on fishing at FMSY, and default arguments for configuring [SP](#).
- SP_75MSY: A surplus production model with a TAC recommendation based on fishing at 75% of FMSY.
- SP_4010: A surplus production model with a 40-10 control rule.
- SSS_MSY: Simple stock synthesis (terminal depletion fixed to 0.4 in [SSS](#)) with a TAC recommendation based on fishing at FMSY.
- SSS_75MSY: Simple stock synthesis (terminal depletion fixed to 0.4) with with a TAC recommendation based on fishing at 75% FMSY.
- SSS_4010: Simple stock synthesis (terminal depletion fixed to 0.4) with a 40-10 control rule.

Examples

```
avail("MP", all_avail = FALSE)

## Not run:
myMSE <- DLMtool::runMSE(DLMtool::testOM, MPs = c("FMSYref", "SCA_MSY", "SCA_4010"))

## End(Not run)
```

MOM-class

Class 'MOM'

Description

An object containing all the parameters needed to control a multi-stock, multi-fleet MSE which can be build from component Stock, Fleet, Obs, and Imp objects.

Details

Almost all of these inputs are a vector of length 2 which describes the upper and lower bounds of a uniform distribution from which to sample the parameter.

Slots

Name Name of the operating model

Agency Name of the agency responsible for the management of the fishery. Character string

Region Name of the general geographic region of the fishery. Character string

Sponsor Name of the organization who sponsored the OM. Character string

Latitude Latitude (decimal degrees). Negative values represent the South of the Equator. Numeric. Single value

Longitude Longitude (decimal degrees). Negative values represent the West of the Prime Meridian. Numeric. Single value

nsim The number of simulations

proyears The number of projected years

interval The assessment interval - how often would you like to update the management system?

pstar The percentile of the sample of the management recommendation for each method

maxF Maximum instantaneous fishing mortality rate that may be simulated for any given age class

reps Number of samples of the management recommendation for each method. Note that when this is set to 1, the mean value of the data inputs is used.

cpars A hierarcical list nstock then nfleet long of custom parameters. Time series are a matrix nsim rows by nyears columns. Single parameters are a vector nsim long

seed A random seed to ensure users can reproduce results exactly

Source A reference to a website or article from which parameters were taken to define the operating model

Stocks List of stock objects

Fleets List of Fleet objects

Obs Hierarchical List of Observation model objects Level 1 is stock, level 2 is fleet

Imps Hierarchical List of Implementation model objects Level 1 is stock, level 2 is fleet

CatchFrac A list nstock long, of matrices nsim x nfleet representing the fraction of current catches of the various fleets to each stock (each matrix is nsim by nfleet long and rows sum to 1 for each stock)

Allocation A list nstock long, of matrices nsim x nfleet representing the fraction of future TACs of the various fleets to each stock (each matrix is nsim by nfleet long and rows sum to 1 for each stock).

Efactor A list nstock long, of current effort factors by fleet (default is 1 - same as current effort)

Complexes A list of stock complexes. Each position is a vector of stock numbers (as they appear in StockPars) for which data should be aggregated and TAC recommendations split among stocks according to vulnerable biomass

SexPars A list of slots that control sex-specific dynamics

Rel A list of biological / ecological relationships among stocks over-ridden if an MP of class 'MP_F' is supplied that is a multi-fleet MP.

Objects from the Class

Objects can be created by calls of the form `new('MOM', Stock_list, Fleet_list, Obs_list, Imp_list)`.

Author(s)

T. Carruthers and A. Hordyk

MPCalcsNAs	<i>Fill any NAs arising from MPCalcs (hermaphroditism mode)</i>
------------	---

Description

Fill any NAs arising from MPCalcs (hermaphroditism mode)

Usage

```
MPCalcsNAs(MPCalcs)
```

Arguments

MPCalcs	A list of arrays arising from the DLMtool function CalcMPDynamics()
---------	---

Author(s)

T. Carruthers

multiData	<i>Combine data among fleets</i>
-----------	----------------------------------

Description

Catches, CAA, CAL are summed. LFC and LFS are weighted averages. ML, Lc and Lbar are recalculated from summed CAL. All other observations are for fleet 1 (indicative)

Usage

```
multiData(MSElist, StockPars, p, mm, nf)
```

Arguments

MSElist	A hierarcical list of data objects stock then fleet then MP
StockPars	A list of stock parameters
p	Integer the Stock number
mm	Integer the MP number
nf	The number of fleets

Author(s)

T. Carruthers

multiDataS	<i>Combine data among stocks</i>
------------	----------------------------------

Description

Catches, CAA, CAL are summed. LFC and LFS are weighted averages. ML, Lc and Lbar are recalculated from summed CAL. All other observations are for fleet 1 (indicative)

Usage

```
multiDataS(MSElist, StockPars, np, mm, nf, realVB)
```

Arguments

MSElist	A hierarcical list of data objects stock then fleet then MP
StockPars	A list of stock parameters
np	The number of stocks
mm	Integer the MP number
nf	The number of fleets
realVB	A matrix of real vulnerable biomass [nsim,year,np]

Author(s)

T. Carruthers

multidebug	<i>A basic comparison of runMSE output (MSE) and multiMSE (MMSE)</i>
------------	--

Description

A basic comparison of runMSE output (MSE) and multiMSE (MMSE)

Usage

```
multidebug(MSEsingle, MSEmulti, p = 1, f = 1, MPno = 1, maxsims = 4)
```


Arguments

MSEsingle	An object of class MSE arising from a run of runMSE(OM, ...)
MSEmulti	An object of class MMSE arising from a run of multiMSE(MOM, ...)
p	Integer. The stock number from the MSEmulti object (to be plotted)
f	Integer. The fleet number from the MSEmulti object (to be plotted)
MPno	Integer. The MP number from the MSEmulti and MSEsingle object (to be plotted)
maxsims	Integer. The maximum number of simulations to plot.

Author(s)

T.Carruthers

multiMSE	<i>Run a multi-fleet multi-stock Management Strategy Evaluation</i>
----------	---

Description

A function that runs a Management Strategy Evaluation (closed-loop simulation) for a specified operating model

Usage

```
multiMSE(
  MOM,
  MPs = list(c("AvC", "DCAC"), c("FMSYref", "curE")),
  CheckMPs = FALSE,
  timelimit = 1,
  Hist = FALSE,
  ntrials = 50,
  fracD = 0.05,
  CalcBlow = FALSE,
  HZN = 2,
  Bfrac = 0.5,
  AnnualMSY = TRUE,
  silent = FALSE,
  PPD = FALSE,
  parallel = FALSE,
  save_name = NULL,
  checks = FALSE,
  control = NULL
)
```

Arguments

MOM	A multi-fleet multi-stock operating model (class 'MOM')
MPs	A matrix of methods (nstock x nfleet) (character string) of class MP
CheckMPs	Logical to indicate if Can function should be used to check if MPs can be run.
timelimit	Maximum time taken for a method to carry out 10 reps (methods are ignored that take longer)
Hist	Should model stop after historical simulations? Returns a list containing all historical data
ntrials	Maximum of times depletion and recruitment deviations are resampled to optimize for depletion. After this the model stops if more than percent of simulations are not close to the required depletion
fracD	Maximum allowed proportion of simulations where depletion is not close to sampled depletion from OM before model stops with error
CalcBlow	Should low biomass be calculated where this is the spawning biomass at which it takes HZN mean generation times of zero fishing to reach Bfrac fraction of SSBMSY
HZN	The number of mean generation times required to reach Bfrac SSBMSY in the Blow calculation
Bfrac	The target fraction of SSBMSY for calculating Blow
AnnualMSY	Logical. Should MSY statistics be calculated for each projection year? May differ from MSY statistics from last historical year if there are changes in productivity
silent	Should messages be printed out to the console?
PPD	Logical. Should posterior predicted data be included in the MSE object Misc slot?
parallel	Logical. Should the MSE be run using parallel processing?
save_name	Character. Optional name to save parallel MSE list
checks	Logical. Run tests?
control	control options for testing and debugging

Value

A hierarchical list (by stock then fleet) of objects of class [MSE](#)

Author(s)

T. Carruthers and A. Hordyk

NIL *Item in list: get the list values from a list of lists*

Description

Create of vector of values that correspond with a slot in a list of objects

Usage

```
NIL(listy, namey, lev1 = T)
```

Arguments

listy	A list of objects
namey	A character vector representing the list item's name
lev1	Logical, should NIL default to the first level of the list?

Author(s)

T. Carruthers

plot.Assessment *Plot Assessment object*

Description

Produces HTML file (via markdown) figures of parameter estimates and output from an [Assessment](#) object.

Usage

```
## S4 method for signature 'Assessment,missing'
plot(
  x,
  filename = paste0("report_", x@Model),
  dir = tempdir(),
  ret_yr = 0L,
  open_file = TRUE,
  quiet = TRUE,
  render_args = list(),
  ...
)

## S4 method for signature 'Assessment,retro'
plot(
```

```

x,
y,
filename = paste0("report_", x@Model),
dir = tempdir(),
open_file = TRUE,
quiet = TRUE,
render_args = list(),
...
)

```

Arguments

x	An object of class Assessment .
filename	Character string for the name of the markdown and HTML files.
dir	The directory in which the markdown and HTML files will be saved.
ret_yr	If greater than zero, then a retrospective analysis will be performed and results will be reported. The integer here corresponds to the number of peels (the maximum number of terminal years for which the data are removed).
open_file	Logical, whether the HTML document is opened after it is rendered.
quiet	Logical, whether to silence the markdown rendering function.
render_args	Arguments to pass to render .
...	Other arguments.
y	An object of class retro .

Value

Returns invisibly the output from [render](#).

See Also

[retrospective](#)

Examples

```

output <- DD_TMB(Data = Simulation_1)

## Not run:
plot(output)

## End(Not run)

```

plot.MMSE

Standard plot for an object of class MMSE (multi MSE)

Description

Plot the projected biomass, fishing, mortality rate and yield for all stocks and MPs

Usage

```
## S4 method for signature 'MMSE,missing'
plot(
  x,
  maxcol = 6,
  qcol = rgb(0.4, 0.8, 0.95),
  lcol = "dodgerblue4",
  quants = c(0.05, 0.25, 0.75, 0.95),
  curyr = 2018,
  addline = FALSE
)
```

Arguments

x	Object of class MMSE . A Multi-OM object created by <code>multiMSE(MOM, ...)</code>
maxcol	Integer. The maximum number of columns (MPs) to be plotted in each plot
qcol	Character, color. The color of the inner percentile range
lcol	Character, color. The color of the outer percentile range.
quants	Numeric vector. The percentiles that are plotted (LB2, LB1, UB1, UB2). LB2 and UB2 are the outer percentiles, LB1 and UB1 are the inner percentiles.
curyr	Integer. The current year from which projections start.
addline	Logical. Should two individual simulations be added to the percentile plots?

Author(s)

T.Carruthers

plot.MOM

Standard plot for an object of class MOM

Description

Plot the stocks, fleets, catch fractions and relationships in multi operating model object

Usage

```
## S4 method for signature 'MOM,missing'  
plot(x, silent = TRUE, maxsims = 6)
```

Arguments

x	Object of class MOM . A Multi-OM object created by <code>new('MOM', ...)</code>
silent	Logical. Do you wish to see print outs / warnings?
maxsims	Integer. What are the maximum number of individual simulations you wish to plot?

Author(s)

T.Carruthers

plot.prof

Plot profile object

Description

Generates a profile plot generated by [profile](#). If a two-parameter profile is performed, then a contour plot of the likelihood surface is returned.

Usage

```
## S4 method for signature 'prof,missing'  
plot(x, contour_levels = 20, ...)
```

Arguments

x	An object of class prof returned by profile .
contour_levels	Integer, passed to <code>nlevels</code> argument of contour .
...	Miscellaneous. Not used.

Author(s)

Q. Huynh

plot.retro *Methods for retro object*

Description

plot and summary functions for retro object.

Usage

```
## S4 method for signature 'retro,missing'  
plot(x, color = NULL)  
  
## S4 method for signature 'retro'  
summary(object)
```

Arguments

x	An object of class <code>retro</code> .
color	An optional character vector of colors for plotting.
object	An object of class <code>retro</code> .

Author(s)

Q. Huynh

Examples

```
res <- SCA(Data = DLMtool::Red_snapper)  
ret <- retrospective(res)  
  
summary(ret)  
  
## Not run:  
plot(ret)  
  
## End(Not run)
```

plot.SRA

Plot SRA scope output

Description

Produces HTML file (via markdown) figures of parameter estimates and output from an [Assessment](#) object. Plots histograms of operating model parameters that are updated by the SRA scoping function, as well as diagnostic plots for the fits to the SRA for each simulation. `compare_SRA` plots a short report that compares output from multiple SRA objects, assuming the same model structure, i.e., identical matrix and array dimensions among models, but different data weightings, data omissions, etc.

Usage

```
## S4 method for signature 'SRA,missing'
plot(
  x,
  compare = TRUE,
  filename = "SRA_scope",
  dir = tempdir(),
  sims = 1:x@OM@nsim,
  Year = NULL,
  f_name = NULL,
  s_name = NULL,
  MSY_ref = c(0.5, 1),
  bubble_adj = 10,
  scenario = list(),
  title = NULL,
  open_file = TRUE,
  quiet = TRUE,
  render_args,
  ...
)

compare_SRA(
  ...,
  compare = TRUE,
  filename = "compare_SRA",
  dir = tempdir(),
  Year = NULL,
  f_name = NULL,
  s_name = NULL,
  MSY_ref = c(0.5, 1),
  bubble_adj = 10,
  scenario = list(),
  title = NULL,
  open_file = TRUE,
```



```

    quiet = TRUE,
    render_args
  )

```

Arguments

x	An object of class SRA (output from SRA_scope).
compare	Logical, if TRUE, the function will run runMSE to compare the historical period of the operating model and the SRA model output.
filename	Character string for the name of the markdown and HTML files.
dir	The directory in which the markdown and HTML files will be saved.
sims	A logical vector of length <code>x@OM@nsim</code> or a numeric vector indicating which simulations to keep.
Year	Optional, a vector of years for the historical period for plotting.
f_name	Character vector for fleet names.
s_name	Character vector for survey names.
MSY_ref	A numeric vector for reference horizontal lines for B/BMSY plots.
bubble_adj	A number to adjust the size of bubble plots (for residuals of age and length comps).
scenario	Optional, a named list to label each simulation in the SRA for plotting, e.g.: <code>list(names = c("low M", "high M"), col = c("blue", "red"))</code> .
title	Optional character string for an alternative title for the markdown report.
open_file	Logical, whether the HTML document is opened after it is rendered.
quiet	Logical, whether to silence the markdown rendering function.
render_args	A list of other arguments to pass to render .
...	For <code>compare_SRA</code> , multiple SRA objects for comparison.

Value

Returns invisibly the output from [render](#).

See Also

[SRA](#) [SRA_scope](#)

plotmulti	<i>A basic SSB plot for debugging runMSE output</i>
-----------	---

Description

A basic SSB plot for debugging runMSE output

Usage

```
plotmulti(MSEmulti, maxsim = 8)
```

Arguments

MSEmulti	An object of class MMSE arising from a run of multiMSE(MOM, ...)
maxsim	Integer. The number of simulations to plot

Author(s)

T.Carruthers

plotquant	<i>A fairly tidy time-series quantile plot</i>
-----------	--

Description

A fairly tidy time-series quantile plot

Usage

```
plotquant(  
  x,  
  p = c(0.05, 0.25, 0.75, 0.95),  
  yrs,  
  qcol,  
  lcol,  
  addline = T,  
  ablines = NA  
)
```

Arguments

x	Matrix. A time series quantity [simulation, year]
p	Numeric vector. The percentiles that are plotted (LB2, LB1, UB1, UB2). LB2 and UB2 are the outer percentiles, LB1 and UB1 are the inner percentiles.
yrs	Numeric vector. The years corresponding to the indexing of x
qcol	Character, color. The color of the inner percentile range
lcol	Character, color. The color of the outer percentile range.
addline	Logical. Should two individual simulations be added to the percentile plots?
ablines	Numeric vector. Horizontal lines to be added to the plot.

Author(s)

T.Carruthers

plotRel

Plot a relationship between stocks

Description

Plot a relationship between stocks

Usage

```
plotRel(Stocks, Rel, Relno, Snames, leg = F, extras = 0)
```

Arguments

Stocks	A list of stock objects (MOM@Stocks)
Rel	A list of inter-stock MICE relationships (MOM@Rel)
Relno	Integer. The relationship you wish to plot
Snames	A vector of stock names
leg	Logical. Do you want to plot a legend?
extras	Integer. The number of blank plots to create at the end.

Author(s)

T.Carruthers

plot_betavar	<i>Plots a beta variable</i>
--------------	------------------------------

Description

Plots the probability distribution function of a beta variable from the mean and standard deviation in either transformed (logit) or untransformed space.

Usage

```
plot_betavar(m, sd, label = NULL, is_logit = FALSE, color = "black")
```

Arguments

m	A vector of means of the distribution.
sd	A vector of standard deviations of the distribution.
label	Name of the variable to be used as x-axis label.
is_logit	Logical that indicates whether the means and standard deviations are in transformed (logit) or untransformed space.
color	A vector of colors.

Value

A plot of the probability distribution function. Vertical dotted line indicates mean of distribution. This function can plot multiple curves when multiple means and standard deviations are provided.

Author(s)

Q. Huynh

See Also

[plot_lognormalvar](#) [plot_steepness](#)

Examples

```
mu <- 0.5
stddev <- 0.1
plot_betavar(mu, stddev) # mean of plot should be 0.5

#logit parameters
mu <- 0
stddev <- 0.1
plot_betavar(mu, stddev, is_logit = TRUE) # mean of plot should be 0.5
```

plot_composition	<i>Plot composition data</i>
------------------	------------------------------

Description

Plots annual length or age composition data.

Usage

```
plot_composition(
  Year = 1:nrow(obs),
  obs,
  fit = NULL,
  plot_type = c("annual", "bubble_data", "bubble_residuals", "mean"),
  N = rowSums(obs),
  CAL_bins = NULL,
  ages = NULL,
  ind = 1:nrow(obs),
  annual_ylab = "Frequency",
  annual_yscale = c("proportions", "raw"),
  bubble_adj = 5,
  bubble_color = c("black", "white"),
  fit_linewidth = 3,
  fit_color = "red"
)
```

Arguments

Year	A vector of years.
obs	A matrix of either length or age composition data. For lengths, rows and columns should index years and length bin, respectively. For ages, rows and columns should index years and age, respectively.
fit	A matrix of predicted length or age composition from an assessment model. Same dimensions as obs.
plot_type	Indicates which plots to create. Options include annual distributions, bubble plot of the data, and bubble plot of the residuals, and annual means.
N	Annual sample sizes. Vector of length nrow(obs).
CAL_bins	A vector of lengths corresponding to the columns in obs. and fit. Ignored for age data.
ages	An optional vector of ages corresponding to the columns in obs.
ind	A numeric vector for plotting a subset of rows (which indexes year) of obs and fit.
annual_ylab	Character string for y-axis label when plot_type = "annual".
annual_yscale	For annual composition plots (plot_type = "annual"), whether the raw values ("raw") or frequencies ("proportions") are plotted.

bubble_adj	Numeric, for adjusting the relative size of bubbles in bubble plots (larger number = larger bubbles).
bubble_color	Colors for negative and positive residuals, respectively, for bubble plots.
fit_linewidth	Argument lwd for fitted line.
fit_color	Color of fitted line.

Value

Plots depending on plot_type.

Author(s)

Q. Huynh

Examples

```
data(Red_snapper)
plot_composition(obs = Red_snapper@CAA[1, , ], plot_type = "annual")
plot_composition(obs = Red_snapper@CAA[1, , ], plot_type = "bubble_data")

plot_composition(obs = Red_snapper@CAL[1, , ], plot_type = "annual", Red_snapper@CAL_bins[1:43])
plot_composition(obs = Red_snapper@CAL[1, , ], plot_type = "bubble_data",
CAL_bins = Red_snapper@CAL_bins[1:43])
```

plot_crosscorr	<i>Produce a cross-correlation plot of the derived data arising from getinds(MSE_object)</i>
----------------	--

Description

Produce a cross-correlation plot of the derived data arising from getinds(MSE_object)

Usage

```
plot_crosscorr(
  indPPD,
  indData,
  pp = 1,
  dnam = c("CS", "CV", "CM", "IS", "MLS"),
  res = 1
)
```

Arguments

indPPD	A 3D array of results arising from running getind on an MSE of the Null operating model (type of data/stat (e.g. mean catches),time period (chunk), simulation)
indData	A 3D array of results arising from running getind on an MSE of the Alternative operating model (type of data/stat (e.g. mean catches),time period (chunk), simulation)
pp	Positive integer, the number of time chunks (blocks of years normally, second dimension of indPPD and indData) to produce the plot for.
dnam	A character vector of names of the data for plotting purposes (as long as dimension 1 of indPPD and indData).
res	The size of the temporal blocking that created indPPD and indData - this is just used for labelling purposes

Value

A cross-correlation plot (ndata-1) x (ndata-1)

Author(s)

T. Carruthers

References

Carruthers and Hordyk 2018

plot_lognormalvar *Plots a lognormal variable*

Description

Plots the probability distribution function of a lognormal variable from the mean and standard deviation in either transformed (normal) or untransformed space.

Usage

```
plot_lognormalvar(m, sd, label = NULL, logtransform = FALSE, color = "black")
```

Arguments

m	A vector of means of the distribution.
sd	A vector of standard deviations of the distribution.
label	Name of the variable to be used as x-axis label.
logtransform	Indicates whether the mean and standard deviation are in transformed (normal) or untransformed space.
color	A vector of colors.

Value

A plot of the probability distribution function. Vertical dotted line indicates mean of distribution. This function can plot multiple curves when multiple means and standard deviations are provided.

Author(s)

Q. Huynh

See Also

[plot_betavar](#) [plot_steepness](#)

Examples

```
mu <- 0.5
stddev <- 0.1
plot_lognormalvar(mu, stddev) # mean of plot should be 0.5

#logtransformed parameters
mu <- 0
stddev <- 0.1
plot_lognormalvar(mu, stddev, logtransform = TRUE) # mean of plot should be 1
```

plot_residuals

Plot residuals

Description

Plots figure of residuals (or any time series with predicted mean of zero).

Usage

```
plot_residuals(
  Year,
  res,
  res_sd = NULL,
  res_sd_CI = 0.95,
  res_upper = NULL,
  res_lower = NULL,
  res_ind_blue = NULL,
  draw_zero = TRUE,
  zero_linetype = 2,
  label = "Residual"
)
```


Arguments

Year	A vector of years for the data.
res	A vector of residuals.
res_sd	A vector of year specific standard deviation for res.
res_sd_CI	The confidence interval for the error bars based for res_sd.
res_upper	A vector of year-specific upper bounds for the error bars of the residual (in lieu of argument res_CV).
res_lower	A vector of year-specific lower bounds for the error bars of the residual (in lieu of argument res_CV).
res_ind_blue	Indices of obs for which the plotted residuals and error bars will be blue.
draw_zero	Indicates whether a horizontal line should be drawn at zero.
zero_linetype	Passes argument lty (e.g. solid line = 1, dotted = 2) to draw_zero.
label	Character string that describes the data to label the y-axis.

Author(s)

Q. Huynh

See Also

[plot_timeseries](#)

plot_SR

Plot stock-recruitment function

Description

Plot stock-recruitment (with recruitment deviations if estimated).

Usage

```
plot_SR(
  Spawners,
  expectedR,
  R0 = NULL,
  S0 = NULL,
  rec_dev = NULL,
  trajectory = FALSE,
  y_zoom = NULL,
  ylab = "Recruitment"
)
```

Arguments

Spawners	A vector of the number of the spawners (x-axis).
expectedR	A vector of the expected recruitment (from the stock-recruit function) corresponding to values of Spawners.
R0	Virgin recruitment.
S0	Virgin spawners.
rec_dev	If recruitment deviations are estimated, a vector of estimated recruitment (in normal space) corresponding to values of Spawners.
trajectory	Indicates whether arrows will be drawn showing the trajectory of spawners and recruitment deviations over time.
y_zoom	If recruitment deviations are plotted, the y-axis limit relative to maximum expected recruitment expectedR. If NULL, all recruitments are plotted.
ylab	Character string for label on y-axis.

Value

A stock-recruit plot

Author(s)

Q. Huynh

plot_steepness	<i>Plots probability distribution function of stock-recruit steepness</i>
----------------	---

Description

Plots the probability distribution function of steepness from the mean and standard deviation.

Usage

```
plot_steepness(
  m,
  sd,
  is_transform = FALSE,
  SR = c("BH", "Ricker"),
  color = "black"
)
```

Arguments

m	The mean of the distribution (vectorized).
sd	The standard deviation of the distribution (vectorized).
is_transform	Logical, whether the mean and standard deviation are in normal space (FALSE) or transformed space.
SR	The stock recruitment relationship (determines the range and, if relevant, transformation of steepness).
color	A vector of colors.

Value

A plot of the probability distribution function. Vertical dotted line indicates mean of distribution.

Note

The function samples from a beta distribution with parameters alpha and beta that are converted from the mean and standard deviation. Then, the distribution is transformed from 0 - 1 to 0.2 - 1.

Author(s)

Q. Huynh

See Also

[plot_lognormalvar](#) [plot_betavar](#)

Examples

```
mu <- DLMtool::Simulation_1@steep
stddev <- DLMtool::Simulation_1@steep * DLMtool::Simulation_1@CV_steep
plot_steepness(mu, stddev)
```

plot_timeseries

Plot time series of data

Description

Plot time series of observed (with lognormally-distributed error bars) vs. predicted data.

Usage

```
plot_timeseries(
  Year,
  obs,
  fit = NULL,
  obs_CV = NULL,
  obs_CV_CI = 0.95,
  obs_upper = NULL,
  obs_lower = NULL,
  obs_ind_blue = NULL,
  fit_linewidth = 3,
  fit_color = "red",
  label = "Observed data"
)
```

Arguments

Year	A vector of years for the data.
obs	A vector of observed data.
fit	A vector of predicted data (e.g., from an assessment model).
obs_CV	A vector of year-specific coefficient of variation in the observed data.
obs_CV_CI	The confidence interval for the error bars based for obs_CV.
obs_upper	A vector of year-specific upper bounds for the error bars of the observed data (in lieu of argument obs_CV).
obs_lower	A vector of year-specific lower bounds for the error bars of the observed data (in lieu of argument obs_CV).
obs_ind_blue	Indices of obs for which the plotted points and error bars will be blue.
fit_linewidth	Argument lwd for fitted line.
fit_color	Color of fitted line.
label	Character string that describes the data to label the y-axis.

Author(s)

Q. Huynh

See Also

[plot_residuals](#)

Examples

```
data(Red_snapper)
plot_timeseries(Red_snapper@Year, Red_snapper@Cat[1, ],
  obs_CV = Red_snapper@CV_Cat, label = "Catch")
```

PRBcalc	<i>Calculate mahalanobis distance (null and alternative MSEs) and statistical power for all MPs in an MSE</i>
---------	---

Description

Calculate mahalanobis distance (null and alternative MSEs) and statistical power for all MPs in an MSE

Usage

```
PRBcalc(
  MSE_null,
  MSE_alt,
  tsd = c("Cat", "Cat", "Cat", "Ind", "ML"),
  stat = c("slp", "AAV", "mu", "slp", "slp"),
  dnam = c("C_S", "C_V", "C_M", "I_S", "ML_S"),
  res = 6,
  alpha = 0.05,
  plotCC = FALSE,
  removedat = FALSE,
  removethresh = 0.025
)
```

Arguments

MSE_null	An object of class MSE representing the null hypothesis
MSE_alt	An object of class MSE representing the alternative hypothesis
tsd	Character string of data types: Cat = catch, Ind = relative abundance index, ML = mean length in catches
stat	Character string defining the quantity to be calculated for each data type, slp = slope(log(x)), AAV = average annual variability, mu = mean(log(x))
dnam	Character string of names for the quantities calculated
res	Integer, the resolution (time blocking) for the calculation of PPD
alpha	Probability of incorrectly rejecting the null operating model when it is valid
plotCC	Logical, should the PPD cross correlations be plotted?
removedat	Logical, should data not contributing to the mahalanobis distance be removed?
removethresh	Positive fraction: the cumulative percentage of removed data (removedat=TRUE) that contribute to the mahalanobis distance

Value

A list object with two hierarchies of indexing, first by MP, second has two positions as described in [Probs](#): (1) mahalanobis distance, (2) a matrix of type 1 error (first row) and statistical power (second row), by time block.

Author(s)

T. Carruthers

References

Carruthers, T.R, and Hordyk, A.R. In press. Using management strategy evaluation to establish indicators of changing fisheries. Canadian Journal of Fisheries and Aquatic Science.

```
prelim_AM
```

Preliminary Assessments in MSE

Description

Evaluates the likely performance of Assessment models in the operating model. This function will apply the assessment model for Data generated during the historical period of the MSE, and report the convergence rate for the model and total time elapsed in running the assessments.

Usage

```
prelim_AM(x, Assess, ncpus = NULL, ...)
```

Arguments

x	Either a Hist, Data or OM object.
Assess	An Assess function of class Assess.
ncpus	Numeric, the number of CPUs to run the Assessment model (will run in parallel if greater than 1).
...	Arguments to be passed to Assess, e.g., model configurations.

Value

Returns invisibly a list of [Assessment](#) objects of length OM@nsim. Messages via console.

Author(s)

Q. Huynh

Examples

```
## Not run:
prelim_AM(DLMtool::testOM, DD_TMB)

## End(Not run)
```

Probs	<i>Calculates mahalanobis distance and rejection of the Null operating model</i>
-------	--

Description

Calculates mahalanobis distance and rejection of the Null operating model, used by wrapping function [PRBcalc](#).

Usage

```
Probs(indPPD, indData, alpha = 0.05, removedat = FALSE, removethresh = 0.05)
```

Arguments

indPPD	A 3D array of results arising from running getind on an MSE of the Null operating model (type of data/stat (e.g. mean catches),time period (chunk), simulation)
indData	A 3D array of results arising from running getind on an MSE of the Alternative operating model (type of data/stat (e.g. mean catches),time period (chunk), simulation)
alpha	Positive fraction: rate of type I error, alpha
removedat	Logical, should data not contributing to the mahalanobis distance be removed?
removethresh	Positive fraction: the cumulative percentage of removed data (removedat=TRUE) that contribute to the mahalanobis distance

Value

A list object. Position 1 is an array of the mahalanobis distances. Dimension 1 is length 2 for the Null OM (indPPD) and the alternative OM (indData). Dimension 2 is the time block (same length as indPPD dim 2). Dimension 3 is the simulation number (same length at indPPD dim 3.), Position 2 is a matrix (2 rows, ntimeblock columns) which is (row 1) alpha: the rate of false positives, and row 2 the power (1-beta) the rate of true positives

Author(s)

T. Carruthers

References

Carruthers and Hordyk 2018

prof-class	<i>Class-prof</i>
------------	-------------------

Description

An S4 class that contains output from [profile](#).

Slots

Model Name of the assessment model.

Name Name of Data object.

Par Character vector of parameters that were profiled.

MLE Numeric vector of the estimated values of the parameters (corresponding to Par) from the assessment.

grid A data.frame of the change in negative log-likelihood (nll) based on the profile of the parameters.

Author(s)

Q. Huynh

See Also

[plot.prof](#) [profile](#)

profile	<i>Profile likelihood of assessment models</i>
---------	--

Description

Profile the likelihood for parameters of assessment models.

Usage

```
profile(fitted, ...)
```

```
## S4 method for signature 'Assessment'
```

```
profile(fitted, figure = TRUE, ...)
```

Arguments

fitted, Assessment

An object of class [Assessment](#).

... A sequence of values of the parameter(s) for the profile. See details and example below. See details for name of arguments to be passed on.

figure Logical, indicates whether a figure will be plotted.

Details

For the following assessment models, possible sequence of values for profiling are:

- DD_TMB and DD_SS: R_0 and h
- SP and SP_SS: FMSY and MSY
- DD and cDD_SS: R_0 and h
- SCA and SCA_Pope: R_0 and h
- SCA2: meanR
- VPA: F_{term}
- SSS: R_0

Value

An object of class `prof` that contains a data frame of negative log-likelihood values from the profile and, optionally, a figure of the likelihood surface.

Author(s)

Q. Huynh

Examples

```
output <- DD_TMB(Data = DLMtool::Red_snapper)
pro <- profile(output, R0 = seq(0.75, 1.25, 0.025), h = seq(0.9, 0.99, 0.01))
pro <- profile(output, R0 = seq(0.75, 1.25, 0.025)) # Profile R0 only

# Ensure your grid is of proper resolution. A grid that is too coarse
# will likely distort the shape of the likelihood surface.
```

project-class

Class-project

Description

An S4 class for the output from [projection](#).

Slots

Model Name of the assessment model.

Name Name of Data object.

FMort A matrix of fishing mortality over `p_sim` rows and `p_years` columns.

B An matrix of biomass with `p_sim` rows and `p_years` columns.

SSB A matrix of spawning biomass with `p_sim` rows and `p_years` columns.

VB A matrix of vulnerable biomass with p_sim rows and p_years columns.
 R A matrix of recruitment over p_sim rows and p_years columns.
 N A matrix of abundance over p_sim rows and p_years columns.
 Catch A matrix of observed catch over p_sim rows and p_years columns.
 Index A matrix of observed index over p_sim rows and p_years columns.
 C_at_age An array for catch-at-age with dimension c(p_sim, p_years, maxage).

Author(s)

Q. Huynh

See Also

[projection](#)

projection

Projections for assessment models

Description

This function takes an assessment model and runs a stochastic projection based on future F or catch.

Usage

```
projection(
  Assessment,
  constrain = c("F", "Catch"),
  FMort = NULL,
  Catch = NULL,
  p_years = 50,
  p_sim = 200,
  obs_error = NULL,
  process_error = NULL,
  max_F = 3,
  seed = 499
)
```

Arguments

Assessment	An object of class Assessment .
constrain	Whether to project on future F or catch. By default, projects on F.
FMort	The projection F, either of length 1 for constant F for the entirety of the projection or length p_years.
Catch	The projection catch, either of length 1 for constant catch for the entirety of the projection or length p_years.

p_years	Integer for the number of projection years.
p_sim	Integer for the number of simulations for the projection.
obs_error	Vector of length two for standard deviation of error to be added to the index and catch, respectively. If NULL, uses values from assessment model.
process_error	Numeric, standard deviation for process error (e.g., recruitment or biomass deviates). If NULL, uses values from assessment model.
max_F	The maximum allowable F if the projection is constrained on catch.
seed	An integer to set the seed for the sampling observation and process error deviates.

Examples

```
myAssess <- SCA(Data = SimulatedData)
do_projection <- projection(myAssess, FMort = myAssess@FMSY)
```

read.control.file *Reads iSCAM control file*

Description

A function for returning the results of the iscam control file

Usage

```
read.control.file(
  file = NULL,
  num.gears = NULL,
  num.age.gears = NULL,
  verbose = FALSE
)
```

Arguments

file	File location
num.gears	The number of gears
num.age.gears	The number age-gears
verbose	should detailed results be printed to console

Author(s)

Chris Grandin (DFO PBS)

read.data.file	<i>Reads iSCAM dat file</i>
----------------	-----------------------------

Description

A function for returning the results of the .dat iscam file

Usage

```
read.data.file(file = NULL, verbose = FALSE)
```

Arguments

file	File location
verbose	should detailed results be printed to console

Author(s)

Chris Grandin (DFO PBS)

read.mcmc	<i>Reads iSCAM mcmc output files</i>
-----------	--------------------------------------

Description

A function for returning the results of the iscam mcmc files

Usage

```
read.mcmc(model.dir = NULL, verbose = TRUE)
```

Arguments

model.dir	Folder name
verbose	should detailed results be printed to console

Author(s)

Chris Grandin (DFO PBS)

read.par.file	<i>Reads iSCAM parameter file</i>
---------------	-----------------------------------

Description

A function for returning the results of the iscam .par file

Usage

```
read.par.file(file = NULL, verbose = FALSE)
```

Arguments

file	File location
verbose	should detailed results be printed to console

Author(s)

Chris Grandin (DFO PBS)

read.projection.file	<i>Reads iSCAM projection file</i>
----------------------	------------------------------------

Description

A function for returning the results of the iscam projection file

Usage

```
read.projection.file(file = NULL, verbose = FALSE)
```

Arguments

file	File location
verbose	should detailed results be printed to console

Author(s)

Chris Grandin (DFO PBS)

read.report.file	<i>Reads iSCAM Rep file</i>
------------------	-----------------------------

Description

A function for returning the results of the .rep iscam file

Usage

```
read.report.file(fn)
```

Arguments

fn	File location
----	---------------

Author(s)

Chris Grandin (DFO PBS)

retro-class	<i>Class-retro</i>
-------------	--------------------

Description

An S4 class that contains output from [retrospective](#).

Slots

Model Name of the assessment model.

Name Name of Data object.

TS_var Character vector of time series variables, e.g. recruitment, biomass, from the assessment.

TS An array of time series assessment output of dimension, indexed by: peel (the number of terminal years removed from the base assessment), years, and variables (corresponding to TS_var).

Est_var Character vector of estimated parameters, e.g. R0, steepness, in the assessment.

Est An array for estimated parameters of dimension, indexed by: peel, variables (corresponding to Est_var), and value (length 2 for estimate and standard error).

Author(s)

Q. Huynh

See Also

[plot.retro](#) [summary.retro](#) [plot.Assessment](#)

retrospective	<i>Retrospective analysis of assessment models</i>
---------------	--

Description

Perform a retrospective analysis, successive removals of most recent years of data to evaluate resulting parameter estimates.

Usage

```
retrospective(x, ...)  
  
## S4 method for signature 'Assessment'  
retrospective(x, nyr = 5, figure = TRUE)  
  
## S4 method for signature 'SRA'  
retrospective(x, nyr = 5, figure = TRUE)
```

Arguments

x	An S4 object of class Assessment of SRA .
...	More arguments.
nyr	The maximum number of years to remove for the retrospective analysis.
figure	Indicates whether plots will be drawn.

Value

A list with an array of model output and of model estimates from the retrospective analysis. Figures showing the time series of biomass and exploitation and parameter estimates with successive number of years removed. For a variety of time series output (SSB, recruitment, etc.) and estimates (R0, steepness, etc.), also returns a matrix of Mohn's rho (Mohn 1999).

Author(s)

Q. Huynh

References

Mohn, R. 1999. The retrospective problem in sequential population analysis: an investigation using cod fishery and simulated data. *ICES Journal of Marine Science* 56:473-488.

Examples

```
output <- DD_TMB(Data = DLMtool::Red_snapper)  
get_retro <- retrospective(output, nyr = 5, figure = FALSE)
```

retrospective_AM *retrospective_AM (retrospective of Assessment model in MSE)*

Description

Plots the true retrospective of an assessment model during the MSE. A series of time series estimates of SSB, F, and VB are plotted over the course of the MSE are plotted against the operating model (true) values (in black).

Usage

```
retrospective_AM(MSE, sim = 1, MP, MSE_Hist = NULL, plot_legend = FALSE)
```

Arguments

MSE	An object of class MSE created by runMSE with PPD = TRUE.
sim	Integer between 1 and MSE@nsim. The simulation number for which the retrospectives will be plotted.
MP	Character. The name of the management procedure created by make_MP containing the assessment model.
MSE_Hist	Optional. The list containing historical data for the MSE, created by runMSE with argument Hist = TRUE. Currently only used to plot operating model vulnerable biomass in historical period.
plot_legend	Logical. Whether to plot legend to reference year of assessment in the MSE.

Details

For assessment models that utilize annual harvest rates (u), the instantaneous fishing mortality rates are obtained as $F = -\log(1 - u)$.

Value

A series of figures for spawning stock biomass (SSB, including absolute magnitude and relative to MSY and virgin), fishing mortality (F, including absolute magnitude and relative to MSY), and vulnerable biomass (VB) estimates over the course of the MSE are plotted against the operating model (true) values (in black).

Note

This function only plots retrospectives from a single simulation in the MSE. Results from one figure may not be indicative of general assessment behavior and performance overall.

For [SP](#) and [SP_SS](#) assessment models don't model SSB. Instead, the estimated vulnerable biomass is plotted.

Author(s)

Q. Huynh

See Also[diagnostic_AM](#)**Examples**

```
## Not run:
DD_MSY <- makeMP(DD_TMB, HCR_MSY, diagnostic = "full")
myMSE_hist <- DLMtool::runMSE(DLMtool::testOM, Hist = TRUE)
myMSE <- DLMtool::runMSE(DLMtool::testOM, MPs = "DD_MSY", PPD = TRUE)
retrospective_AM(myMSE, sim = 1, MP = "DD_MSY")
retrospective_AM(myMSE, sim = 1, MP = "DD_MSY", Hist = myMSE_hist)

## End(Not run)
```

SCA

*Statistical catch-at-age (SCA) model***Description**

A generic statistical catch-at-age model (single fleet, single season) that uses catch, index, and catch-at-age composition data. SCA parameterizes R_0 and steepness as leading productivity parameters in the assessment model. Recruitment is estimated as deviations from the resulting stock-recruit relationship. In SCA2, the mean recruitment in the time series is estimated and recruitment deviations around this mean are estimated as penalized parameters (similar to Cadigan 2016). The standard deviation is set high so that the recruitment is almost like free parameters. Unfished and MSY reference points are inferred afterwards from the assessment output (SSB and recruitment estimates). SCA_Pope is a variant of SCA that fixes the expected catch to the observed catch, and Pope's approximation is used to calculate the annual harvest rate (U).

Usage

```
SCA(
  x = 1,
  Data,
  SR = c("BH", "Ricker"),
  vulnerability = c("logistic", "dome"),
  CAA_dist = c("multinomial", "lognormal"),
  CAA_multiplier = 50,
  I_type = c("B", "VB", "SSB"),
  rescale = "mean1",
  max_age = Data@MaxAge,
  start = NULL,
  fix_h = TRUE,
  fix_F_equilibrium = TRUE,
  fix_omega = TRUE,
  fix_sigma = FALSE,
  fix_tau = TRUE,
```

```

early_dev = c("comp_onegen", "comp", "all"),
late_dev = "comp50",
integrate = FALSE,
silent = TRUE,
opt_hess = FALSE,
n_restart = ifelse(opt_hess, 0, 1),
control = list(iter.max = 2e+05, eval.max = 4e+05),
inner.control = list(),
...
)

```

```

SCA2(
  x = 1,
  Data,
  SR = c("BH", "Ricker"),
  vulnerability = c("logistic", "dome"),
  CAA_dist = c("multinomial", "lognormal"),
  CAA_multiplier = 50,
  I_type = c("B", "VB", "SSB"),
  rescale = "mean1",
  max_age = Data@MaxAge,
  start = NULL,
  fix_h = TRUE,
  fix_F_equilibrium = TRUE,
  fix_omega = TRUE,
  fix_sigma = FALSE,
  fix_tau = TRUE,
  common_dev = "comp50",
  integrate = FALSE,
  silent = TRUE,
  opt_hess = FALSE,
  n_restart = ifelse(opt_hess, 0, 1),
  control = list(iter.max = 2e+05, eval.max = 4e+05),
  inner.control = list(),
  ...
)

```

```

SCA_Pope(
  x = 1,
  Data,
  SR = c("BH", "Ricker"),
  vulnerability = c("logistic", "dome"),
  CAA_dist = c("multinomial", "lognormal"),
  CAA_multiplier = 50,
  I_type = c("B", "VB", "SSB"),
  rescale = "mean1",
  max_age = Data@MaxAge,
  start = NULL,

```

```

    fix_h = TRUE,
    fix_U_equilibrium = TRUE,
    fix_sigma = FALSE,
    fix_tau = TRUE,
    early_dev = c("comp_onegen", "comp", "all"),
    late_dev = "comp50",
    integrate = FALSE,
    silent = TRUE,
    opt_hess = FALSE,
    n_restart = ifelse(opt_hess, 0, 1),
    control = list(iter.max = 2e+05, eval.max = 4e+05),
    inner.control = list(),
    ...
)

```

Arguments

x	A position in the Data object (by default, equal to one for assessments).
Data	An object of class Data
SR	Stock-recruit function (either "BH" for Beverton-Holt or "Ricker").
vulnerability	Whether estimated vulnerability is "logistic" or "dome" (double-normal). See details for parameterization.
CAA_dist	Whether a multinomial or lognormal distribution is used for likelihood of the catch-at-age matrix. See details.
CAA_multiplier	Numeric for data weighting of catch-at-age matrix if CAA_hist = "multinomial". Otherwise ignored. See details.
I_type	Whether the index surveys population biomass (B; this is the default in the DLMtool operating model), vulnerable biomass (VB), or spawning stock biomass (SSB).
rescale	A multiplicative factor that rescales the catch in the assessment model, which can improve convergence. By default, "mean1" scales the catch so that time series mean is 1, otherwise a numeric. Output is re-converted back to original units.
max_age	Integer, the maximum age (plus-group) in the model.
start	Optional list of starting values. Entries can be expressions that are evaluated in the function. See details.
fix_h	Logical, whether to fix steepness to value in Data@steep in the model for SCA. This only affects calculation of reference points for SCA2.
fix_F_equilibrium	Logical, whether the equilibrium fishing mortality prior to the first year of the model is estimated. If TRUE, F_equilibrium is fixed to value provided in start (if provided), otherwise, equal to zero (assumes unfisher conditions).
fix_omega	Logical, whether the standard deviation of the catch is fixed. If TRUE, sigma is fixed to value provided in start (if provided), otherwise, value based on Data@CV_Cat.

<code>fix_sigma</code>	Logical, whether the standard deviation of the index is fixed. If TRUE, sigma is fixed to value provided in <code>start</code> (if provided), otherwise, value based on <code>Data@CV_Ind</code> .
<code>fix_tau</code>	Logical, the standard deviation of the recruitment deviations is fixed. If TRUE, tau is fixed to value provided in <code>start</code> (if provided), otherwise, value based on <code>Data@sigmaR</code> .
<code>early_dev</code>	Numeric or character string describing the years for which recruitment deviations are estimated in SCA. By default, equal to <code>"comp_onegen"</code> , where rec devs are estimated one full generation prior to the first year when catch-at-age (CAA) data are available. With <code>"comp"</code> , rec devs are estimated starting in the first year with CAA. With <code>"all"</code> , rec devs start at the beginning of the model. If numeric, the number of years after the first year of the model for which to start estimating rec devs. Use negative numbers for years prior to the first year.
<code>late_dev</code>	Typically, a numeric for the number of most recent years in which recruitment deviations will not be estimated in SCA (recruitment in these years will be based on the mean predicted by stock-recruit relationship). By default, <code>"comp50"</code> uses the number of ages (smaller than the mode) for which the catch-at-age matrix has less than half the abundance than that at the mode.
<code>integrate</code>	Logical, whether the likelihood of the model integrates over the likelihood of the recruitment deviations (thus, treating it as a random effects/state-space variable). Otherwise, recruitment deviations are penalized parameters.
<code>silent</code>	Logical, passed to <code>MakeADFun</code> , whether TMB will print trace information during optimization. Used for diagnostics for model convergence.
<code>opt_hess</code>	Logical, whether the hessian function will be passed to <code>nlminb</code> during optimization (this generally reduces the number of iterations to convergence, but is memory and time intensive and does not guarantee an increase in convergence rate). Ignored if <code>integrate = TRUE</code> .
<code>n_restart</code>	The number of restarts (calls to <code>nlminb</code>) in the optimization procedure, so long as the model hasn't converged. The optimization continues from the parameters from the previous (re)start.
<code>control</code>	A named list of arguments for optimization to be passed to <code>nlminb</code> .
<code>inner.control</code>	A named list of arguments for optimization of the random effects, which is passed on to <code>newton</code> .
<code>...</code>	Other arguments to be passed.
<code>common_dev</code>	Typically, a numeric for the number of most recent years in which a common recruitment deviation will be estimated (in SCA2, uninformative years will have a recruitment closer to the mean, which can be very misleading, especially near the end of the time series). By default, <code>"comp50"</code> uses the number of ages (smaller than the mode) for which the catch-at-age matrix has less than half the abundance than that at the mode.
<code>fix_U_equilibrium</code>	Logical, same as <code>'fix_F_equilibrium'</code> for <code>'SCA_Pope'</code> .

Details

The basic data inputs are catch (by weight), index (by weight/biomass), and catch-at-age matrix (by numbers). Annual F 's are estimated parameters assuming continuous fishing over the year. Note:

prior to version 1.2, catches were assumed to be known perfectly with an annual harvest rate from pulse fishing in SCA. That feature has now moved to SCA_Pope.

By default, steepness is fixed in the model to the value in `Data@steep`.

The annual sample sizes of the catch-at-age matrix is provided to the model (used in the likelihood for catch-at-age assuming a multinomial distribution), and is manipulated via argument `CAA_multiplier`. This argument is interpreted in two different ways depending on the value provided. If `CAA_multiplier > 1`, then this value will cap the annual sample sizes to that number. If `CAA_multiplier <= 1`, then all the annual samples sizes will be re-scaled by that number. By default, sample sizes are capped at 50.

Alternatively, a lognormal distribution with inverse proportion variance can be used for the catch at age (Punt and Kennedy, 1994, as cited by Maunder 2011).

For start (optional), a named list of starting values of estimates can be provided for:

- `R0` Virgin recruitment, only for SCA.
- `h` Steepness, only for SCA. If not provided, the value in `Data@steep` is used.
- `meanR` Mean recruitment, only for SCA2.
- `F_equilibrium` Fishing mortality prior to the first year of model, e.g. zero means unfished conditions. Defaults to zero.
- `vu1_par` Vulnerability parameters (length 2 vector for logistic or length 4 for dome, see below). Users should provide estimates of the parameters in normal space, e.g. `vu1_max` between 0-1, and the function will perform the appropriate transformations for the model.
- `F` A vector of `F`'s of length `nyears`, `length(Data@Year)`. If not provided, defaults to 0.1.
- `omega` Standard deviation of catch. If not provided, the value based on `Data@CV_Cat` is used.
- `sigma` Standard deviation of index. If not provided, the value based on `Data@CV_Ind` is used.
- `tau` Standard deviation of recruitment deviations. If not provided, the value in `Data@sigmaR` is used.

Vulnerability can be specified to be either logistic or dome. If logistic, then the parameter vector `vu1_par` is of length 2:

- `vu1_par[1]`: `a_95`, the age of 95% vulnerability, via logit transformation to constrain `a_95` to less than 75% of the maximum age: $a_{95} = 0.75 * \text{max_age} * \text{plogis}(vu1_par[1])$.
- `vu1_par[2]`: `a_50`, the age of 50% vulnerability as an offset, i.e., $a_{50} = a_{95} - \exp(vu1_par[2])$.

A vague prior for `vu1_par[2] ~ N(0, sd = 3)` is used to aid convergence, for example, when vulnerability $\gg 0.5$ for the youngest age class.

With dome vulnerability, a double Gaussian parameterization is used, where `vu1_par` is an estimated vector of length 4:

- `vu1_par[1]`: `a_asc`, the first age of full vulnerability for the ascending limb, via logit transformation to constrain `a_95` to less than 75% of the maximum age: $a_{asc} = 0.75 * \text{max_age} * \text{plogis}(vu1_par[1])$.
- `vu1_par[2]`: `a_50`, the age of 50% vulnerability for the ascending limb as an offset, i.e., $a_{50} = a_{asc} - \exp(vu1_par[2])$.

- `vul_par[3]`: `a_des`, the last age of full vulnerability (where the descending limb starts) via logit transformation to constrain between `a_asc` and `max_age`, i.e., $a_des = (max_age - a_asc) * plogis(vul_par[3]) + a_asc$. By default, fixed to a small value so that the dome is effectively a three-parameter function.
- `vul_par[4]`: `vul_max`, the vulnerability (in logit space) at the maximum age.

Vague priors of `vul_par[2] ~ N(0, sd = 3)` and `vul_par[3] ~ N(0, 3)` are used to aid convergence, for example, when vulnerability $\gg 0.5$ for the youngest age class.

Value

An object of class `Assessment`.

Required Data

- `SCA`, `SCA_Pope`, and `SCA_Pope`: `Cat`, `Ind`, `Mort`, `L50`, `L95`, `CAA`, `vbK`, `vbLinf`, `vbt0`, `wla`, `wlb`, `MaxAge`

Optional Data

- `SCA`: `Rec`, `steep`, `sigmaR`, `CV_Ind`, `CV_Cat`
- `SC2`: `Rec`, `steep`, `CV_Ind`, `CV_Cat`
- `SCA_Pope`: `Rec`, `steep`, `sigmaR`, `CV_Ind`

Author(s)

Q. Huynh

References

- Cadigan, N.G. 2016. A state-space stock assessment model for northern cod, including under-reported catches and variable natural mortality rates. *Canadian Journal of Fisheries and Aquatic Science* 72:296-308.
- Maunder, M.N. 2011. Review and evaluation of likelihood functions for composition data in stock-assessment models: Estimating the effective sample size. *Fisheries Research* 209:311-319.
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See Also

[plot.Assessment.summary.Assessment.retrospective.profile.make_MP](#)

Examples

```
res <- SCA(Data = DLMtool::SimulatedData)
res2 <- SCA2(Data = DLMtool::SimulatedData)

compare_models(res, res2)
```

```

SCA_assess <- SCA2(Data = DLMtool::Simulation_1)

## Not run:
plot(res)

## End(Not run)

```

SIL

Slot in list: get the slot values from a list of objects

Description

Create of vector of values that correspond with a slot in a list of objects

Usage

```
SIL(listy, sloty)
```

Arguments

listy	A list of objects
sloty	A character vector representing the slot name

Author(s)

T. Carruthers

simmov

Calculates movement matrices from user inputs

Description

A wrapper function for [makemov](#) used to generate movement matrices for a DLMtool operating model. Calculates a movement matrix from user-specified unfished stock biomass fraction in each area and probability of staying in the area in each time step.

Usage

```

simmov(
  OM,
  dist = c(0.1, 0.2, 0.3, 0.4),
  prob = 0.5,
  distE = 0.1,
  probE = 0.1,
  prob2 = NA,

```

```

    figure = TRUE
  )

  plot_mov(mov, age = 1, type = c("matrix", "all"))

```

Arguments

OM	Operating model, an object of class OM .
dist	A vector of fractions of unfished stock in each area. The length of this vector will determine the number of areas (nareas) in the OM.
prob	Mean probability of staying across all areas (single value) or a vector of the probability of individuals staying in each area (same length as dist)
distE	Logit (normal) St.Dev error for sampling stock fractions from the frags vector
probE	Logit (normal) St.Dev error for sampling desired probability of staying either by area (prob is same length as dist) or the mean probability of staying (prob is a single number)
prob2	Optional vector as long as prob and dist. Upper bounds on uniform sampling of probability of staying, lower bound is prob.
figure	Logical to indicate if the movement matrix will be plotted (mean values and range across OM@nsim simulations.)
mov	A four-dimensional array of dimension <code>c(nsim, maxage, nareas, nareas)</code> specifying movement in the operating model.
age	An age from 1 to maxage for the movement-at-age matrix figure when <code>type = "matrix"</code> .
type	Whether to plot a movement matrix for a single age (<code>"matrix"</code>) or the full movement versus age figure (<code>"all"</code>)

Value

The operating model OM with movement parameters in slot cpars. The mov array is of dimension `nsim, maxage, nareas, nareas`.

Functions

- `simmov`: Estimation function for creating movement matrix.
- `plot_mov`: Plotting function.

Note

Array mov is age-specific, but currently the movement generated by `simmov` is independent of age.

Author(s)

T. Carruthers and Q. Huynh

Examples

```

movOM_5areas <- simmov(testOM, dist = c(0.01,0.1,0.2,0.3,0.39), prob = c(0.1,0.6,0.6,0.7,0.9))
movOM_5areas@cpars$mov[1, 1, , ] # sim 1, age 1, movement from areas in column i to areas in row j
plot_mov(movOM_5areas@cpars$mov)
plot_mov(movOM_5areas@cpars$mov, type = "all")

```

SOL

*Sum over list: get the list values from a list of lists***Description**

Create of vector of values that correspond with a named position in a list of objects

Usage

```
SOL(listy, namey)
```

Arguments

listy	A list of objects
namey	A character vector representing the list item's name

Author(s)

T. Carruthers

SP

*Surplus production model with FMSY and MSY as leading parameters***Description**

A surplus production model that uses only a time-series of catches and a relative abundance index and coded in TMB. The base model, SP, is conditioned on catch and estimates a predicted index. Continuous surplus production and fishing is modeled with sub-annual time steps which should approximate the behavior of ASPIC (Prager 1994). The Fox model, SP_Fox, fixes $BMSY/K = 0.37$ ($1/e$). The state-space version, SP_SS estimates annual deviates in biomass. An option allows for setting a prior for the intrinsic rate of increase. The function for the spict model (Pedersen and Berg, 2016) is available in [DLMextra](#).

Usage

```
SP(  
  x = 1,  
  Data,  
  AddInd = "B",  
  rescale = "mean1",  
  start = NULL,  
  fix_dep = TRUE,  
  fix_n = TRUE,  
  LWT = NULL,  
  n_seas = 4L,  
  n_itF = 3L,  
  use_r_prior = FALSE,  
  r_reps = 100,  
  SR_type = c("BH", "Ricker"),  
  silent = TRUE,  
  opt_hess = FALSE,  
  n_restart = ifelse(opt_hess, 0, 1),  
  control = list(iter.max = 5000, eval.max = 10000),  
  ...  
)
```

```
SP_SS(  
  x = 1,  
  Data,  
  AddInd = "B",  
  rescale = "mean1",  
  start = NULL,  
  fix_dep = TRUE,  
  fix_n = TRUE,  
  fix_sigma = TRUE,  
  fix_tau = TRUE,  
  LWT = NULL,  
  early_dev = c("all", "index"),  
  n_seas = 4L,  
  n_itF = 3L,  
  use_r_prior = FALSE,  
  r_reps = 100,  
  SR_type = c("BH", "Ricker"),  
  integrate = FALSE,  
  silent = TRUE,  
  opt_hess = FALSE,  
  n_restart = ifelse(opt_hess, 0, 1),  
  control = list(iter.max = 5000, eval.max = 10000),  
  inner.control = list(),  
  ...  
)
```

SP_Fox(x = 1, Data, ...)

Arguments

x	An index for the objects in Data when running in runMSE . Otherwise, equals to 1 When running an assessment interactively.
Data	An object of class Data.
AddInd	A vector of integers or character strings indicating the indices to be used in the model. Integers assign the index to the corresponding index in Data@AddInd, "B" (or 0) represents total biomass in Data@Ind, "VB" represents vulnerable biomass in Data@VInd, and "SSB" represents spawning stock biomass in Data@SpInd.
rescale	A multiplicative factor that rescales the catch in the assessment model, which can improve convergence. By default, "mean1" scales the catch so that time series mean is 1, otherwise a numeric. Output is re-converted back to original units.
start	Optional list of starting values. Entries can be expressions that are evaluated in the function. See details.
fix_dep	Logical, whether to fix the initial depletion (ratio of biomass to carrying capacity in the first year of the model). If TRUE, uses the value in start, otherwise equal to 1 (unfished conditions).
fix_n	Logical, whether to fix the exponent of the production function. If TRUE, uses the value in start, otherwise equal to n = 2, where the biomass at MSY is half of carrying capacity.
LWT	A vector of likelihood weights for each survey.
n_seas	Integer, the number of seasons in the model for calculating continuous surplus production.
n_itF	Integer, the number of iterations to solve F conditional on the observed catch given multiple seasons within an annual time step. Ignored if n_seas = 1.
use_r_prior	Logical, whether a prior for the intrinsic rate of increase will be used in the model. See details.
r_reps	If use_r_prior = TRUE, the number of samples of natural mortality and steepness for calculating the mean and standard deviation of the r prior. To override and directly provide the r-prior mean and standard deviation, use the start list, e.g. start = list(r_prior = c(0.1, 0.05)) (mean of 0.1 and s.d. of 0.05).
SR_type	If use_r_prior = TRUE, the stock-recruit relationship used to calculate unfished recruits per spawner at the origin of spawning biomass approaches zero. Used for the r prior.
silent	Logical, passed to MakeADFun , whether TMB will print trace information during optimization. Used for diagnostics for model convergence.
opt_hess	Logical, whether the hessian function will be passed to nlminb during optimization (this generally reduces the number of iterations to convergence, but is memory and time intensive and does not guarantee an increase in convergence rate). Ignored if integrate = TRUE.

<code>n_restart</code>	The number of restarts (calls to <code>nlmminb</code>) in the optimization procedure, so long as the model hasn't converged. The optimization continues from the parameters from the previous (re)start.
<code>control</code>	A named list of parameters regarding optimization to be passed to <code>nlmminb</code> .
<code>...</code>	For <code>SP_Fox</code> , additional arguments to pass to SP.
<code>fix_sigma</code>	Logical, whether the standard deviation of the index is fixed. If TRUE, sigma is fixed to value provided in <code>start</code> (if provided), otherwise, value based on <code>Data@CV_Ind</code> .
<code>fix_tau</code>	Logical, the standard deviation of the biomass deviations is fixed. If TRUE, tau is fixed to value provided in <code>start</code> (if provided), otherwise, equal to 0.1.
<code>early_dev</code>	Character string describing the years for which biomass deviations are estimated in <code>SP_SS</code> . By default, deviations are estimated in each year of the model (" <code>all</code> "), while deviations could also be estimated once index data are available (" <code>index</code> ").
<code>integrate</code>	Logical, whether the likelihood of the model integrates over the likelihood of the biomass deviations (thus, treating it as a state-space variable).
<code>inner.control</code>	A named list of arguments for optimization of the random effects, which is passed on to <code>newton</code> via <code>MakeADFun</code> .

Details

To provide starting values for the SP, a named list can be provided for `FMSY`, `MSY`, `dep`, and `n` via the `start` argument (see example).

For `SP_SS`, a start value can also be provided for `sigma` and `tau`, the standard deviation of the index and log-biomass deviates, respectively. Default for `tau` is 0.1. Deviations are estimated beginning in the year when index data are available.

If `use_r_prior = TRUE`, `SP` and `SP_SS` will use a prior for the intrinsic rate of increase in the objective function. A vector of length two can be passed in the `start` list for the mean and standard deviation of the prior (see example). The normal distribution is used.

If no values are provided, a prior is created using the Euler-Lotka method (Equation 15a of McAllister et al. 2001). The Euler-Lotka method is modified to multiply the left-hand side of equation 15a by the alpha parameter of the stock-recruit relationship (Stanley et al. 2009). Natural mortality and steepness are sampled in order to generate a prior distribution for `r`. See `vignette("Surplus_production")` for more details.

Value

An object of `Assessment` containing objects and output from TMB.

Required Data

- `SP`: `Cat`, `Ind`
- `SP_SS`: `Cat`, `Ind`

Optional Data

`SP_SS`: `CV_Ind`

Note

The model uses the Fletcher (1978) formulation and is parameterized with FMSY and MSY as leading parameters. The default conditions assume unfished conditions in the first year of the time series and a symmetric production function ($n = 2$).

Tip: to create the Fox model (Fox 1970), just fix $n = 1$. See example.

Author(s)

Q. Huynh

References

- Fletcher, R. I. 1978. On the restructuring of the Pella-Tomlinson system. *Fishery Bulletin* 76:515:521.
- Fox, W.W. 1970. An exponential surplus-yield model for optimizing exploited fish populations. *Transactions of the American Fisheries Society* 99:80-88.
- McAllister, M.K., Pikitch, E.K., and Babcock, E.A. 2001. Using demographic methods to construct Bayesian priors for the intrinsic rate of increase in the Schaefer model and implications for stock rebuilding. *Can. J. Fish. Aquat. Sci.* 58: 1871-1890.
- Pedersen, M. W. and Berg, C. W. 2017. A stochastic surplus production model in continuous time. *Fish and Fisheries*. 18:226-243.
- Pella, J. J. and Tomlinson, P. K. 1969. A generalized stock production model. *Inter-Am. Trop. Tuna Comm., Bull.* 13:419-496.
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- Stanley, R.D., M. McAllister, P. Starr and N. Olsen. 2009. Stock assessment for bocaccio (*Sebastes paucispinis*) in British Columbia waters. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2009/055. xiv + 200 p.

See Also

[SP_production plot.Assessment summary.Assessment retrospective profile make_MP](#)

Examples

```
data(swordfish)

#### Observation-error surplus production model
res <- SP(Data = swordfish)

# Provide starting values, assume B/K = 0.875 in first year of model
# and symmetrical production curve (n = 2)
start <- list(dep = 0.875, n = 2)
res <- SP(Data = swordfish, start = start)

## Not run:
plot(res)

## End(Not run)
```

```

profile(res, FMSY = seq(0.1, 0.4, 0.01))
retrospective(res)

#### State-space version
res_SS <- SP_SS(Data = swordfish, start = list(dep = 0.875, sigma = 0.1, tau = 0.1))

## Not run:
plot(res_SS)

## End(Not run)

#### Fox model
res_Fox <- SP(Data = swordfish, start = list(n = 1), fix_n = TRUE)
res_Fox2 <- SP_Fox(Data = swordfish)

#### SP with r_prior
res_prior <- SP(Data = SimulatedData, use_r_prior = TRUE)

#### Pass an r_prior to the model with mean = 0.35, sd = 0.10
res_prior2 <- SP(Data = SimulatedData, use_r_prior = TRUE, start = list(r_prior = c(0.35, 0.10)))

```

SP_production

Find the production parameter based on depletion that produces MSY

Description

For surplus production models, this function returns the production exponent n corresponding to BMSY/K (Fletcher 1978).

Usage

```
SP_production(depletion, figure = TRUE)
```

Arguments

depletion	The hypothesized depletion that produces MSY.
figure	Local, plots figure of production function as a function of depletion (B/K)

Value

The production function exponent n (numeric).

Note

May be useful for parameterizing n in [SP](#) and [SP_SS](#).

Author(s)

Q. Huynh

References

Fletcher, R. I. 1978. On the restructuring of the Pella-Tomlinson system. Fishery Bulletin 76:515:521.

See Also[SP SP_SS](#)**Examples**

```
SP_production(0.5)
SP_production(0.5)
```

SRA-class

Class-SRA

Description

An S4 class for the output from [SRA_scope](#).

Slots

- OM An updated operating model, class [OM](#).
- SSB A matrix of estimated spawning biomass with `OM@nsim` rows and `OM@years+1` columns.
- NAA An array for the predicted numbers at age with dimension `OM@nsim`, `OM@years+1`, and `OM@maxage`.
- CAA An array for the predicted catch at age with dimension `OM@nsim`, `OM@years`, `OM@maxage`, and `nfleet`.
- CAL An array for the predicted catch at length with dimension `OM@nsim`, `OM@years`, length bins, and `nfleet`.
- conv A logical vector of length `OM@nsim` indicating convergence of the SRA scoping model in the *i*-th simulation.
- Misc A list of length `OM@nsim` with more output from the fitted SRA scoping model. Within each simulation, items of interest include:
- B - total biomass - vector of length `nyears+1`
 - E0 - annual unfished spawning biomass - vector of length `nyears`
 - E0_SR - unfished spawning biomass for the stock-recruit relationship - numeric
 - Arec - alpha parameter of the stock-recruit relationship - numeric
 - Brec - beta parameter of the stock-recruit relationship - numeric
 - R - recruitment - vector of length `nyears+1`
 - R_early - recruitment for the cohorts in first year of the model - vector `maxage-1`
 - VB - vulnerable biomass - matrix of `nyears x nfleet`

- `N` - abundance at age - matrix of `nyears+1` x `maxage`
- `F` - apical fishing mortality - matrix of `nyears` x `nfleet`
- `F_at_age` - fishing mortality at age - array of `nyears` x `maxage` x `nfleet`
- `F_equilibrium` - equilibrium fishing mortality prior to first year - vector of length `nfleet`
- `M` - natural mortality - matrix of `nyears` x `maxage`
- `Z` - total mortality - matrix of `nyears` x `maxage`
- `q` - survey catchability - vector of length `nsurvey`
- `s_vul` - survey selectivity at age - array of dim `nyears+1`, `maxage`, `nsurvey`
- `s_vul_len` - corresponding survey selectivity at length - matrix of `nbins` x `nsurvey`
- `Ipred` - predicted index values - matrix of `nyears` x `nsurvey`
- `s_CAApred` - predicted survey catch at age - array of dim `nyears`, `maxage`, `nsurvey`
- `vul` - fleet selectivity at age - array of dim `nyears+1`, `maxage`, `nfleet` (or `nset_block`)
- `vul_len` - corresponding fleet selectivity at length - matrix of `nbins` x `nfleet` (or `nset_block`)
- `s_CALpred` - predicted survey catch at length - array of dim `nyears`, `nbins`, `nsurvey`
- `m_len_pred` - predicted mean lengths - matrix of `nyears` x `nfleet`
- `CAApred` - predicted catch at age - array of `nyears`, `maxage`, `nfleet`
- `CALpred` - predicted catch at length - array of `nyears`, `nbins`, `nfleet`
- `Cpred` - predicted catch in weight - matrix of `nyears` x `nfleet`
- `CN` - predicted catch in numbers - matrix of `nyears` x `nfleet`
- `nll` - Total objective function of the model - numeric

`mean_fit` A list of output from fit to mean values of life history parameters in the operating model. The named list consists of:

- `obj` - a list with components returned from [MakeADFun](#).
- `opt` - a list with components from calling `nlm` to `obj`.
- `SD` - a list (class `sdreport`) with parameter estimates and their standard errors, obtained from [sdreport](#).
- `report` - a list of model output reported from the TMB executable, i.e. `obj$report()`. See `Misc`.

`data` A list of the data inputs for the SRA scoping model.

`config` A data frame describing configuration of the SRA scoping model (not currently used).

Author(s)

Q. Huynh

See Also

[plot.SRA](#) [SRA_scope](#)

Description

Intended for conditioning operating models for data-limited stocks. From a historical time series of total catch or effort, and potentially age/length compositions and multiple indices of abundance, the SRA returns a range of values for depletion, selectivity, unfished recruitment (R0), historical fishing effort, and recruitment deviations for the operating model. This is done by sampling life history parameters provided by the user and fitting to the data in a statistical catch-at-age model (with the predicted catch equal to the observed catch). Alternatively one can do a single model fit and sample the covariance matrix to generate an operating model with uncertainty based on the model fit. This function is intended to generate a range of potential depletion scenarios that could be supported from sparse data. Either a full catch (conditioned on catch) or effort (conditioned on effort) time series is needed but missing data (as NAs) are allowed for all other data types.

Usage

```
SRA_scope(
  OM,
  data = list(),
  condition = c("catch", "catch2", "effort"),
  selectivity = "logistic",
  s_selectivity = NULL,
  LWT = list(),
  comp_like = c("multinomial", "lognormal"),
  ESS = c(30, 30),
  max_F = 3,
  cores = 1L,
  integrate = FALSE,
  mean_fit = FALSE,
  drop_nonconv = FALSE,
  drop_highF = FALSE,
  control = list(iter.max = 2e+05, eval.max = 4e+05),
  ...
)
```

```
Sub_cpars(OM, sims = 1:OM@nsim)
```

Arguments

OM	An object of class OM that specifies natural mortality (M), growth (Linf, K, t0, a, b), stock-recruitment relationship, steepness, maturity parameters (L50 and L50_95), standard deviation of recruitment variability (Perr), as well as index uncertainty (Iobs).
data	A list of data inputs. See Data section below.

condition	String to indicate whether the SRA model is conditioned on "catch" (where F are estimated parameters), "catch2" (where F is solved internally using Newton's method), or "effort".
selectivity	A character vector of length nfleet to indicate "logistic", "dome", or "free" selectivity for each fleet in Chist. If there is time-varying selectivity, this is a character vector of length nsel_block (see Data section below). "free" indicates independent selectivity parameters for each age, and additional modifications for fixing selectivity parameters will likely be needed (see details).
s_selectivity	Only used if any of the corresponding entries of data\$I_type = "est". A vector of length nsurvey to indicate "logistic", "dome", or "free" selectivity for each survey corresponding to the columns in data\$Index.
LWT	A named list of likelihood weights for the SRA model. See details.
comp_like	A string indicating either "multinomial" (default) or "lognormal" distributions for the composition data.
ESS	If comp_like = "multinomial", a numeric vector of length two to cap the maximum effective samples size of the age and length compositions, respectively, for the multinomial likelihood function. The effective sample size of an age or length composition sample is the minimum of ESS or the number of observations (sum across columns). For more flexibility, set ESS to be very large and alter the age and length arrays as needed.
max_F	The maximum F for any fleet in the scoping model (higher F's in the model are penalized in the objective function). See also 'drop_highF'.
cores	Integer for the number of CPU cores for the stock reduction analysis.
integrate	Logical, whether to treat recruitment deviations as penalized parameters in the likelihood (FALSE) or random effects to be marginalized out of the likelihood (TRUE).
mean_fit	Logical, whether to run an additional with mean values of life history parameters from the OM.
drop_nonconv	Logical, whether to drop non-converged fits of the SRA model.
drop_highF	Logical, whether to drop fits of the SRA model where F hits max_F. Only applies if drop_nonconv = TRUE.
control	A named list of arguments (e.g. max. iterations, etc.) for optimization, to be passed to the control argument of <code>nlminb</code> .
...	Other arguments to pass in for starting values of parameters and fixing parameters. See details.
sims	A logical vector of length OM@nsim or a numeric vector indicating which simulations to keep.

Details

Fleet selectivity is fixed to values sampled from OM if no age or length compositions are provided.

Survey selectivity is estimable only if s_CAA or s_CAL is provided. Otherwise, the selectivity should be mirrored to a fleet (vulnerable biomass selectivity) or indexed to total or spawning biomass (see I_type).

Parameters that were used in the fitting model are placed in objects in `OM@cpars`.

`Sub_cpars` is a convenient function to subset simulations for the operating model, for example, to remove simulations from unconverged model fits or outlier simulations.

If the operating model `OM` uses time-varying growth or `M`, then those trends will be used in the SRA as well. Time-varying life history parameters create ambiguity in the calculation and interpretation of depletion and reference points in `runMSE`. See section D.5 of `DLMtool::userguide()`.

The easiest way to turn off time-varying growth/`M` is by setting: `OM@Msd <-OM@Linfsd <-OM@Ksd <-c(0,0)`.

Value

An object of class `SRA` (see link for description of output).

Vignette

Three vignettes are available for the SRA model:

- [General overview of approach](#)
- [Mathematical description](#)
- [Setup of selectivity settings](#) (useful for more data-rich cases)

Data

One of indices, age compositions, or length compositions should be provided in addition to the historical catch or effort. Not all arguments are needed to run the model (some have defaults, while others are ignored if not applicable depending on the data provided).

The data list can include:

- `Chist` - A vector of historical catch, should be of length `OM@nyears`. If there are multiple fleets: a matrix of `OM@nyears` rows and `nfleet` columns. Ideally, the first year of the catch series represents unfisher conditions (see also `C_eq`).
- `Ehist` - A vector of historical effort, should be of length `OM@nyears` (see also `E_eq`).
- `Index` - A vector of values of an index (of length `OM@nyears`). If there are multiple surveys: a matrix of historical indices of abundances, with rows indexing years and columns indexing surveys. Age-specific indices should be numbers-specific while all others are weight-based.
- `I_sd` - A vector or matrix of standard deviations (lognormal distribution) for the indices corresponding to the entries in `Index`. If not provided, this function will use values from `OM@Iobs`.
- `I_type` - A character vector of length `nsurvey` to indicate the type of biomass for which each index follows. Either "B" for total biomass, or "SSB" for spawning biomass. If not provided, "B" is used. Use numbers if the index corresponds to a fleet in `Chist`. Use "est" to set survey selectivity to be an independent component of the model, i.e., as an age-specific index or estimated separately. Note, this generally requires age `s_CAA` or length `s_CAL` compositions.
- `CAA` - Fishery age composition matrix with `nyears` rows and `OM@maxage` columns. If multiple fleets: an array with dimension: `nyears`, `OM@maxage`, and `nfleets`.
- `CAL` - Fishery Length composition matrix with `nyears` rows and columns indexing the length bin. If multiple fleets: an array with dimension: `nyears`, `length bins`, and `nfleets`.

- **ML** - A vector of fishery mean length observations (length OM@nyears), or if multiple fleets: matrix of dimension: nyears and nfleets. Generally, should not be used if CAL is also provided, unless mean length and length comps are independently sampled.
- **ML_sd** - The standard deviation (normal distribution) of the observed mean lengths. If there are multiple fleets, a vector of length nfleet. If not provided, default value is $0.1 * \text{mean}(\text{ML})$.
- **s_CAA** - Survey age composition data, an array of dimension nyears, maxage, nsurvey.
- **s_CAL** - Survey length composition data, an array of dimension nyears, length(length_bin), nsurvey.
- **length_bin** - A vector for the midpoints of the length bins for CAL and s_CAL. All bin widths should be equal in size.
- **C_eq** - A numeric vector of length nfleet for the equilibrium catch for each fleet in Chist prior to the first year of the operating model. Zero (default) implies unfished conditions in year one. Otherwise, this is used to estimate depletion in the first year of the data. Alternatively, if one has a full CAA matrix, one could instead estimate "artificial" rec devs to generate the initial numbers-at-age (and hence initial depletion) in the first year of the model (see additional arguments).
- **E_eq** - The equilibrium effort for each fleet in Ehist prior to the first year of the operating model. Zero (default) implies unfished conditions in year one. Otherwise, this is used to estimate depletion in the first year of the data.
- **abs_I** - Optional, an integer vector to indicate which indices are in absolute magnitude. Use 1 to set $q = 1$, otherwise use 0 to estimate q .
- **I_units** - Optional, an integer vector to indicate whether indices are biomass based (1) or abundance-based (0). By default, all are biomass-based.
- **age_error** - Optional, a square matrix of maxage rows and columns to specify ageing error. The aa-th column assigns a proportion of the true age in the a-th row to observed age. Thus, all rows should sum to 1. Default is an identity matrix (no ageing error).
- **sel_block** - Optional, for time-varying fleet selectivity (in time blocks), a matrix of nyears x nfleet that assigns a selectivity function to a fleet-year combination. See the **selectivity** vignette for more details.
- **n_sel_block** - Optional, the number of selectivity blocks.

Additional arguments

For SRA_scope, additional arguments can be passed to the model via . . . :

- **vul_par**: A matrix of 3 rows and nfleet columns for starting values for fleet selectivity. The three rows correspond to LFS (length of full selectivity), L5 (length of 5 percent selectivity), and Vmaxlen (selectivity at length Linf). By default, the starting values are values from the OM object. If any selectivity = "free", then this matrix needs to be of maxage rows where the row specifies the selectivity at age. See the **selectivity** vignette for more information.
- **s_vul_par**: A matrix of 3 rows and nsurvey columns for starting values for fleet selectivity. Same setup as vul_par. These values are only used if s_selectivity = "est" for the corresponding fleet. Otherwise, placeholders should be used to complete the matrix.

- `map_vul_par`: The map argument for `vul_par` in TMB, see [MakeADFun](#), which indicates whether selectivity parameters are fixed or estimated. A matrix of the same dimension as `vul_par`. If an entry is NA, the corresponding parameter is fixed in the model to the starting value. Otherwise, an integer for each independent parameter. By default, selectivity is fixed if there are no age or length composition for that fleet or survey, otherwise estimated. Unused cells in the `vul_par` matrix should be given NA in the map matrix.
- `map_s_vul_par`: The map argument for the survey selectivity parameters (same dimension as `s_vul_par`). Placeholder parameters should have a map value of NA.
- `map_log_early_rec_dev`: A vector of length `OM@maxage - 1` that indexes which recruitment deviates for the cohorts in the first year of the model are fixed (using NA) or estimated (a separate integer). By default, no deviates are estimated.
- `map_log_rec_dev`: A vector of length `OM@nyears` that indexes which recruitment deviates are fixed (using NA) or estimated (a separate integer). By default, all deviates are estimated.
- `plusgroup`: Logical for whether the maximum age is a plusgroup or not. By default, TRUE.
- `fix_dome`: Logical for whether the dome selectivity parameter for fleets is fixed. Used primarily for backwards compatibility, this is overridden by `map_vul_par`.
- `resample`: Logical, whether the OM conditioning parameters (recruitment, fishing mortality, SSB, selectivity, etc.) are obtained by sampling the Hessian matrix from a single model fit. By default FALSE. This feature requires identical biological parameters among simulations.

Likelihood weights

LWT is an optional named list containing the likelihood weights (values ≥ 0) with the possible options:

- `Chist`: A vector of length `nfleet`.
- `Index`: A vector of length `nsurvey`.
- `CAA`, `CAL`, `ML`, `C_eq`: A vector of length `nfleet` for each.
- `s_CAA`, `s_CAL`: A vector of length `nsurvey` for each.

By default, all likelihood weights are equal to one if not specified by the user. Weighting for CAA and CAL can also be adjusted by changing the multinomial sample size. For CAA, CAL, `s_CAA`, and `s_CAL`, the arrays should be set up so that the annual number of observations (summed over columns) should be equal to the presumed effective sample size. Argument `ESS` provides a shortcut to cap the the effective sample size.

To play with alternative fits by excluding indices, for example, set the corresponding likelihood weight to zero. The model will still generate the inferred index but the data won't enter the likelihood.

Author(s)

Q. Huynh

See Also

[plot.SRA SRA](#)

SS2Data	<i>Reads data Stock Synthesis file structure into a Data object using package r4ss</i>
---------	--

Description

A function that uses the file location of a fitted SS3 model including input files to population the various slots of an Data object.

Usage

```
SS2Data(
  SSdir,
  Name = "Object generated by SS2Data function",
  Common_Name = "",
  Species = "",
  Region = "",
  min_age_M = 1,
  gender = 1,
  comp_fleet = "all",
  comp_season = "sum",
  comp_partition = "all",
  comp_gender = "all",
  index_fleet = "SSB",
  index_season = "mean",
  ...
)
```

Arguments

SSdir	A folder with Stock Synthesis input and output files in it
Name	The name for the Data object
Common_Name	Character string for the common name of the stock.
Species	Scientific name of the species
Region	Geographic region of the stock or fishery.
min_age_M	Currently, the Data object supports a single value of M for all ages. The argument selects the minimum age for calculating the mean of age-dependent M from the SS assessment.
gender	An integer index for the sex for which life history values are importing (1 = female, 2 = male).
comp_fleet	A vector of indices corresponding to fleets in the assessment over which to aggregate the composition (catch-at-length and catch-at-age) data. By default, character string "all" will aggregate across all fleets.
comp_season	Integer, for seasonal models, the season for which the value of the index will be used. By default, "mean" will take the average across seasons.

<code>comp_partition</code>	Integer vector for selecting length/age observations that are retained (2), discarded (1), or both (0). By default, "all" sums over all available partitions.
<code>comp_gender</code>	Integer vector for selecting length/age observations that are female (1), male (2), or both (0), or both scaled to sum to one (3). By default, "all" sums over all gender codes.
<code>index_fleet</code>	Integer for selecting the fleet of the index to put in the Data object. By default, "SSB" will use the relative trend in spawning stock biomass as estimated in the model as the index.
<code>index_season</code>	Integer, for seasonal models, the season for which the value of the index will be used. By default, "mean" will take the average across seasons.
<code>...</code>	Arguments to pass to SS_output

Value

An object of class Data.

Note

Currently supports the version of r4ss on CRAN (v.1.24) and Github (v.1.34-35). Function may be incompatible with other versions of r4ss.

Author(s)

T. Carruthers and Q. Huynh

See Also

[SS2OM](#)

SS2OM

Reads MLE estimates from Stock Synthesis file structure into an operating model using package r4ss.

Description

A function that uses the file location of a fitted SS3 model including input files to population the various slots of an operating model with MLE parameter estimates. The function mainly populates the Stock and Fleet portions of the operating model; the user still needs to parameterize most of the observation and implementation portions of the operating model.

Usage

```

SS2OM(
  SSdir,
  nsim = 48,
  proyears = 50,
  reps = 1,
  maxF = 3,
  seed = 1,
  interval = 1,
  Obs = DLMtool::Generic_Obs,
  Imp = DLMtool::Perfect_Imp,
  import_mov = TRUE,
  gender = 1:2,
  age_rec = 1,
  silent = FALSE,
  Name = "OM generated by SS2OM function",
  Source = "No source provided",
  Author = "No author provided",
  report = FALSE,
  filename = "SS2OM",
  dir = tempdir(),
  open_file = TRUE,
  ...
)

```

Arguments

SSdir	A folder with Stock Synthesis input and output files in it.
nsim	The number of simulations to take for parameters with uncertainty (for OM@cpar custom parameters).
proyears	The number of projection years for MSE
reps	The number of stochastic replicates within each simulation in the operating model.
maxF	The maximum allowable F in the operating model.
seed	The random seed for the operating model.
interval	The interval at which management procedures will update the management advice in runMSE , e.g., 1 = annual updates.
Obs	The observation model (class Obs). This function only updates the catch and index observation error.
Imp	The implementation model (class Imp). This function does not update implementation parameters.
import_mov	Logical, whether to import movement matrix from the assessment.
gender	An integer that indexes the sex for importing life history parameters (1 = usually female, 2 = usually male, 1:2 = mean across both sexes).

age_rec	Integer for the age of recruitment. The default is 1 for DLMtool operating models. Generally, should not be changed.
silent	Whether to silence messages to the console.
Name	The name of the operating model
Source	Reference to assessment documentation e.g. a url
Author	Who did the assessment
report	Logical, if TRUE, the function will run runMSE to generate historical data from the operating model to compare against SS output. A markdown report will be generated.
filename	If report = TRUE, character string for the name of the markdown and HTML files.
dir	If report = TRUE, the directory in which the markdown and HTML files will be saved.
open_file	If report = TRUE, whether the HTML document is opened after it is rendered.
...	Arguments to pass to SS_output .

Details

The function generally uses values from the terminal year of the assessment for most life history parameters (maturity, M, etc). This function does detect time-varying growth in the assessment and uses annual length/weight-at-age for historical years. Selectivity is derived from the F-at-age matrix.

Value

An object of class OM.

Note

Currently supports versions of r4ss on CRAN (v.1.24) and Github (v.1.34-35). Function may be incompatible with other versions of r4ss.

Author(s)

T. Carruthers and Q. Huynh

See Also

[SS2Data](#)

Description

A simple age-structured model ([SCA_Pope](#)) fitted to a time series of catch going back to unfished conditions. Terminal depletion (ratio of current biomass to unfished biomass) is by default fixed to 0.4. Selectivity is fixed to the maturity ogive, although it can be overridden with the `start` argument. The sole parameter estimated is `R0` (unfished recruitment).

Usage

```
SSS(
  x = 1,
  Data,
  dep = 0.4,
  SR = c("BH", "Ricker"),
  rescale = "mean1",
  start = NULL,
  silent = TRUE,
  opt_hess = FALSE,
  n_restart = ifelse(opt_hess, 0, 1),
  control = list(iter.max = 2e+05, eval.max = 4e+05),
  ...
)
```

Arguments

<code>x</code>	A position in the <code>Data</code> object (by default, equal to one for assessments).
<code>Data</code>	An object of class <code>Data</code>
<code>dep</code>	Depletion value to use in the model. Can be an expression that will be evaluated inside the function.
<code>SR</code>	Stock-recruit function (either "BH" for Beverton-Holt or "Ricker").
<code>rescale</code>	A multiplicative factor that rescales the catch in the assessment model, which can improve convergence. By default, "mean1" scales the catch so that time series mean is 1, otherwise a numeric. Output is re-converted back to original units.
<code>start</code>	Optional named list of starting values. Entries can be expressions that are evaluated in the function: <ul style="list-style-type: none"> • <code>R0</code> - unfished recruitment • <code>vul_par</code> - a length-two vector for the age of 95% and 50% fleet selectivity. Fixed to maturity otherwise.
<code>silent</code>	Logical, passed to MakeADFun , whether TMB will print trace information during optimization. Used for diagnostics for model convergence.

opt_hess	Logical, whether the hessian function will be passed to <code>nlminb</code> during optimization (this generally reduces the number of iterations to convergence, but is memory and time intensive and does not guarantee an increase in convergence rate).
n_restart	The number of restarts (calls to <code>nlminb</code>) in the optimization procedure, so long as the model hasn't converged. The optimization continues from the parameters from the previous (re)start.
control	A named list of arguments for optimization to be passed to <code>nlminb</code> .
...	Other arguments to be passed (not currently used).

Author(s)

Q. Huynh

References

Cope, J.M. 2013. Implementing a statistical catch-at-age model (Stock Synthesis) as a tool for deriving overfishing limits in data-limited situations. *Fisheries Research* 142:3-14.

Examples

```
res <- SSS(1, Data = Red_snapper)

SSS_MP <- make_MP(SSS, HCR40_10, dep = 0.3) # Always assume depletion = 0.3
```

summary.Assessment *Summary of Assessment object*

Description

Returns a summary of parameter estimates and output from an [Assessment](#) object.

Usage

```
## S4 method for signature 'Assessment'
summary(object)
```

Arguments

object An object of class [Assessment](#)

Value

A list of parameters.

Examples

```
output <- DD_TMB(Data = DLMtool::Simulation_1)
summary(output)
```

swordfish	<i>North Atlantic Swordfish dataset</i>
-----------	---

Description

An S4 object containing catch and index time series for North Atlantic swordfish.

Usage

```
swordfish
```

Format

An object of class [Data](#).

Source

ASPIC Software at <https://www.mhprager.com/aspic.html>

Examples

```
data(swordfish)
```

TAC_MSY	<i>Calculate MSY-based TAC from Assessment object</i>
---------	---

Description

A function to calculate the total allowable catch (TAC). Based on the MSY (maximum sustainable yield) principle, the TAC is the product of either UMSY or FMSY and the available biomass, i.e. vulnerable biomass, in terminal year.

Usage

```
TAC_MSY(Assessment, reps, MSY_frac = 1)
```

```
calculate_TAC(Assessment, reps, MSY_frac = 1)
```

Arguments

Assessment An Assessment object with estimates of UMSY or FMSY and terminal year vulnerable biomass.

reps The number of stochastic draws of UMSY or FMSY.

MSY_frac The fraction of FMSY or UMSY for calculating the TAC (e.g. `MSY_frac = 0.75` fishes at 75% of FMSY).

Value

A vector of length reps of stochastic samples of TAC recommendation. Returns NA's if missing either UMSY/FMSY or vulnerable biomass.

Note

calculate_TAC is deprecated as of version 1.2 in favor of TAC_MSY because the latter has a more informative name.

See Also

[HCR_MSY](#) [HCR40_10](#) [HCR60_20](#)

TEG	<i>Toms expand grid</i>
-----	-------------------------

Description

Create an indexing grid from just a vector of maximum dimension sizes

Usage

TEG(vec)

Arguments

vec A vector of maximum array sizes

Author(s)

T. Carruthers

userguide	<i>Get the MSEtool vignettes</i>
-----------	----------------------------------

Description

A convenient function to open a web browser with the MSEtool package vignettes

Usage

userguide()

See Also

[userguide](#)

Examples

```
## Not run:
MSEtool::userguide()
DLMtool::userguide()

## End(Not run)
```

VPA

*Virtual population analysis (VPA)***Description**

A VPA model that back-calculates abundance-at-age assuming that the catch-at-age is known without error and tuned to an index. The population dynamics equations are primarily drawn from VPA-2BOX (Porch 2018). MSY reference points are then calculated from the VPA output.

Usage

```
VPA(
  x = 1,
  Data,
  expanded = FALSE,
  SR = c("BH", "Ricker"),
  vulnerability = c("logistic", "dome", "free"),
  I_type = c("B", "VB", "SSB"),
  start = NULL,
  fix_h = TRUE,
  fix_sigma = FALSE,
  fix_Fratio = TRUE,
  vul_pen = c(3, 0.4),
  R_pen = c(3, Data@sigmaR[x]),
  nitF = 5L,
  silent = TRUE,
  opt_hess = FALSE,
  n_restart = ifelse(opt_hess, 0, 1),
  control = list(iter.max = 2e+05, eval.max = 4e+05),
  ...
)
```

Arguments

x	A position in the Data object (by default, equal to one for assessments).
Data	An object of class Data
expanded	Whether the catch at age in Data has been expanded. If FALSE, then the catch in weight should be provided in Data@Cat so that the function can calculate annual expansion factors.

SR	Stock-recruit function (either "BH" for Beverton-Holt or "Ricker") for calculating MSY reference points.
vulnerability	Whether the terminal year vulnerability is "logistic" or "dome" (double-normal). If "free", independent F's are calculated in the terminal year (subject to the assumed ratio of F of the plus-group to the previous age class). See details for parameterization.
I_type	Whether the index surveys population biomass (B; this is the default in the DLMtool operating model), vulnerable biomass (VB), or spawning stock biomass (SSB).
start	Optional list of starting values. Entries can be expressions that are evaluated in the function. See details.
fix_h	Logical, whether to fix steepness to value in Data@steep. This only affects calculation of reference points.
fix_sigma	Logical, whether the standard deviation of the index is fixed. If TRUE, sigma is fixed to value provided in start (if provided), otherwise, value based on Data@CV_Ind.
fix_Fratio	Logical, whether the ratio of F of the plus-group to the previous age class is fixed in the model.
vul_pen	A length two vector that parameterizes how the model constrains the vulnerability in the most recent years. The first number is the number of years in which vulnerability will be constrained (as a random walk), the second number is the standard deviation of the random walk.
R_pen	A length two vector that parameterizes how the model constrains the recruitment in the most recent years. The first number is the number of years in which recruitment will be constrained (as a random walk), the second number is the standard deviation of the random walk.
nitF	The number of iterations for solving F in the model (via Newton's method).
silent	Logical, passed to <code>MakeADFun</code> , whether TMB will print trace information during optimization. Used for diagnostics for model convergence.
opt_hess	Logical, whether the hessian function will be passed to <code>nlminb</code> during optimization (this generally reduces the number of iterations to convergence, but is memory and time intensive and does not guarantee an increase in convergence rate). Ignored if <code>integrate = TRUE</code> .
n_restart	The number of restarts (calls to <code>nlminb</code>) in the optimization procedure, so long as the model hasn't converged. The optimization continues from the parameters from the previous (re)start.
control	A named list of arguments for optimization to be passed to <code>nlminb</code> .
...	Other arguments to be passed.

Details

The VPA is initialized by estimating the terminal F-at-age. Parameter `F_term` is the apical terminal F if a functional form for vulnerability is used in the terminal year. If the terminal F-at-age are otherwise independent parameters, `F_term` is the F for the reference age which is half the maximum

age. Once terminal-year abundance is estimated, the abundance in historical years can be back-calculated. The oldest age group is a plus-group, and requires an assumption regarding the ratio of F's between the plus-group and the next youngest age class. The F-ratio can be fixed (default) or estimated.

For `start` (optional), a named list of starting values of estimates can be provided for:

- `F_term` The terminal year fishing mortality.
- `F_ratio` The ratio of F in the plus-group to the next youngest age. If not provided, a value of 1 is used.
- `vul_par` Vulnerability parameters in the terminal year. This will be of length 2 vector for "logistic" or length 4 for "dome", see [SCA](#) for further documentation on parameterization. For option "free", this will be a vector of length A-2 where A is the number of age classes in the model. To estimate parameters, vulnerability is initially set to one at half the max age (and subsequently re-calculated relative to the maximum F experienced in that year). Vulnerability in the plus-group is also constrained by the Fratio.
- `sigma` Standard deviation of the index. If not provided, the value based on `Data@CV_Ind` is used.

Value

An object of class [Assessment](#). The F vector is the apical fishing mortality experienced by any age class in a given year. The U vector is the ratio of catch (weight) and vulnerable biomass, which may be a better description of fishing pressure (and $UMSY = MSY/VBMSY$).

References

Porch, C.E. 2018. VPA-2BOX 4.01 User Guide. NOAA Tech. Memo. NMFS-SEFSC-726. 67 pp.

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