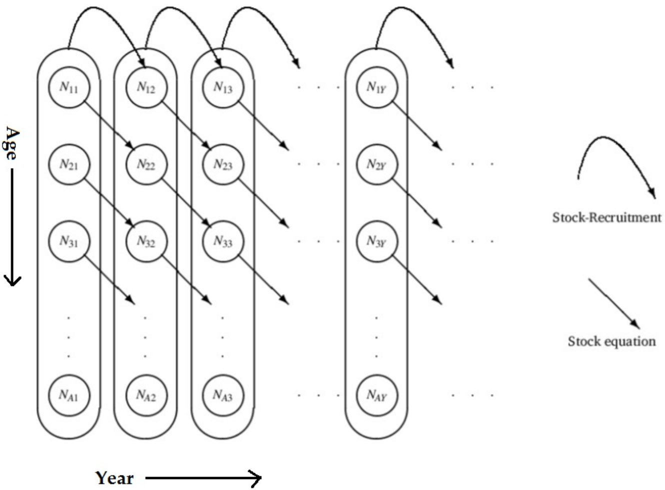
Explaining SAM

Olav Nikolai Breivik

Let $N_{a,y}$ be the number of fish at age a in year y.



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\log N_{A,y} &= \log(N_{A-1,y-1} e^{-F_{A-1,y-1} - M_{A-1,y-1}} + N_{A,y-1} e^{-F_{A,y-1} - M_{A,y-1}}) + \eta_{A,y}
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were

$$\log \mathbf{F}_y = \log \mathbf{F}_{y-1} + \boldsymbol{\xi}_y.$$

Observe:

$$\begin{aligned}
\log C_{a,y} &= \log\left(\frac{F_{a,y}}{F_{a,y} + M_{a,y}}(1 - e^{-F_{a,y} - M_{a,y}}) N_{a,y}\right) + \epsilon^{c}_{a,y} \\
\log I^{(s)}_y &= \log(Q^{(s)}_a e^{-(F_{a,y} + M_{a,y}) day^{(s)}/365} N_{a,y}) + \epsilon^{s}_{a,y}
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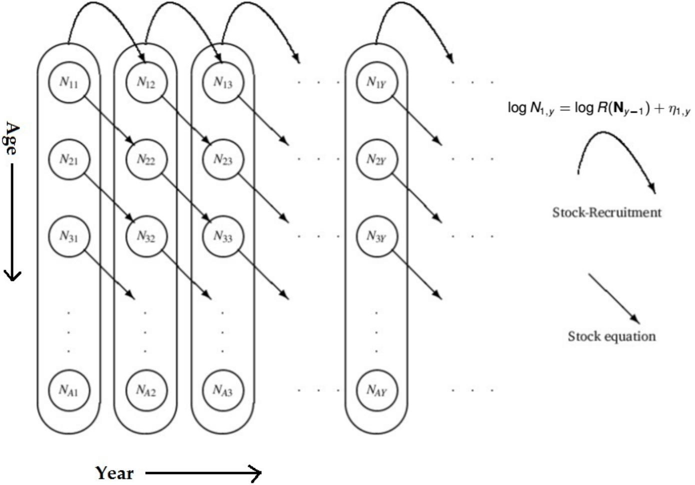
$$

Assumes $\boldsymbol{\eta}_y$, $\boldsymbol{\xi}_y$ and $\boldsymbol{\epsilon}^C_y$ and $\boldsymbol{\epsilon}^s_y$ all Gaussian distributed.

Let $N_{a,y}$ be the number of fish at age a in year y.



Recruitment

In SAM four types of recrutiment can be assumed:

- Random walk: $\log N_{1,y} \sim N(\log N_{1,y-1}, \sigma_r^2)$
- Ricker or Beverton-Holt: $\log N_{1,y} \sim N(f(SSB), \sigma_r^2)$
- Constant mean: $\log N_{1,y} \sim N(\mu_r, \sigma_r^2)$

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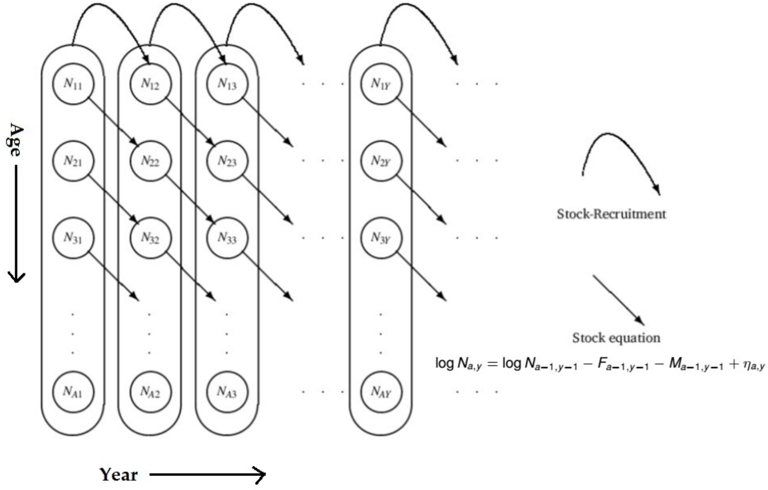

$$\log N_{a,y} = \log N_{a-1,y-1} - F_{a-1,y-1} - M_{a-1,y-1} + \eta_{a,y}$$

Fishing mortality F

In SAM it is typically assumed that:

$$\log \mathbf{F}_y = \log \mathbf{F}_{y-1} + \xi_y$$

were $\xi_y \sim N(0, \boldsymbol{\Sigma}_F)$.

- Several option of $\boldsymbol{\Sigma}_F$ are available.
- Note that this definition accommodate for time varying selectivity
- We can impose restrictions on **F** such that the fishing mortality is equal for some ages.

Separable F (used in herring assessment)

We can assume:

$$\log \mathbf{F}_y = \log \mathbf{U}_y + \log \mathbf{V}_y + \boldsymbol{\epsilon}_y^{(F)}$$

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were

$$\log \mathbf{U}_y = \rho_U \log \mathbf{U}_{y-1} + \boldsymbol{\alpha}_u + \boldsymbol{\epsilon}_y^{(U)}, \qquad \sum_a \log U_{a,y} = 1$$

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and

$$\log V_y = \rho_V \log V_{y-1} + \alpha_V + \epsilon_y^{(V)}$$

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and

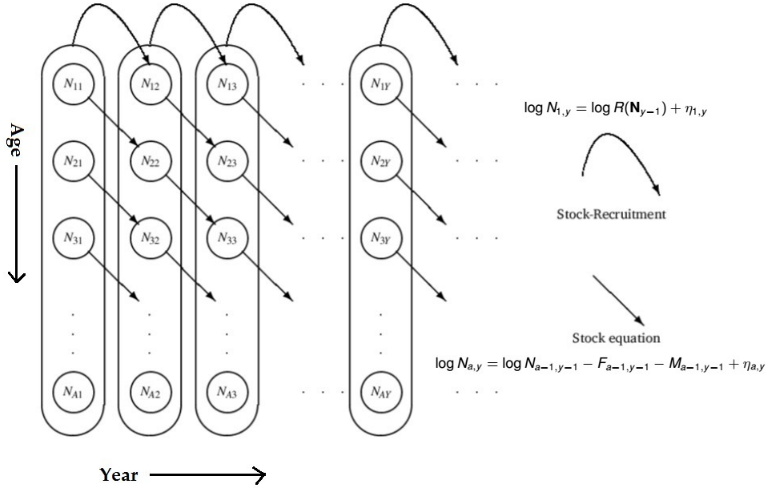
$$\log V_y = \rho_V \log V_{y-1} + \alpha_V + \epsilon_y^{(V)}$$

were

$$\boldsymbol{\epsilon}_y^{(F)} \sim N(\mathbf{0}, \boldsymbol{\Sigma}_F), \quad \boldsymbol{\epsilon}_y^{(U)} \sim N(\mathbf{0}, \boldsymbol{\Sigma}_U), \quad \epsilon_y^{(V)} \sim N(\mathbf{0}, \sigma_V^2)$$

See Link for implementation in SAM ($\boldsymbol{\epsilon}_y^{(F)}$ excluded).

Let $N_{a,y}$ be the number of fish at age a in year y.



Observation equations

We observe catch:

$$\log C_{a,y} = \log\left(\frac{F_{a,y}}{F_{a,y} + M_{a,y}}(1 - e^{-F_{a,y} - M_{a,y}})N_{a,y}\right) + \epsilon^{c}_{a,y}$$

Note

- $\frac{F_{a,y}}{F_{a,y}+M_{a,y}}$ is the proportion died in fishery
- $(1 - e^{-F_{a,y} - M_{a,y}})N_{a,y}$ is the total amount of fish died

It is assumed $\boldsymbol{\epsilon}^{c}_{y} \sim N(0, \boldsymbol{\Sigma}_C)$. Several option for $\boldsymbol{\Sigma}_C$ are available.

Observation equations

We observe indices:

$$\log I_{a,y}^{(s)} = \log(Q_a^{(s)} e^{-(F_{a,y}+M_{a,y})day^{(s)}/365} N_{a,y}) + \epsilon_{a,y}^{s}$$

- $Q_a^{(s)}$ is a catchability constant.
- $e^{-(F_{a,y}+M_{a,y})day^{(s)}/365} N_{a,y}$ is the abundance at survey time

It is assumed $\epsilon_y^s \sim N(0, \mathbf{\Sigma}_s)$. Several option for $\mathbf{\Sigma}_s$ are available.

External covariance (used in the NSSS herring assessment)

We can assume that

$$\epsilon_y^C \sim N(0, c^C \mathbf{R}_y^C)$$
$$\epsilon_y^I \sim N(0, c^s \mathbf{R}_y^s),$$

were $\mathbf{R}_y^C$ and $\mathbf{R}_y^s$ are provided outside of the assessment model. Further is c^C and c^s estimated inside the assessment model.

This structure is implemented in SAM.

- See testmore/nscodcovar on the SAM GitHub page for an example Link

External covariance (used in the NSSS herring assessment)

- In the herring assessment, smoothed estimates of $\mathbf{R}^c$ and $\mathbf{R}^s$ are provided.

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- In the herring assessment, smoothed estimates of $\mathbf{R}^c$ and $\mathbf{R}^s$ are provided.

Smoothed estimates of e.g. $\mathbf{R}^c$ are provided with the following procedure outside of SAM:

Let $v_{a,y}$ be estimated variance of $C_{a,y}$. By assuming that

$$\log v_{a,y} = \alpha + \beta \log(C_{a,y}) + \epsilon_{a,y}^{(s)}$$

and that $C_{a,y}$ is log-normal, we have that

$$\sigma_{a,y}^2 = \log(e^{\alpha} C_{a,y}^{\beta-2} + 1) \quad (1)$$

is an estimate of the standard deviation of log-catch. Let $\mathbf{R}^c = \boldsymbol{\sigma}' \mathbf{I} \boldsymbol{\sigma}$.

Link between mean and variance inside SAM

- The smoothing procedure can be included inside SAM
  - Implemented in a development version of SAM .
  - By smoothing the variances we can accommodate for that the CV's are typically smaller for larger catches or indices.

```
# Configuration saved: Thu Aug 15 14:47:08 2019
#
# Where a matrix is specified rows corresponds to fleets and columns to ages.
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive
#
$minAge
# The minimium age class in the assessment
 3

$maxAge
# The maximum age class in the assessment
 15

$maxAgePlusGroup
# Is last age group considered a plus group (1 yes, or 0 no).
 1

$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
   0   1   2   3   4   5   6   7   8   9  10  11  11
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, or 2 AR(1)
 2

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is not used, as that is covered by fishing mortality).
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1   0   1   2   3   4   5   6   7   7  -1  -1  -1
  -1   8   9  10  11  12  13  14  15  15  -1  -1  -1
  16  17  18  19  20  21  22  23  24  24  -1  -1  -1
  25  26  27  28  29  30  31  32  33  33  -1  -1  -1

$keyQpow
# Density dependent catchability power parameters (if any).
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarF
# Coupling of process variance parameters for log(F)-process (nomally only first row is used)
   0   0   0   0   0   0   0   0   0   0   0   0   0
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1 1 1 1 1 1 1
```

```
$keyVarObs
# Coupling of the variance parameters for the observations.
   0   0   0   0   0   0   0   0   0   0   0   0   0
  -1   1   1   1   1   1   1   1   1   1  -1  -1  -1
  -1   2   2   2   2   2   2   2   2   2  -1  -1  -1
   3   3   3   3   3   3   3   3   3   3  -1  -1  -1
   4   4   4   4   4   4   4   4   4   4  -1  -1  -1

$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). | Possible values are: "ID" "AR" "US"
 "ID" "AR" "AR" "AR" "AR"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they cannot).
#V1 V2 V3 V4 V5 V6 V7 V8 V9 V10 V11 V12
  NA  NA  NA  NA  NA  NA  NA  NA  NA  NA  NA  NA
  -1   0   1   2   3   4   4   4   4  -1  -1  -1
  -1   5   6   7   8   9  10  10  10  -1  -1  -1
  11  12  13  14  14  14  14  14  14  -1  -1  -1
  15  16  17  18  19  20  20  20  20  -1  -1  -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton-Holt, and 3 piece-wise constant).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.


$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled years, ncols = no ages).

$fbarRange
# lowest and higest age included in Fbar
 5 10

$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index, and 2 FSB index).
 -1 -1 -1 -1 -1

$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN" "LN" "LN" "LN"

$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treatment (0 relative weight, 1 fix variance to weight).
 0

$fracMixF
# The fraction of t(3) distribution used in logF increment distribution
 0
```

```
$fracMixN
# The fraction of t(3) distribution used in logN increment distribution
 0

$fracMixObs
# A vector with same length as number of fleets, where each element is the fraction of t(3) distribution used in the distribution
 0 0 0 0 0

$constRecBreaks
# Vector of break years between which recruitment is at constant level. The break year is included in the left interval.
```

Haddock assessment

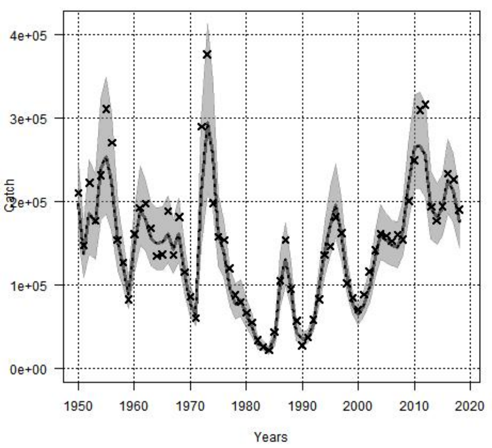

Figure: Catch plot with current settings

Haddock assessment

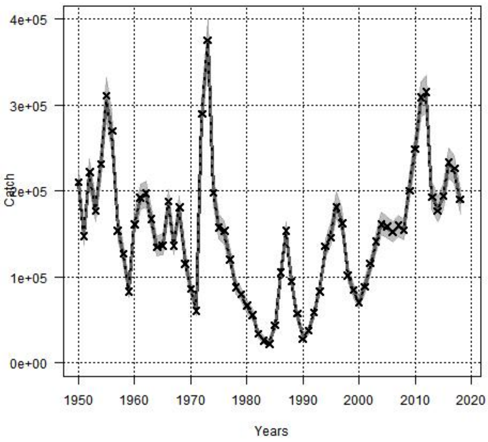

Figure: Catch plot with internal mean-variance link.