Package: cat3advice (via r-universe)

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Type Package

Title ICES category 3 empirical harvest control rules

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Description A package to apply the the ICES category 3 empirical (model-free) harvest control rules.

License GPL-3

Encoding UTF-8

LazyData true

Imports methods, dplyr, tidyr, ggplot2, scales, icesAdvice, patchwork, stats, utils, magrittr

Suggests knitr, rmarkdown

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VignetteBuilder knitr

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Contents

`A-class` *A-class*

Description

An S4 class to represent component Ay (the last advice or reference catch) of the rfb, rb, and chr rules.

The classes `rfb_A`, `rb_A`, and `chr_A` inherit from `A` and their only difference is that the slot `hcr` is set to the corresponding catch rule name ('rfb', 'rb', or 'chr').

Slots

`value` The value of component Ay (reference catch)

`hcr` The harvest control rule (hcr) for which Ay is used. One of 'rfb', 'rb', or 'chr'.

`data` Time series of historical catches and/or advice

`avg_years` Number of years for calculating average catch

`basis` Basis of Ay. Either "advice" for using previous advice or "average catch" when based on average of historical catch

`advice_metric` Advice metric, 'catch' or 'landings'.

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advice *ICES advice sheet-style output table*

Description

This function returns an advice sheet-style table for the empirical harvest control rules. The argument passed to the function can either be a single component of any rules (components r, f, b, ...) or the output from applying any of the rules (rfb, rb, chr).

Usage

```
advice(object)
```

Arguments

`object`	A component of any of the empirical harvest control rules or the the output from applying the rule.

Value

NULL. A table is displayed in the R terminal.

---

b *rb/rfb/chr rule - component b (biomass safeguard)*

Description

This function calculates component b (the biomass safeguard) of the rb, rfb, and chr rule. The index needs to be a biomass index without age structure.

Usage

```
b(object, idx_value, Itrigger, Iloss, w, yr_ref, n0, units, hcr, ...)

rfb_b(
  object,
  idx_value,
  Itrigger,
  Iloss,
  w,
  yr_ref,
  n0,
  units,
  hcr = "rfb",
  ...
)

rb_b(object, idx_value, Itrigger, Iloss, w, yr_ref, n0, units, hcr = "rb", ...)

chr_b(
  object,
  idx_value,
  Itrigger,
  Iloss,
  w,
  yr_ref,
  n0,
  units,
  hcr = "chr",
  ...
)
```

Arguments

object	The biomass index. Can be a data.frame with columns 'data' and 'index'.
idx_value	Optional. The current index value. Only used if no index time series is supplied.
Itrigger	Optional. The index trigger value below which the biomass safeguard reduces the catch advice.
Iloss	Optional. The lowest index value, can be used to calculate Itrigger.
w	Optional. The index trigger buffer (multiplier) to link Itrigger to Iloss. Defaults to w=1.4.
yr_ref	Optional. If supplied, this specifies the year in the biomass index which is used as Iloss and Itrigger is calculated from this value.
n0	Optional. Time lag between the last index year and the last year to be used. By default, the last index year is used (n0=0)
units	Optional. The units of the biomass index, e.g. 'kg/hr'. Only used for plotting.
hcr	Optional. One of 'rfb', 'rb', or 'chr'.
...	Additional arguments. Not used.

Details

The biomass safeguard compares the last index value (I) to an index trigger value (I_{trigger}). If the current index value is below the trigger, the biomass safeguard reduces the catch advice:

b = min1, I / I_{trigger}

, where I_{trigger} is usually derived from the lowest observed biomass index value (I_{loss}) as:

I_{trigger} = w * I_{loss}

with

w = 1.4

See ICES (2022) for the full definition definition.

Usually, this method is used by providing only a biomass index, e.g. as a `data.frame`. The method uses this index, searches for the lowest index value (`Iloss`), multiplies this value by the index trigger buffer (`w`) to get the index trigger value (`Itrigger`). The last index value in the time series is then compared to `Itrigger` and if the index value is below, the biomass safeguard reduces the catch advice.

The biomass safeguard is identical in the rfb, rb, and chr rules. `rfb_b()`, `rb_b()` and `chr_b()` are aliases for `b()` with identical arguments and functionality.

Value

An object of class b with the value of the biomass safeguard

Warning

Please note that I_{trigger} should only be defined once the first time the empirical harvest control rule is applied. In the following years, the same value should be used for I_{trigger}. For application in ICES, do not change the defaults unless the change is supported by stock-specific simulations.

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2023. Risk equivalence in data-limited and data-rich fisheries management: An example based on the ICES advice framework. Fish and Fisheries, 24: 231–247. https://doi.org/10.1111/faf.12722.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2022. Exploring a relative harvest rate strategy for moderately data-limited fisheries management. ICES Journal of Marine Science, 79: 1730–1741. https://doi.org/10.1093/icesjms/fsac103.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Application of explicit precautionary principles in data-limited fisheries management. ICES Journal of Marine Science, 78: 2931–2942. https://doi.org/10.1093/icesjms/fsab169.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Using a genetic algorithm to optimize a data-limited catch rule. ICES Journal of Marine Science, 78: 1311–1323. https://doi.org/10.1093/icesjms/fsab018.

Fischer, S. H., De Oliveira, J. A. A., and Kell, L. T. 2020. Linking the performance of a data-limited empirical catch rule to life-history traits. ICES Journal of Marine Science, 77: 1914–1926. https://doi.org/10.1093/icesjms/fsaa054.

Examples

```
# If the value of the biomass safeguard is known
b(1)

# First application of the biomass safeguard
# Use a data.frame with index values
df_idx <- data.frame(year = 2017:2021,
                     index = c(1.33, 1.13, 0.84, 0.60, 1.03))
b <- b(df_idx)
b
advice(b)

# plot
plot(b(df_idx, units = "kg/hr"))

# Use of the biomass safeguard in a following year without updating Itrigger
df_idx <- data.frame(year = 2017:2022,
                     index = c(1.33, 1.13, 0.84, 0.60, 1.03, 0.5))
b(df_idx, yr_ref = 2020)
```

`b-class` *b-class*

Description

An S4 class to represent component b of the rfb/rb/chr rules.

This class (b) stores the input for component b (the biomass safeguard) as well as the resulting b value.

The classes `rfb_b`, `rb_b`, and `chr_b` inherit from `b` and their only difference is that the slot `hcr` is set to the corresponding catch rule name ('rfb', 'rb', or 'chr').

Slots

`value` The value of component b

`idx_value` Index value that is compared to Itrigger.

`Itrigger` The index trigger value below which the advice is reduced. Usually calculated as `Itrigger=Iloss*w`.

`Iloss` The lowest observed index value. Can be used as the basis for `Itrigger`.

`w` Index trigger buffer. Connects `Itrigger` to `Iloss`.

`yr_ref` Reference year on which Itrigger is based.

`yr_last` Last data year of the biomass index. The index value in this year is compared to `Itrigger`.

`n0` Time lag between the last index year and the last year to be used.

`idx` `data.frame`. A `data.frame` with the index values.

`units` `character`. The units of the biomass index, e.g. 'kg/hr'.

`hcr` `character`. The harvest control rule (hcr) for which the biomass safeguard is used. One of 'rfb', 'rb', or 'chr'.

`chr` *chr rule*

Description

This function applies the chr rule.

Usage

```
chr(
  object = new("chr"),
  A = object@A,
  I = object@I,
  F = object@F,
  b = object@b,
  m = object@m,
  cap = "conditional",
  cap_upper = 20,
  cap_lower = -30,
  years,
  frequency = "annual",
  discard_rate = NA,
  ...
)
```

Arguments

`object`	Optional. An object of class `chr`.
`A`	`A`. The reference catch (previous catch advice). Required for calculating change in advice and for the application of the stability clause.
`I`	`I`. The biomass index value.
`F`	`F`. The harvest rate target.
`b`	`b`. The biomass safeguard.
`m`	`m`. The multiplier.

cap	The uncertainty cap (stability clause). Defaults to 'conditional', i.e. it is only considered when b=1.
cap_upper	Optional. numeric. The maximum allowed increase in the catch advice in %. Default to +20.
cap_lower	Optional. numeric. The maximum allowed decrease in the catch advice in %. Default to -20.
years	Optional. numeric. The years for which the advice should be given.
frequency	Optional. The frequency of the advice ('annual'/'biennial'/'triennial'). Defaults to 'annual'.
discard_rate	Optional. numeric. The discard rate for the advice. If provided, advice values for catch and landings are given.
...	Additional parameters. Not used.

Details

This function applies the chr rule following the ICES technical guidelines (ICES, 2022). The function requires the elements of the chr rule: I (the biomass index, see chr_I), F_{MSYproxy} (the target harvest rate, see F), b (the biomass safeguard, see chr_b) and m (the multiplier, see chr_m). The catch advice is then calculated as

A_{y+1} = I * F_{MSYproxy} * b * m

restricted by the stability clause relative to A_y. See the help files of the components for their definition (chr_I, F, chr_b, chr_m)

Value

An object of class chr.

Warning

For application in ICES, do not change the default parameters (frequency, stability clause, etc) unless the changes are supported by case-specific simulations.

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2023. Risk equivalence in data-limited and data-rich fisheries management: An example based on the ICES advice framework. Fish and Fisheries, 24: 231–247. https://doi.org/10.1111/faf.12722.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2022. Exploring a relative harvest rate strategy for moderately data-limited fisheries management. ICES Journal of Marine Science, 79: 1730–1741. https://doi.org/10.1093/icesjms/fsac103.

Examples

```
# calculate elements of chr rule for plaice
# reference catch
data(ple7e_catch)
A <- A(object = ple7e_catch, basis = "advice", units = "tonnes", advice_metric = "catch")
# biomass index value
data(ple7e_idx)
I <- I(ple7e_idx)
plot(I)
# target harvest rate
data(ple7e_length)
data(ple7e_catch)
lc <- Lc(data = ple7e_length, pool = 2017:2021) # length at first capture
plot(lc)
lmean <- Lmean(data = ple7e_length, Lc = lc, units = "mm") # mean catch length
plot(lmean)
lref <- Lref(Lc = 264, Linf = 528) # reference length
f <- f(Lmean = lmean, Lref = lref, units = "mm") # f indicator
plot(f)
df <- merge(ple7e_catch, ple7e_idx, all = TRUE) # combine catch & index data
hr <- HR(df, units_catch = "tonnes", units_index = "kg/hr") # harvest rate
plot(hr)
F <- F(hr, f) # calculate (relative) target harvest rate
plot(F)
# biomass safeguard
b <- b(ple7e_idx)
plot(b)
# multiplier
m <- m(hcr = "chr")

# apply chr rule
advice <- chr(A = A, I = I, F = F, b = b, m = m, discard_rate = 27)
advice
advice(advice)

# application in following years without updating reference levels
A <- A(object = ple7e_catch, basis = "advice", units = "tonnes", advice_metric = "catch")
I <- I(ple7e_idx)
hr <- HR(merge(ple7e_catch, ple7e_idx, all = TRUE), units_catch = "tonnes", units_index = "kg/hr")
F <- F(hr, yr_ref = c(2016, 2019)) # use reference years to define target
b <- b(ple7e_idx, yr_ref = 2007) # use reference year for Itrigger
m <- m(0.5) # keep multiplier
advice <- chr(A = A, I = I, F = F, b = b, m = m, discard_rate = 27)
advice
```

`chr-class` *An S4 class to represent the chr rule.*

Description

This class contains the components of the chr rule (I, F, b, m).

Slots

advice The value of the catch advice.

advice_landings Landings corresponding to the catch advice.

advice_uncapped The value of the catch advice without the uncertainty cap.

units The unit (e.g. tonnes) of the catch advice.

advice_metric The advice metric, 'catch' or 'landings'.

frequency The advice frequence (annual/biennial).

years The years for which the advice is valid.

A The reference catch (previous catch advice).

I Component I (the biomass index value).

F Component F (the relative harvest rate target).

b Component b (the biomass safeguard).

m Component m (the multiplier).

cap Uncertainty cap (stability clause, restricts changes in advice).

cap_lower Maximum allowed reduction in advice in %, e.g. -30.

cap_upper Maximum allowed increase in advice in %, e.g. 20.

change Change in advice compared to previous advice.

change_uncapped Change in advice compared to previous advice before application of the uncertainty cap.

discard_rate Discard rate (%).

F *Calculation of the (relative) harvest rate target*

Description

This function calculates the target harvest rate for chr rule.

Usage

```
F(object, indicator, yr_ref, units, ...)
```

Arguments

object	The time series with (relative) harvest rate values. See HR.
indicator	The length based indicator. See f.
yr_ref	Optional. Allows direct specification of years to include in the calculation instead of using indicator.
units	Optional. The units of the harvest rate. Can be derived automatically from argument HR.
...	Additional arguments. Not currently used.

Details

Usually, this functions is used by providing a time series of (relative) harvest rate values (see HR) and a length-based indicator based on the mean catch length (see f). The functions then finds those years where the indicator values is above 1, indicating that the fishing pressure is likely below Fmsy, extracts the corresponding (relative) harvest rate values for these years, and returns the average of these values as the target harvest rate. Alternatively, years can directly be specified with the argument yr_ref and the target harvest rate is then calculated as the average of the (relative) harvest rates for these years. See the ICES technical guidelines (ICES, 2022) for details.

If an object of class F is provided, its validity is checked.

Value

An object of class F with the target harvest rate and the input data.

Warning

For application in ICES, the target harvest rate should only be calculated in the first year the chr rule is used and the same value used in subsequent years.

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

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Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2022. Exploring a relative harvest rate strategy for moderately data-limited fisheries management. ICES Journal of Marine Science, 79: 1730–1741. https://doi.org/10.1093/icesjms/fsac103.

Examples

```
# load harvest rate time series and length-based indicator
data(ple7e_hr)
data(ple7e_f2)
# calculate target harvest rate
```

```
F <- F(ple7e_hr, ple7e_f2)
F
advice(F)
plot(F)

# use reference years when using in following years
F(ple7e_hr, yr_ref = c(2016, 2019))

# full example with ple7e data
data(ple7e_length)
# calculate (pooled) length at first capture first
lc <- Lc(data = ple7e_length, pool = 2017:2021)
# calculate mean catch length
lmean <- Lmean(data = ple7e_length, Lc = lc, units = "mm")
# reference length
lref <- Lref(Lc = 264, Linf = 528)
# calculate component f
f <- f(Lmean = lmean, Lref = lref, units = "mm")
# harvest rate
data(ple7e_idx)
data(ple7e_catch)
df <- merge(ple7e_catch, ple7e_idx, all = TRUE) # combine catch & index data
hr <- HR(df, units_catch = "tonnes", units_index = "kg/hr")
# calculate (relative) target harvest rate
F <- F(hr, f)
F
advice(F)
plot(F)

# application in following years without updating target harvest rate
F <- F(hr, yr_ref = c(2016, 2019))
```

`f` *rfb rule - component f (fishing pressure proxy, length indicator)*

Description

This function calculates component f (the fishing pressure proxy, derived from a length indicator) of the rfb rule.

Usage

```
f(object, Lmean, Lref, n0 = 0, units, hcr, ...)
```

Arguments

`object`	Optional. An object of class `f`.
`Lmean`	The mean catch length. Either a `data.frame` with columns 'year' and 'Lmean' or an object of class `Lmean`.

Lref	The reference length. Either a numeric with the value or an object of class Lref.
n0	Time lag between the last indicator year and the last year to be used. Defaults to 0.
units	Optional. The units of the length dat, e.g. 'cm'. Only used for plotting.
hcr	Optional. Defaults to 'rfb'.
...	Additional arguments. Not currently used.

Details

The value is calculated by comparing the mean catch length (above length of first capture Lc) to a reference length.

rfb_f() is an alias for f() with identical arguments and functionality.

Value

An object of class f with the length indicator value(s).

Note

The reference length Lref should be kept constant for all years unless there is a substantial changes in the fishery or fishery selectivity.

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2023. Risk equivalence in data-limited and data-rich fisheries management: An example based on the ICES advice framework. Fish and Fisheries, 24: 231–247. https://doi.org/10.1111/faf.12722.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Application of explicit precautionary principles in data-limited fisheries management. ICES Journal of Marine Science, 78: 2931–2942. https://doi.org/10.1093/icesjms/fsab169.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Using a genetic algorithm to optimize a data-limited catch rule. ICES Journal of Marine Science, 78: 1311–1323. https://doi.org/10.1093/icesjms/fsab018.

Fischer, S. H., De Oliveira, J. A. A., and Kell, L. T. 2020. Linking the performance of a data-limited empirical catch rule to life-history traits. ICES Journal of Marine Science, 77: 1914–1926. https://doi.org/10.1093/icesjms/fsaa054.

Examples

```
# use ple7e example data
data(ple7e_length)
# calculate (pooled) length at first capture first
lc <- Lc(data = ple7e_length, pool = 2017:2021)
# calculate mean catch length
```

```
lmean <- Lmean(data = ple7e_length, Lc = lc, units = "mm")
# reference length
lref <- Lref(Lc = 264, Linf = 585)
# calculate component f
f <- f(Lmean = lmean, Lref = lref, units = "mm")
f
advice(f)
plot(f)
```

`f-class` *f-class*

Description

An S4 class to represent component f of the rfb rule.

This class (`f`) stores the input for component f (the length indicator as well as the resulting f value.

Slots

`value` The value of component f

`indicator` Length indicator time series

`yr_last numeric`. The last year with data.

`years` Years with data.

`Lmean` Mean catch length.

`Lref` Reference catch length.

`n0` Time lag between the last index year and the last year to be used.

`units character`. The units of the biomass index, e.g. 'kg/hr'.

`hcr factor`. The harvest control rule (hcr) for which component f is used (rfb).

`Ftarget-class` *F*

Description

An S4 class to represent component F (the target harvest rate) of the chr rule.

This class (`F`) stores the input for the target harvest rate (if any) as well as the resulting target harvest rate.

Slots

`value` The target harvest rate value.

`data data.frame`. The data (harvest rates) used for calculating the target harvest rate.

`yr_ref numeric`. The years from which data are used.

`units character`. The units of the harvest rate.

`HR HR`. The harvest rate input data.

`indicator F`. The indicator used to select years of the harvest rate.

`hcr character`. The harvest control rule (hcr) for which the index is used. Only applicable to 'chr'.

HR *Calculation of the (relative) harvest rate*

Description

The (relative) harvest rate is calculated by dividing the catch values by biomass index values.

Usage

```
HR(object, units_catch, units_index, units, ...)
```

Arguments

`object`	The data to use. Usually a `data.frame` with columns 'year', 'catch' and 'index'.
`units_catch`	Optional. The units of the catch, e.g. 'tonnes'.
`units_index`	Optional. The units of the biomass index, e.g. 'kg/hr'.
`units`	Optional. The units of the harvest rate. Can be derived automatically from `units_catch` and `units_index`.
`...`	Additional arguments. Not currently used.

Details

Usually, this functions is used by providing a `data.frame` with columns 'year', 'catch' and 'index' is provided. The catch can be split into landings and discards by providing 'landings' and 'discards' columns.

If an object of class `HR` is provided, its validity is checked.

Value

An object of class `HR` with the harvest rate value(s).

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

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Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2022. Exploring a relative harvest rate strategy for moderately data-limited fisheries management. ICES Journal of Marine Science, 79: 1730–1741. https://doi.org/10.1093/icesjms/fsac103.

Examples

```
# create data.frame with data
df <- data.frame(year = 2017:2021,
                 index = c(1.33, 1.13, 0.84, 0.60, 1.03),
                 catch = c(2949, 2513, 2091, 1888, 1615))
# calculate harvest rate
HR(df)

# check objects validity
HR(HR(df))

# plot harvest rate
# plot(HR(df, units_catch = "tonnes", units_index = "kg/hr"))
```

`HR-class` *HR-class*

Description

An S4 class to represent the harvest rate (hr) of the chr rule.

This class (`HR`) stores the input for the harvest rate (catch, landings) as well as the resulting harvest rates.

Slots

`value` The values of the harvest rate time series.

`data` `data.frame`. The input data (catch and index values)

`units` `character`. The units of the harvest rate.

`units_catch` `character`. The units of the catch.

`units_index` `character`. The units of the index.

`hcr` `character`. The harvest control rule (hcr) for which the index is used. Only applicable to 'chr'.

I *chr rule - component I (biomass index value)*

Description

This function calculates component I (the last biomass index value) of the chr rule. The index needs to be a biomass index without age structure.

Usage

```
I(object, lag = 0, n_yrs = 1, units, hcr = "chr", ...)

chr_I(object, lag = 0, n_yrs = 1, units, hcr = "chr", ...)
```

Arguments

`object`	The biomass index. Can be a `data.frame` with columns 'data' and 'index', a vector, or a single value.
`lag`	Optional. The time lag (in years) between the last available index value and the value to be used. Defaults to 0 (the last value is used).
`n_yrs`	Optional. The number of years if an average index value is used. Defaults to 1 (use last year's value only).
`units`	Optional. The units of the biomass index, e.g. 'kg/hr'. Only used for plotting.
`hcr`	Optional. Should be 'chr'.
`...`	Additional arguments. Not used.

Details

See ICES (2022) for the full definition definition.

Usually, this method is used by providing only a biomass index, e.g. as a `data.frame`. The method uses this index, and takes the last index value.

`chr_I()` is an alias for `I()` with identical arguments and functionality.

Value

An object of class `I` with the value of the biomass index

Warning

For application in ICES, do not change the defaults unless the change is supported by stock-specific simulations.

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2023. Risk equivalence in data-limited and data-rich fisheries management: An example based on the ICES advice framework. Fish and Fisheries, 24: 231–247. https://doi.org/10.1111/faf.12722.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2022. Exploring a relative harvest rate strategy for moderately data-limited fisheries management. ICES Journal of Marine Science, 79: 1730–1741. https://doi.org/10.1093/icesjms/fsac103.

Examples

```
# Use a data.frame with index values
df_idx <- data.frame(year = 2017:2021,
                     index = c(1.33, 1.13, 0.84, 0.60, 1.03))
I <- I(df_idx)
I
advice(I)


# If only the value of the last biomass index is known
I(1)

# ple7e example data
data(ple7e_idx)
I <- I(ple7e_idx)
advice(I)
plot(I)
```

`I-class` *I-class*

Description

An S4 class to represent component I (the current biomass index value) of the chr rule.

This class (`I`) stores the input for component I as well as the resulting I value.

Slots

`value` The value of component I

`lag` The time lag (in years) between the last available index value and the value to be used.

`n_years` `numeric`. The number of years used for the index value.

`idx` `data.frame`. A `data.frame` with the index values.

`yr_last` `numeric`. The last year with index data.

`units` `character`. The units of the biomass index, e.g. 'kg/hr'.

`hcr` `character`. The harvest control rule (hcr) for which the index is used. Only applicable to 'chr'.

`indicator` *indicator*

Description

This function returns the indicator value(s) for the empirical harvest control rules, e.g. the length indicator.

Usage

```
indicator(object)

## S4 method for signature 'f'
indicator(object)
```

Arguments

`object`	The object from which the indicator is requested.

`inverse_indicator` *Return the inverse indicator for component f of the chr rule.*

Description

Return the inverse indicator for component f of the chr rule.

Usage

```
inverse_indicator(object)
```

Arguments

`object`	An object of class `f`.

Value

A `data.frame` with the inverse length indicator value(s).

Lc *Length at first capture Lc*

Description

This function calculates length at first capture Lc from a length frequency distribution for use with the rfb/chr rules.

Usage

```
Lc(
  data,
  pool = FALSE,
  average = FALSE,
  lmin,
  lmax,
  lstep,
  rounding = floor,
  units,
  ...
)

## S4 method for signature 'numeric'
Lc(
  data,
  pool = FALSE,
  average = FALSE,
  lmin,
  lmax,
  lstep,
  rounding = floor,
  units,
  ...
)

## S4 method for signature 'Lc'
Lc(
  data,
  pool = FALSE,
  average = FALSE,
  lmin,
  lmax,
  lstep,
  rounding = floor,
  units,
  ...
)
```

```
## S4 method for signature 'data.frame'
Lc(
  data,
  pool = FALSE,
  average = FALSE,
  lmin,
  lmax,
  lstep,
  rounding = floor,
  units,
  ...
)
```

Arguments

data	The input data with the length distribution. (see details below)
pool	Pool data from several years in the calculation? TRUE/FALSE or a vector specifying years to use.
average	Calculate Lc as the average of several annual values? TRUE/FALSE or a vector specifying years to use.
lmin	Optional. Smallest length class to use. If defined, length classes below lmin are ignored.
lmax	Optional. Largest length class to use. If defined, length classes above lmax are ignored.
lstep	Optional. Size of length classes. Allows combining length classes into larger length classes. (see details below)
rounding	Optional. The method used to round length classes when using lstep. Defaults to floor, can also be ceiling or round.
units	Units of length data, e.g. "cm".
...	Additional arguments. Not currently used.

Details

Length at first capture Lc is defined as the first length class, in which the numbers of fish is at or above the mode of the distribution (the length class with the highest number of fish).

The length distribution is passed to Lc with the argument data. data is ideally a data.frame with columns "year", "length", and "numbers".

The argument pool allows the pooling of length data from several years in the estimation of Lc. If set to FALSE (default), Lc will be calculated for each year, if set to TRUE, all years will be combined. Alternatively, a vector of years can be provided and only these years will be used.

The argument average allows the averaging of annual Lc values over several years. If set to FALSE (default), Lc will be calculated for each year, if set to TRUE, Lc values from all years will be averaged. Alternatively, a vector of years can be provided and only these years will be used for the average.

The optional arguments `lmin` and `lmax` allow removing of length classes outside this range. `lstep` can be used to combine the length into broader length classes. This can be useful if data are noisy with several local minima/maxima and to smooth the length distribution.

Value

An object of class `Lc`

Note

For application with the rfb or chr rule, Lc should be set once in the first year of the implementation. At every subsequent application of the method, the previous Lc should then be kept unless a substantial change happened (e.g. because of changed in the fishery or fishery selectivity).

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Examples

```
# example data for plaice
data(ple7e_length)
# annual length at first capture
lc <- Lc(data = ple7e_length)
lc
plot(lc)

# pool data over several years (recommended)
lc <- Lc(data = ple7e_length, pool = 2017:2021)
plot(lc)
```

Lc-class *An S4 class to represent length at first capture*

Description

This class (`Lc`) stores the input data (length frequencies) for the length at first capture and the resulting length at first capture value(s).

Slots

`value` The length at first capture value(s)

`summary` A summary of the length at first capture value(s)

`years` The years used in the calculation of length at first capture

`pooled` Are length data from several years combined (pooled)?

`averaged` Are annual values from several years average?

`units` The units for length data (e.g. cm)

`data` The data (length frequencies) used in the calculation

`Lmean` *Mean catch length Lmean*

Description

This function calculates the mean catch length above the length of first capture.

Usage

```
Lmean(
  data,
  Lc,
  lmin,
  lmax,
  lstep,
  rounding = floor,
  include_Lc = TRUE,
  units,
  ...
)

## S4 method for signature 'numeric,missing'
Lmean(
  data,
  Lc,
  lmin,
  lmax,
  lstep,
  rounding = floor,
  include_Lc = TRUE,
  units,
  ...
)

## S4 method for signature 'Lmean,missing'
Lmean(
  data,
  Lc,
  lmin,
  lmax,
  lstep,
```

```
  rounding = floor,
  include_Lc = TRUE,
  units,
  ...
)

## S4 method for signature 'data.frame,missing'
Lmean(
  data,
  Lc,
  lmin,
  lmax,
  lstep,
  rounding = floor,
  include_Lc = TRUE,
  units,
  ...
)

## S4 method for signature 'data.frame,data.frame'
Lmean(
  data,
  Lc,
  lmin,
  lmax,
  lstep,
  rounding = floor,
  include_Lc = include_Lc,
  units,
  ...
)

## S4 method for signature 'data.frame,Lc'
Lmean(
  data,
  Lc,
  lmin,
  lmax,
  lstep,
  rounding = floor,
  include_Lc = include_Lc,
  units,
  ...
)
```

Arguments

data	The input data with the length distribution. (see details below)

Lc	Length of first capture. Either a single value used for all years or a data.frame with columns "year" and "Lc".
lmin	Optional. Smallest length class to use. If defined, length classes below lmin are ignored.
lmax	Optional. Largest length class to use. If defined, length classes above lmax are ignored.
lstep	Optional. Size of length classes. Allows combining length classes into larger length classes. (see details below)
rounding	Optional. The method used to round length classes when using lstep. Defaults to floor, can also be ceiling or round.
include_Lc	Optional. Include individuals at the length of first capture (Lc)? Defaults to TRUE. If set to FALSE, only individuals above Lc are considered.
units	Units of length data, e.g. "cm".
...	Additional arguments. Not currently used.

Details

The mean catch length is calculated as the mean length of fish in the catch which are above the length of first capture (Lc). The mean catch length is essentially the mean of lengths, weighted by the number of fish in the length classes.

The length distribution is passed to Lmean with the argument data. data is ideally a data.frame with columns "year", "length", and "numbers". An optional column, "catch_category", can be included to distinguish between categories such as "landings" and "discards".

The mean catch length calculation only considers length classes above the length of first capture Lc. Lc can be provided as a single value (recommended) or annual values can be provided with a data.frame with columns "year" and "Lc". Generally, it is recommended to use a single value for Lc and only change it if there are substantial changes between years.

If Lc is not provided, the input data is passed to Lc() to estimate Lc.

The optional arguments lmin and lmax allow removing of length classes outside this range. lstep can be used to combine the length into broader length classes. This can be useful if data are noisy with several local minima/maxima and to smooth the length distribution.

By default, the calculation of the mean length includes individuals at the length of first capture (Lc). This can be manually turned off by providing the argument include_Lc = FALSE. If this is turned off, only fish above Lc are considered.

Value

An object of class Lc

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Examples

```
# example data for plaice
data(ple7e_length)
# calculate (pooled) length at first capture first
lc <- Lc(data = ple7e_length, pool = 2017:2021)
# mean catch length
lmean <- Lmean(data = ple7e_length, Lc = lc, units = "mm")
lmean
plot(lmean)
```

Lmean-class *An S4 class to represent mean catch length*

Description

This class (Lmean) stores the input data (length frequencies) for the mean catch length and the resulting mean catch length(s), above the length at first capture (Lc).

Slots

`value` The mean catch length value(s)

`summary` A summary of the mean catch length value(s)

`years` The years for which mean catch length is calculated

`Lc` The length at first capture

`include_Lc` Include Lc in the calculation of the mean length? (default: `TRUE`)

`units` The units for length data (e.g. cm)

`data` The data (length frequencies) used in the calculation

Lref *Reference catch length*

Description

This function calculates the reference catch length.

Usage

```
Lref(
  value,
  basis = "LF=M",
  Lc,
  Linf,
  Mk = 1.5,
  gamma = 1,
  theta = 1/Mk,
  units,
  ...
)
```

Arguments

value	Optional. The reference length value, if already known.
basis	The basis for the calculation, defaults to "LF=M".
Lc	The length at first capture.
Linf	The asymptotic length from a von Bertalanffy growth model.
Mk	The ratio of natural mortality M to von Bertalanffy k.
gamma	Links fishing mortality F to natural mortality M to set the proxy for MSY (see details).
theta	Alternative option to link M and k.
units	The units for length data (e.g. cm)
...	Additional arguments. Not currently used.

Details

The default is to calculate the MSY proxy reference length following Beverton & Holt (1957) and as derived by Jardim et al. (2015):

`(theta * Linf + Lc * (gamma + 1)) / (theta + gamma + 1)`

where `Linf` is the asymptotic length of a von Bertalanffy growth model, `Lc` the length of first capture, theta links von Bertalanffy individual growth parameter k and natural mortality (M) through `k = theta * M` and gamma links fishing mortality F to M through `F = gamma * M`. The default reference length calculation assumes `theta = 2/3`, i.e. that `M/k = 1.5` and that `gamma = 1`, i.e. that `F = M` can be used as a proxy for MSY. The ratio M/k can be set directly with the argument `Mk` or indirectly with `theta` which defaults to `1/Mk`.

Value

An object of class `Lref`

Warning

Changing the default parameters is discouraged. Any change to the default parameters should be well justified.

The reference length is usually set once the first time the rfb rule is applied and should then be kept constant unless there a substantial changes in the fishery or fishery selectivity.

References

Beverton, R. J. H., and Holt, S. J. 1957. On the Dynamics of Exploited Fish Populations. Fishery Investigation Series 2. HMSO for Ministry of Agriculture, Fisheries and Food, London. 533 pp. ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564. Jardim, E., Azevedo, M., and Brites, N. M. 2015. Harvest control rules for data limited stocks using length-based reference points and survey biomass indices. Fisheries Research, 171: 12–19. https://doi.org/10.1016/j.fishres.2014.11.013.

Examples

```
# calculate MSY proxy LF=M
Lref(Lc = 26.4, Linf = 58.5)
```

Lref-class *An S4 class to represent the reference catch length*

Description

This class (`Lref`) stores the value of the reference catch length, e.g. LF=M.

Arguments

`value`	The reference catch length.
`basis`	The basis for the calculation, defaults to "LF=M".
`Lc`	The length at first capture.
`Linf`	The asymptotic length from a von Bertalanffy growth model.
`Mk`	The ratio of natural mortality M to von Bertalanffy k.
`gamma`	Links fishing mortality F to natural mortality M to set the proxy for MSY (see details).
`theta`	Alternative option to link M and k.
`years`	Years, if annual values provided.
`units`	The units for length data (e.g. cm)

m *rfb/rb/chr rule - component m (multiplier)*

Description

This function returns the default multiplier for the rfb, rb, and chr rules.

Usage

```
m(object, hcr, k, ...)

rfb_m(object, hcr = "rfb", k, ...)

rb_m(object, hcr = "rb", k, ...)

chr_m(object, hcr = "chr", k, ...)
```

Arguments

object	Optional. A multiplier m value, if known, or an existing m object.
hcr	The harvest control rule (hcr) for which the multiplier is used. One of 'rfb', 'rb', or 'chr'.
k	Optional. The von Bertalanffy k parameter (individual growth rate, unit: 1/year).
...	Additional arguments. Not used.

Details

rfb_m(), rb_m(), and chr_m() are aliases for m() in which the hcr argument is already set to 'rfb', 'rb', or 'chr'.

The multiplier is set following ICES (2022).

For the rfb rule, the multiplier is set depending on the von Bertalanffy parameter k (individual growth rate, units: 1/year; ICES, 2022). For species where k is below 0.2/year, the multiplier is set to m=0.95. For species where k is at or above 0.2/year, but below 0.32/year, the multiplier is set to m=0.90. If the rfb rule is applied and k is unknown, the more precautionary multiplier of m=0.90 is used.

For the rb rule, the multiplier is set to m=0.50 (ICES, 2022).

For the chr rule, the multiplier is set to m=0.50 (ICES, 2022).

Value

An object of class m

Warning

For application in ICES, do not change the default multiplier unless the change is supported by stock-specific simulations.

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Examples

```
# rfb rule with known k
rfb_m(k = 0.1) # 0.95
m(hcr = "rfb", k = 0.1) # 0.95
rfb_m(k = 0.25) # 0.90
m(hcr = "rfb", k = 0.25) # 0.90
# rfb rule with unknown k
rfb_m() # 0.90
m(hcr = "rfb") # 0.90

# rb rule
rb_m() # 0.5
m(hcr = "rb") # 0.5

# chr rule
chr_m() # 0.5
m(hcr = "chr") # 0.5
```

`m-class` *m-class*

Description

An S4 class to represent component m (the multiplier) of the rfb, rb, and chr rules.

The classes `rfb_m`, `rb_m`, and `chr_m` inherit from `m` and their only difference is that the slot `hcr` is set to the corresponding catch rule name ('rfb', 'rb', or 'chr').

Slots

`value` The value of component m

`hcr` The harvest control rule (hcr) for which the multiplier is used. One of 'rfb', 'rb', or 'chr'.

`k` Optional. The von Bertalanffy k parameter (individual growth rate, unit: 1/year).

ple7e	*Western English Channel plaice example data This data set contains 2022 example data from Western English Channel plaice (ple.27.7e) to illustrate the application of the ICES category 3 empirical harvest control rules.*

Description

Western English Channel plaice example data

This data set contains 2022 example data from Western English Channel plaice (ple.27.7e) to illustrate the application of the ICES category 3 empirical harvest control rules.

Usage

```
ple7e_catch

ple7e_f

ple7e_f2

ple7e_hr

ple7e_idx

ple7e_length
```

Format

An object of class `data.frame` with 36 rows and 5 columns.

An object of class `comp_f` of length 1.

An object of class `f` of length 1.

An object of class `HR` of length 1.

An object of class `data.frame` with 19 rows and 2 columns.

An object of class `data.frame` with 777 rows and 4 columns.

Source

https://github.com/ices-taf

plot,Lc,ANY-method *Plot length frequencies*

Description

A convenience function for plotting length frequencies and length reference points.

Usage

```
## S4 method for signature 'Lc,ANY'
plot(x, y, y_label, show.data = TRUE, ...)

## S4 method for signature 'Lmean,ANY'
plot(x, y, y_label, show.data = TRUE, ...)
```

Arguments

x	An object of class Lc, Lmean, ...
y	Not used.
y_label	Not used.
show.data	Not used.
...	Additional arguments. Not currently used.

Value

An object of class gg/ggplot with the plot. Can be manipulated with the usual ggplot2 commands, e.g. ylim().

r *rfb/rb rule - component r (index ratio)*

Description

This function calculates component r (the index ratio) of the rfb and rb rule. The index needs to be a biomass index without age structure.

Usage

```
r(object, n0, n1, n2, units, hcr, ...)

rfb_r(object, n0, n1, n2, units, hcr = "rfb", ...)

rb_r(object, n0, n1, n2, units, hcr = "rb", ...)
```

Arguments

object	The biomass index. Can be a data.frame with columns 'data' and 'index' or an FLQuant object defined by FLCore.
n0	Optional. Time lag between the last index year and the last year to be used. By default, the last index year is used (n0=0)
n1	Optional. Number of years used in the numerator of the r component. Defaults to 2 (i.e. n1 and n2 use a 2 over 3 ratio).
n2	Optional. Number of years used in the denominator of the r component. Defaults to 3.
units	Optional. The units of the biomass index, e.g. 'kg/hr'. Only used for plotting.
hcr	Optional. One of 'rfb' or 'rb'.
...	Additional arguments. Not used.

Details

Usually, this method is used by providing only a biomass index, e.g. as a data.frame. The default index ratio is the average of the last two index values, divided by the average of the three preceeding index values.

The index ratio is identical in the rfb and rb rules. rfb_r() and rb_b() are aliases for r() with identical arguments and functionality.

Value

An object of class r

Warning

For application in ICES, do not change the defaults (n0, n1, n2) unless the change is supported by stock-specific simulations.

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2023. Risk equivalence in data-limited and data-rich fisheries management: An example based on the ICES advice framework. Fish and Fisheries, 24: 231–247. https://doi.org/10.1111/faf.12722.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Application of explicit precautionary principles in data-limited fisheries management. ICES Journal of Marine Science, 78: 2931–2942. https://doi.org/10.1093/icesjms/fsab169.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Using a genetic algorithm to optimize a data-limited catch rule. ICES Journal of Marine Science, 78: 1311–1323. https://doi.org/10.1093/icesjms/fsab018.

Fischer, S. H., De Oliveira, J. A. A., and Kell, L. T. 2020. Linking the performance of a data-limited empirical catch rule to life-history traits. ICES Journal of Marine Science, 77: 1914–1926. https://doi.org/10.1093/icesjms/fsaa054.

Examples

```
# If the value of r is known
rfb_r(0.9)
r(0.9)

# Use a data.frame with index values
df_idx <- data.frame(year = 2017:2021,
                     index = c(1.33, 1.13, 0.84, 0.60, 1.03))
r <- r(df_idx)
r
advice(r)

# plot
plot(r(df_idx, units = "kg/hr"))
```

`r-class` *r-class*

Description

An S4 class to represent component r of the rfb and rb rules.

This class (`r`) stores the input for component r (the index ratio) as well as the resulting r value.

Slots

`value` The value of component r

`n0,n1,n2` Parameters for the calculation of the r component. See `?rfb_r` for details.

`yr_last numeric`. The last year with index data.

`n1_yrs,n2_yrs numeric`. The years used for `n1` and `n2`.

`n1_mean,n2_mean numeric`. The mean index values over `n1_yrs` and `n2_yrs`.

`idx data.frame`. A `data.frame` with the index values.

`units character`. The units of the biomass index, e.g. 'kg/hr'.

`hcr character`. The harvest control rule (hcr) for which the biomass safeguard is used. One of 'rfb' or 'rb'.

rb *rb rule*

Description

This function applies the rb rule.

Usage

```
rb(
  object,
  A,
  r,
  b,
  m,
  cap = "conditional",
  cap_upper = 20,
  cap_lower = -30,
  years,
  frequency = "biennial",
  discard_rate = NA,
  ...
)
```

Arguments

object	Optional. An object of class rfb.
A	The reference catch. Should be an object of class A, see A.
r	The biomass index ratio. Should be an object of class r, see r.
b	The biomass safeguard. Should be an object of class b, see b.
m	The multiplier. Should be an object of class m, see m.
cap	logical. The uncertainty cap (stability clause). Defaults to TRUE
cap_upper	Optional. numeric. The maximum allowed increase in the catch advice in %. Default to +20.
cap_lower	Optional. numeric. The maximum allowed decrease in the catch advice in %. Default to -20.
years	Optional. numeric. The years for which the advice should be given.
frequency	Optional. The frequency of the advice ('annual'/'biennial'/'triennial'). Defaults to 'biennial'.
discard_rate	Optional. The discard rate for the advice (numeric). If provided, advice values for catch and landings are given.
...	Additional parameters. Not used.

Details

The function requires the elements of the rb rule: A (the reference) catch, r (the biomass index ratio), f (the fising pressure proxy), b (the biomass safeguard) and m (the multiplier). See the help files for details A, vr, b, and m.

Value

An object of class rb.

Warning

For application in ICES, do not change the default parameters (frequency, stability clause, etc) unless the changes are supported by case-specific simulations.

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2023. Risk equivalence in data-limited and data-rich fisheries management: An example based on the ICES advice framework. Fish and Fisheries, 24: 231–247. https://doi.org/10.1111/faf.12722.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Application of explicit precautionary principles in data-limited fisheries management. ICES Journal of Marine Science, 78: 2931–2942. https://doi.org/10.1093/icesjms/fsab169.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Using a genetic algorithm to optimize a data-limited catch rule. ICES Journal of Marine Science, 78: 1311–1323. https://doi.org/10.1093/icesjms/fsab018.

Fischer, S. H., De Oliveira, J. A. A., and Kell, L. T. 2020. Linking the performance of a data-limited empirical catch rule to life-history traits. ICES Journal of Marine Science, 77: 1914–1926. https://doi.org/10.1093/icesjms/fsaa054.

Examples

```
#' # calculate elements of rb rule for plaice
# reference catch
data(ple7e_catch)
A <- A(object = ple7e_catch, basis = "advice", units = "tonnes", advice_metric = "catch")
# biomass index trend
data(ple7e_idx)
r <- r(ple7e_idx)
# biomass safeguard
b <- b(ple7e_idx)
# multiplier
m <- m(hcr = "rb", k = 0.1)
# apply rb rule
advice <- rb(A = A, r = r, b = b, m = m, discard_rate = 27)
advice
advice(advice)
```

```
### application in subsequent years (without updating reference levels)
A <- A(object = ple7e_catch, basis = "advice", units = "tonnes", advice_metric = "catch")
r <- r(ple7e_idx)
b <- b(ple7e_idx, yr_ref = 2007) # use reference year for Itrigger
m <- m(0.95) # keep multiplier
advice <- rb(A = A, r = r, b = b, m = m, discard_rate = 27)
advice
advice(advice)
```

`rb-class` *An S4 class to represent the rb rule.*

Description

This class contains the components of the rb rule (`rb_A`, `rb_r`, `rb_b`, `rb_m`).

Slots

`advice` The value of the catch advice.

`advice_landings` Landings corresponding to the catch advice.

`advice_uncapped` The value of the catch advice without the uncertainty cap.

`units` The unit (e.g. tonnes) of the catch advice.

`advice_metric` The advice metric, 'catch' or 'landings'.

`frequency` The advice frequence (annual/biennial).

`years` The years for which the advice is valid.

`A` Component A (the reference catch).

`r` Component r (the biomass index ratio).

`b` Component b (the biomass safeguard).

`m` Component m (the multiplier).

`cap` Uncertainty cap (stability clause, restricts changes in advice).

`cap_lower` Maximum allowed reduction in advice in %, e.g. -30.

`cap_upper` Maximum allowed increase in advice in %, e.g. 20.

`change` Change in advice compared to previous advice.

`change_uncapped` Change in advice compared to previous advice before application of the uncertainty cap.

`discard_rate` Discard rate (%).

rfb *rfb rule*

Description

This function applies the rfb rule.

Usage

```
rfb(
  object,
  A,
  r,
  f,
  b,
  m,
  cap = "conditional",
  cap_upper = 20,
  cap_lower = -30,
  years,
  frequency = "biennial",
  discard_rate = NA,
  ...
)
```

Arguments

object	Optional. An object of class rfb.
A	The reference catch. Should be an object of class A, see A.
r	The biomass index ratio. Should be an object of class r, see r.
f	The fishing pressure proxy. Should be an object of class f, see f.
b	The biomass safeguard. Should be an object of class b, see b.
m	The multiplier. Should be an object of class m, see m.
cap	logical. The uncertainty cap (stability clause). Defaults to TRUE
cap_upper	Optional. numeric. The maximum allowed increase in the catch advice in %. Default to +20.
cap_lower	Optional. numeric. The maximum allowed decrease in the catch advice in %. Default to -20.
years	Optional. numeric. The years for which the advice should be given.
frequency	Optional. The frequency of the advice ('annual'/'biennial'/'triennial'). Defaults to 'biennial'.
discard_rate	Optional. The discard rate for the advice (numeric). If provided, advice values for catch and landings are given.
...	Additional parameters. Not used.

Details

The function requires the elements of the rfb rule: A (the reference) catch, r (the biomass index ratio), f (the fising pressure proxy), b (the biomass safeguard) and m (the multiplier). See the help files for details: A, vr, f, b, and m.

Value

An object of class rfb.

Warning

For application in ICES, do not change the default parameters (frequency, stability clause, etc) unless the changes are supported by case-specific simulations.

References

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2023. Risk equivalence in data-limited and data-rich fisheries management: An example based on the ICES advice framework. Fish and Fisheries, 24: 231–247. https://doi.org/10.1111/faf.12722.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Application of explicit precautionary principles in data-limited fisheries management. ICES Journal of Marine Science, 78: 2931–2942. https://doi.org/10.1093/icesjms/fsab169.

Fischer, S. H., De Oliveira, J. A. A., Mumford, J. D., and Kell, L. T. 2021. Using a genetic algorithm to optimize a data-limited catch rule. ICES Journal of Marine Science, 78: 1311–1323. https://doi.org/10.1093/icesjms/fsab018.

Fischer, S. H., De Oliveira, J. A. A., and Kell, L. T. 2020. Linking the performance of a data-limited empirical catch rule to life-history traits. ICES Journal of Marine Science, 77: 1914–1926. https://doi.org/10.1093/icesjms/fsaa054.

Examples

```
# calculate elements of rfb rule for plaice
# reference catch
data(ple7e_catch)
A <- A(object = ple7e_catch, basis = "advice", units = "tonnes", advice_metric = "catch")
# biomass index trend
data(ple7e_idx)
r <- r(ple7e_idx)
plot(r)
# fishing pressure proxy
data(ple7e_length)
lc <- Lc(data = ple7e_length, pool = 2017:2021)
lmean <- Lmean(data = ple7e_length, Lc = lc, units = "mm")
lref <- Lref(Lc = 264, Linf = 585)
f <- f(Lmean = lmean, Lref = lref, units = "mm")
plot(f)
```

```
# biomass safeguard
b <- b(ple7e_idx)
plot(b)
plot(b, r)
# multiplier
m <- m(hcr = "rfb", k = 0.1)
# apply rfb rule
advice <- rfb(A = A, r = r, f = f, b = b, m = m, discard_rate = 27)
advice
advice(advice)

### application in subsequent years (without updating reference levels)
A <- A(object = ple7e_catch, basis = "advice", units = "tonnes", advice_metric = "catch")
r <- r(ple7e_idx)
lref <- Lref(344.25) # use previous value
f <- f(Lmean = lmean, Lref = lref, units = "mm")
b <- b(ple7e_idx, yr_ref = 2007) # use reference year for Itrigger
m <- m(0.95) # keep multiplier
advice <- rfb(A = A, r = r, f = f, b = b, m = m, discard_rate = 27)
advice
advice(advice)
```

`rfb-class` *An S4 class to represent the rfb rule.*

Description

This class contains the components of the rfb rule (`rfb_A`, `rfb_r`, `rfb_f`, `rfb_b`, `rfb_m`).

Slots

`advice` The value of the catch advice.

`advice_landings` Landings corresponding to the catch advice.

`advice_uncapped` The value of the catch advice without the uncertainty cap.

`units` The unit (e.g. tonnes) of the catch advice.

`advice_metric` The advice metric, 'catch' or 'landings'.

`frequency` The advice frequence (annual/biennial).

`years` The years for which the advice is valid.

`A` Component A (the reference catch).

`r` Component r (the biomass index ratio).

`f` Component f (the fishing pressure proxy).

`b` Component b (the biomass safeguard).

`m` Component m (the multiplier).

`cap` Uncertainty cap (stability clause, restricts changes in advice).

cap_lower Maximum allowed reduction in advice in %, e.g. -30.

cap_upper Maximum allowed increase in advice in %, e.g. 20.

change Change in advice compared to previous advice.

change_uncapped Change in advice compared to previous advice before application of the uncertainty cap.

discard_rate Discard rate (%).

---

rfb_plot *Plot elements of the rfb/rb/chr rule*

Description

A convenience function for plotting elements of the rfb, rb, and chr rules using ggplot2 and loosely following ICES style figures.

Usage

```
plot(x, y, y_label, show.data = TRUE, ...)

## S4 method for signature 'r,missing'
plot(x, y, y_label, show.data = TRUE, ...)

## S4 method for signature 'b,missing'
plot(x, y, y_label, show.data = TRUE, ...)

## S4 method for signature 'r,b'
plot(x, y, y_label, show.data = TRUE, ...)

## S4 method for signature 'b,r'
plot(x, y, y_label, show.data = TRUE, ...)

## S4 method for signature 'I,missing'
plot(x, y, y_label, show.data = TRUE, ...)

## S4 method for signature 'f,missing'
plot(x, y, y_label, show.data = TRUE, ...)

## S4 method for signature 'F,missing'
plot(x, y, y_label, show.data = TRUE, ...)

## S4 method for signature 'HR,ANY'
plot(x, y, y_label, show.data = TRUE, ...)
```

Arguments

x	An object of class rfb_r, rfb_b, ...
y	Optional. An additional object of rfb_b, ...
y_label	Optional. The y-axis label.
show.data	Show input data. Only applicable to some methods.
...	Additional arguments. Not used.

Details

Combinations of object are possible, e.g. for the rfb rule, it is possible to plot components r (index ratio) and b (biomass safeguard) on the same plot.

For the chr rule, plotting component f will return a plot with the absolute value of the mean catch length. The inverse indicator length can be plotted with `plot(f, inverse = TRUE)`.

Value

An object of class gg/ggplot with the plot. Can be manipulated with the usual ggplot2 commands, e.g. `ylim()`.

Examples

```
# Component b
df_idx <- data.frame(year = 2017:2021,
                     index = c(1.33, 1.13, 0.84, 0.60, 1.03))
b <- rfb_b(df_idx)
plot(b, y_label = "Biomass index in kg/hr")

# Component r
r <- rfb_r(df_idx)
plot(r, y_label = "Biomass index in kg/hr")

# Components r and b combined
plot(r, b)
```

---

show *show Show a summary of the elements of the empirical harvest control rule*

Description

show

Show a summary of the elements of the empirical harvest control rule

summary *summary*

Description

This function returns a summary of any component or the advice for the empirical harvest control rules

Usage

```
## S4 method for signature 'A'
summary(object, ...)

## S4 method for signature 'HR'
summary(object)

## S4 method for signature 'b'
summary(object, ...)

## S4 method for signature 'm'
summary(object, ...)

## S4 method for signature 'r'
summary(object, ...)
```

Arguments

object	The object for which a summary is requested.
...	Additional arguments. Not used.

value *value*

Description

This function returns the value of any component or the advice for the empirical harvest control rules

Usage

```
value(object)

## S4 method for signature 'A'
value(object)
```

```
## S4 method for signature 'f'
value(object)

## S4 method for signature 'HR'
value(object)

## S4 method for signature 'F'
value(object)

## S4 method for signature 'I'
value(object)

## S4 method for signature 'm'
value(object)

## S4 method for signature 'chr'
value(object)

## S4 method for signature 'r'
value(object)

## S4 method for signature 'b'
value(object)

## S4 method for signature 'rb'
value(object)

## S4 method for signature 'rfb'
value(object)
```

Arguments

object	The object from which the value is extracted.

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