**User Manual Stock Synthesis**

**Version 3.30 beta**

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1. **Introduction**

This manual provides a guide for using the stock assessment program, Stock Synthesis (SS). The guide contains a description of the input and output files and usage instructions. A technical description of the model itself is in Methot and Wetzel (2013). SS is programmed using Auto Differentiation Model Builder (ADMB; Fournier 2001. ADMB is now available at admb-project.org). SS currently is compiled using ADMB version 11.1 using the Microsoft C++ Optimizing Compiler Version 16.0. The model and a graphical user interface are

available from the NOAA Fisheries Stock Assessment Toolbox website: [http://nft.nefsc.noaa.gov/.](http://nft.nefsc.noaa.gov/) An output processor package, r4ss, in R is available for download from CRAN or GitHub.

Additional information about the package can be located at https://github.com/r4ss/r4ss .

1. **New Features 3.30**

Stock Synthesis version 3.30 has a number of new features:

* 1. Version conditional read
  2. Forecast allocation group by year
  3. Subseasons
  4. Fleets - flexible ordering
  5. Catch - revised input format
  6. Catch multiplier
  7. Catch - bycatch fleets

1. **File Organization**
   1. **Input Files**
      1. starter.ss: required file containing filenames of the data file and the control file plus other run controls (required).
      2. datafile: file containing model dimensions and the data with file extension .dat (required)
      3. control file: file containing set-up for the parameters with file extension .ctl (required)
      4. forecast.ss: file containing specifications for forecasts (required)
      5. ss3.par: previously created parameter file that can be read to overwrite the initial parameter values in the control file (optional)
      6. runnumber.ss: file containing a single number used as runnumber in output to CumReport.sso and in the processing of profilevalues.ss (optional)
      7. profilevalues.ss: file contain special conditions for batch file processing (optional)
   2. **Output Files**
      1. ss3.par, ss3.std, ss33.rep, ss3.cor etc. standard ADMB output files
      2. echoinput.sso: This file is produced while reading the input files and includes an annotated echo of the input. The sole purpose of this output file is debugging input errors.
      3. warning.sso: This file contains a list of warnings generated during program execution.
      4. checkup.sso: Contains details of selectivity parameters and resulting vectors. This is written during the first call of the objective function.
      5. Report.sso: This file is the primary report file.
      6. CompReport.sso: Beginning with version 3.03, the composition data has been separated into a dedicated report
      7. Forecast-report.sso: Output of management quantities and for forecasts
      8. CumReport.sso: This file contains a brief version of the run output, output is appended to current content of file so results of several runs can be collected together. This is useful when a batch of runs is being processed.
      9. Covar.sso: This file replaces the standard ADMB ss3.cor with an output of the parameter and derived quantity correlations in database format
      10. data.ss\_new: contains a user-specified number of datafiles, generated through a parametric bootstrap procedure, and written sequentially to this file
      11. control.ss\_new: Updated version of the control file with final parameter values replacing the Init parameter values.
      12. starter.ss\_new: New version of the starter file with annotations
      13. Forecast.ss\_new: New version of the forecast file with annotations.
      14. rebuild.dat: Output formatted for direct input to Andre Punt’s rebuilding analysis package. Cumulative output is output to REBUILD.SS (useful when doing MCMC or profiles).
   3. **Auxiliary Files**
      1. SS3-OUTPUT.XLS: Excel file with macros to read report.sso and display results
      2. SELEX24\_dbl\_normal.XLS:
         1. This excel file is used to show the shape of a double normal selectivity (option number 20 for age-based and 24 for length-based selectivity) given user-selected parameter values.
         2. Instructions are noted in the XLS file but, to summarize
            1. Users should only change entries in a yellow box.
            2. Parameter values are changed manually or using sliders, depending on the value of cell I5.
         3. It is recommend that users select plausible starting values for double-normal selectivity options, especially when estimating all 6 parameters
         4. Please note that the XLS does NOT show the impact of setting parameters 5 or 6 to ”-999”. In SS3, this allows the the value of selectivity at the initial and final age or length to be determined by the shape of the double-normal arising from parameters 1-4, rather than forcing the selectivity at the intial and final age or length to be estimated separately using the value of parameters 5 and 6.
      3. SELEX17\_age\_randwalk.XLS:
         1. This excel file is used to show the shape of age-based selectivity arising from option 17 given user-selected parameter values
         2. Users should only change entries in the yellow box.
         3. The red box is the maximum cumulative value, which is subtracted from all cumulative values. This is then exponentiated to yield the estimated selectivity curve. Positive values yield increasing selectivity and negative values yield decreasing selectivity.
      4. PRIOR-TESTER.XLS:
         1. The ’compare’ tab of this spreadsheet shows how the various options for defining parameter priors work
      5. SS-Control\_Setup.XLS:
         1. Shows how to setup an example control file for SS
      6. SS-Data\_Input.XLS:
         1. Shows how to setup an example data input for SS
      7. Growth.XLS:
         1. Excel file to test parameterization between the growth curve options within SS.
         2. Instructions are noted in the XLS file but, to summarize
            1. Users should only change entries in a yellow box.
            2. Entries in a red box are used internally, and can be compared with other parameterizations, but should not be changed.
         3. The SS-VB is identical to the standard VB, but uses a parameterization where length is estimated at pre-defined ages, rather than A=0 and A=Inf. The Schnute- Richards is identical to the Richards-Maunder, but similarly uses the parameterization with length at pre-defined ages. The Richards coefficient controls curvature, and

if the curvature coefficient = 1, it reverts to the standard VB curve.

* + 1. Movement.XLS:
       1. Excel file to explore SS movement parameterization

1. **Starting SS**

SS runs as a DOS program with text-based input. The executable is named ss3.exe. It can be run at the command prompt in a DOS window, or called from another program, such as R or the SS-GUI or a DOS batch file. See the section in this manual on use of batch file which can allow ss3.exe to reside in a separate directory. Sometimes you may receive a version of SS with array checking turned on (SS-safe.exe) or without array checking SS\_opt.exe. In this case, it is recommended to rename the one you are planning to use to SS3.exe before running it. Communication with the program is through text files. When the program first starts, it reads the file STARTER.SS, which must be located in the same directory from which SS is being run. The file STARTER.SS contains required input information plus references to other required input files, as described in the File Organization section. Output from SS is as text files containing specific keywords. Output processing programs, such as the SS GUI, Excel, or R can search for these keywords and parse the specific information located below that keyword in the text file.

1. **Computer Requirements and Recommendations**

SS is compiled to run under DOS with a 32-bit or 64-bit Windows operating system. It is recommended that the computer have at least a 2.0 Ghz processor and 2 GB of RAM. In addition SS has now been successfully compiled in Linux.

1. **Starter**

SS begins by reading the file starter.ss. Its format and content is as follows. Note that the term COND in the Typical Value column means that the existence of input shown there is

conditional on a value specified earlier in the file. Omit or comment out these entries if the appropriate condition has not been selected.

STARTER.SS

**Typical Value Options Description**

#C this is a starter comment

Must begin with #C then rest of the line is free form

All lines in this file beginning with #C will be retained and written to the top of several output files

data\_file.dat data\_file.dat File name of the data file

control\_file.ctl control\_file.ctl File name of the control file

0 Initial Parameter Values: Don’t use this if there have been any changes to the control

0=use values in control file;

1=use ss3.par after reading setup in the control file

file that would alter the number or order of parameters stored

in the SS3.par file. Values in SS3.par can be edited, carefully.

1 Run display detail: With option 2, the display shows value of each logL

0=none other than ADMB outputs; 1=one brief line of display for each iteration;

2=fuller display per iteration

component for each iteration and it displays where crash

penalties are created

1 Detailed age-structure report Detailed age-structured report in REPORT.SSO. 0 = omit catch-at-age for each fleet and

cohort

1 = include all output

0 Check-up This output is largely unformatted and undocumented and is

0 = omit

1 = write detailed intermediate calculations to ECHOINPUT.SSO during first call

mostly used by the developer.

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**Typical Value Options Description**

0 Parameter Trace This controls the output to PARMTRACE.SSO. The contents

0 = omit

1 = write good iteration and active parms

2 = write good iterations and all parms 3 = write every iteration and all parms

4 = write every iteration and active parms

of this output can be used to determine which values are

changing when a model approaches a crash condition. It also can be used to investigate patterns of parameter changes as model convergence slowly moves along a ridge.

1 Cumulative Report Controls reporting to the file CUMREPORT.SSO. This

0 = omit

1 = brief

2 = full

cumulative report is most useful when accumulating

summary information from likelihood profiles or when simply accumulating a record of all model runs within the current subdirectory

1 Full Priors Turning on this option causes all prior values to be calculated.

0 = only calculate priors for active parameters

1 = calculate priors for all parameters that have a defined prior

With this option off, the total logL, which includes the

logL for priors, would change between model phases as more parameters became active.

1 Soft Bounds This option creates a weak symmetric beta penalty for

0 = omit

1 = use

the selectivity parameters. This becomes important when

estimating selectivity functions in which the values of some parameters cause other parameters to have negligible gradients, or when bounds have been set too widely such that a parameter drifts into a region in which it has negligible gradient. The soft bound creates a weak penalty to move parameters away from the bounds.

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**Typical Value Options Description**

1 Data File Output All output files are sequentially output to DATA.SS\_new

0 = none

1 = output an annotated replicate of the input data file

2 = add a second data file containing the model’s expected values with no added error

3+ = add N-2 parametric bootstrap data files

and will need to be parsed by the user into separate data

files. The output of the input data file makes no changes, so retains the order of the original file. Output files 2-N contain only observations that have not been excluded through use of the negative year denotation, and the order of these output observations is as processed by the model. The N obs values are adjusted accordingly. At this time, the tag recapture data is not output to DATA.SS\_new.

8 Turn off estimation The 0 option is useful for (1) quickly reading in a messy set of

-1 = exit after reading input files

0 = exit after one call to the calculation routines and production of SSO and SS\_New files

<positive value> = exit after completing this phase

input files and producing the annotated CONTROL.SS\_new and DATA.SS\_new files, or (2) examining model output based solely on input parameter values. Similarly, the value option allows examination of model output after completing a specified phase. Also see usage note for restarting from a specified phase.

10 MCMC burn interval Need to document this and set good default

2 MCMC thin interval Need to document this and set good default

0.0 Jitter The jitter factor is multiplied by a random normal deviation

A positive value here will add a small random jitter to the initial parameter values

rdev = N(0,1) to a transformed parameter value based

upon the predefined parameter bounds. [*click here for more*](#_bookmark11)[*information*](#_bookmark11)

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-1 SD Report Start

-1 = begin annual SD report in start year

<year> = begin SD report this year

**Typical Value Options Description**

-1 SD Report End

-1 = end annual SD report in end year

-2 = end annual SD report in last forecast year

<value> = end SD report in this year

2 Extra SD Report Years In a long time series application, the model variance

0 = none

<value> = number of years to read

COND: If Extra SD report years > 0

calculations will be smaller and faster if not all years are

included in the SD reporting. For example, the annual SD reporting could start in 1960 and the extra option could select reporting in each decade before then.

1940 1950 Vector of years for additional SD reporting

0.0001 Final convergence This is a reasonable default value for the change in logL

denoting convergence. For applications with much data and thus a large total logL value, a larger convergence criterion may still provide acceptable convergence

0 Retrospective year Adjusts the model end year and disregards data after this

0 = none

-x = retrospective year relative to end year

year. May not handle time varying parameters completely.

0 Summary biomass min age Minimum integer age for inclusion in the summary biomass

used for reporting and for calculation of total exploitation rate

1 Depletion basis Selects the basis for the denominator when calculating degree

0 = skip

1 = X\*B0

2 = X\*BMSY

3 = X\*Bstyr

of depletion in SSB. The calculated values are reported to the

SD report.

0.40 Fraction (X) for depletion denominator So would calculate the ratio of SSBy/(0.40\*SSB0)

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**Typical Value Options Description**

1 SPR report basis SPR is the equilibrium SSB per recruit that would result

0 = skip

1 = use 1-SPRTARGET

2 = use 1-SPR at MSY

3 = use 1-SPR at BTARGET

4 = no denominator, so report actual 1-SPR values

from the current year’s pattern and intensity of F’s. The

SPR approach to measuring fishing intensity was implemented because the concept of a single annual F does not exist in SS. The quantities identified by 1, 2, and 3 here are all calculated in the benchmarks section. Then the one specified here is used as the selected denominator in a ratio with the annual value of (1.0 – SPR). This ratio (and its variance) is reported to the SD report output for the years selected above in the SD report year selection.

4 F std report value In addition to SPR, an additional proxy for annual F can

0 = skip

10

1 = exploitation rate in biomass 2 = exploitation rate in numbers 3 = sum(full F’s by fleet)

4 = population F for range of ages

be specified here. As with SPR, the selected quantity will

be calculated annually and in the benchmarks section. The ratio of the annual value to the selected (see F report basis below) benchmark value is reported to the SD report vector. Options 1 and 2 use total catch for the year and summary abundance at the beginning of the year, so combines seasons and areas. But if most catch occurs in one area and there is little movement between areas, this ratio is not informative about the F in the area where the catch is occurring. Option 3 is a simple sum of the full F’s by fleet, so may provide non-intuitive results when there are multi areas or seasons or when the selectivities by fleet do not have good overlap in age. Option 4 is a real annual F calculated as a numbers weighted F for a specified range of ages (read below). The F is calculated as Z-M where Z and M are each calculated an ln(N(t+1)/N(t)) with and without F active, respectively. The numbers are summed over all biology morphs and all areas for the beginning of the year, so subsumes any seasonal pattern.

**Typical Value Options Description**

COND: If F std reporting = 4 Specify range of ages. Upper age must be less than maxage

13 17 Age range if F std reporting = 4

because of incomplete handling of the accumulator age for

this calculation.

1 F report basis Selects the denominator to use when reporting the F std

0 = not relative, report raw values

1 = use F std value corresponding to SPRTARGET

2 = use F std value corresponding to FMSY

3 = use F std value corresponding to FBTARGET

999 999: Indicates that the control and data file are in a previous SS 3.24 version and will be converted to the new formatting in the control.ss\_new and data.ss\_new files. 3.3: Indicates that the control and data files are currently in SS3.30 format.

report values. Note that order of these options differs from

the biomass report basis options.

SSv3.30 will create converted files in the new format from previous version when 999 is given. All ss\_new files are in the 3.30 format, so starter.ss\_new has 3.30 on the last line. Some Mgparms are in new sequence, so 3.30 cannot read a ss3.par file produced by version 3.24 and earlier.

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End of Starter File

**6.1 Jitter**

The jitter factor is multiplied by a random normal deviation rdev = N(0,1) to a transformed parameter value based upon the predefined parameter bounds:

1 *PM AX − PM I N* + 0*.*0000002

*temp* = *−* 2 *rdev × jitter × ln*( *P*

*V AL −*

*PMIN*

+ 0*.*0000001 *−* 1) (1)

with the final jittered starting parameter value backtransformed as:

*PM AX − PM I N*

1. **Forecast**

*PNEW* = *PMIN* +

(2)

1 + *e−*2*×temp*

The specification of options for forecasts is contained in the mandatory input file named FORECAST.SS. For additional detail on the forecast file see Appendix B.

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FORECAST.SS

**Description**

|  |  |  |
| --- | --- | --- |
| **Typical Value** | **Options** |  |
| 1 | Benchmarks/Reference Points |  |
|  | 0 = omit |  |
|  | 1 = calculate F\_spr, F\_btgt, F\_msy | and |

SS checks for consistency of the Forecast specification and the benchmark specification. It will turn benchmarks on if necessary and report a warning.

1 Forecast Method Specifies whether or not to do a forecast and which F to use

1 = F(SPR)

2 = F(MSY)

3 = F(Btarget) 4 = F(end year)

5 = Average recent F(enter years) - not yet implemented

6 = read Fmult - not yet implemented COND: 0-4 No additional input for these options COND: 5

for that forecast.Basis for some additional conditional input.

COND: 6

-4 First year for recent average F relative to the end year.

0 Last year for recent average F.

0.6 F multiplier for option 6 (not yet implemented).

Read a range of years for calculation of recent average F (not yet implemented). Will be used to calculate an average F multiplier for each fleet over a range of years.

13

0.45 SPRTARGET SS searches for F multiplier that will produce this level of spawning biomass (Reproductive output) per recruit relative to unfished value.

**Typical Value Options Description**

0.40 Relative Biomass Target SS searches for F multiplier that will produce this level of

spawning biomass relative to unfished value. This is not “per recruit” and takes into account the Spawner-Recruitment relationship.

0 0 0 0 0 0 Benchmark Years Requires 6 values, beginning and ending years for biology,

beg. bio; end bio; beg. selex; end selex; beg relF; end relF;

>0 = absolute year

<= 0 = year relative to end year

selectivity, and relative Fs, that will be used in to calculate

benchmark quantities

1. Benchmark Relative F Basis Does not affect year range for selectivity and biology. 1 = use year range

2 = set range for relF same as forecast below

1. Forecast This input is ignored in benchmarks are turned off, but

0 = none (no forecast years) 1 = set to F(SPR)

2 = search for F(MSY) 3 = set to F(BTGT)

4 = set to average F scalar for the forecast relative F years below

5 = input annual F scalar

its existence is not conditional on benchmark switch. If

Benchmarks are on, then FSPR and FBTGT are calculated. This MSY switch determines whether FMSY is also calculated or is set to one of these other quantities.

10 N forecast years (must be >= 1) At least one forecast year now required which differs from

14

version 3.24 that allowed zero forecast years.

1 F scalar Only used if Forecast option = 5 (input annual F scalar).

**Typical Value Options Description**

0 0 0 0 Forecast Years Requires 4 values: beginning and ending years for selectivity

Begin selex; end selex; begin relative F; end relative F

>0 = absolute year

<= 0 = year relative to end year

and relative Fs that will be used in population forecasts.

Option to enter the actual year or values of 0 or negative integer values that will set the value to the model ending year.

1 Control Rule

1 = catch = F(SSB) U.S. West Coast 2 = F = F(SSB)

0.40 Control Rule Upper Limit Biomass level (as a fraction of SB0) above which F is constant.

0.10 Control Rule Lower Limit Biomass level (as a fraction of SB0) above which F is set to 0.

0.75 Control Rule Buffer Multiplier applied to forecast F before calculating catch.

3 Number of forecast loops (1,2,3) Maximum number of forecast loops: 1=OFL only, 2=ABC

control rule, 3=set catches equal to control rule or input catch and redo forecast implementation error.

3 First forecast loop with stochastic recruitment

If this is set to 1 or 2, then OFL and ABC will be as if there was perfect knowledge about recruitment deviations in the future.

0 Forecast loop control #3 Reserved for future model features.

0 Forecast loop control #4 Reserved for future model features.

0 Forecast loop control #5 Reserved for future model features. 2015 First year for caps and allocations Should be after years with fixed inputs.

0 Implementation Error The standard deviation of the log of the ratio between the

0 Rebuilder

0 = omit West Coast rebuilder output 1 = do rebuilder output

realized catch and the target catch in the forecast. (set value

> 0.0 to cause active implementation error).

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|  |  |  |
| --- | --- | --- |
| **Typical Value** | **Options** | **Description** |
| 2004 | Rebuilder catch (Year Declared) |  |
|  | >0 = year first catch should be set to zero |  |
|  | -1 = set to 1999 |  |
| 2004 | Rebuilder start year (Year Initial) |  |
|  | >0 = year for current age structure |  |
|  | -1 = set to end year +1 |  |
| 1 | Fleet Relative F |  |
|  | 1 = use first-last allocation year |  |
|  | 2 = read season(row) x fleet (column) set below |  |
| 2 | Basis for maximum forecast catch |  |
|  | 2 = cap in terms of total catch biomass |  |
|  | 3 = cap in terms of retained catch biomass |  |
|  | 5 = cap in terms of total catch numbers |  |
|  | 6 = cap in terms of retained total numbers |  |

COND: 2 (Conditional input for fleet relative F)

1. 0.8 0.1 Fleet allocation by relative F fraction The fraction of the forecast F value. For a multiple area

model user must define a fraction for each fleet and each area. The total fractions must sum to one over all fleets and areas. Starting in version 3.3 this now also includes surveys which are treated similar to fleets. Ex:

# Fleet 1 Fleet 2 Survey X 0.10 0.10 0.30 # Area1

0.10 0.10 0.30 # Area2

**Typical Value Options Description**

-1 -1 -1 Maximum total catch by fleet Must enter value for each fleet. Starting in version 3.3 this

-1 = no maximum

now also includes surveys which are treated similar to fleets.

-1 Maximum total catch by area Must enter value for each area. Starting in version 3.3 this

-1 = no maximum

now also includes surveys which are treated similar to fleets.

0 0 0 Fleet assignment to allocation group Enter group ID # for each fleet. Starting in version 3.3 this

COND: >0

0 = Fleet not included in allocation group

now also includes surveys which are treated similar to fleets.

1. 0.3 0.5 Allocation to each group for each year of the forecast

For each year of the forecast, enter the allocation fraction to each group. Annual values are rescaled to sum to 1.0. Protocol for entering year-specifc info will be changing

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0 Forecast catch levels Number of forecast catch levels to input, else calculated from

the forecast F.

3 Basis for forecast catch 2 = Dead catch

3 = Retained catch

99 = Input harvest rate (F)

COND: >0 Forecasted catches - enter one line per number of fixed forecast year catch 2012 1 1 1200 Year Season Fleet Catch (of F value)

999 End of Input

End of Forecast File

1. **Optional Inputs**

**8.1 Empirical Weight-at-Age (wtatage.ss)**

With version 3.04, SS adds the capability to read empirical body weight at age for the population and each fleet, in lieu of generating these weights internally from the growth parameters, weight-at-length, and size-selectivity. Selection of this option is done by setting Maturity\_Option equal to 5. The values are read from a separate file named, wtatage.ss. This file is only required to exist if this option is selected.

The format of this input file is: *#* syntax for optional input file: wtatage.ss

10 # Number of rows

40 # Number of ages (equal to Maximum Age)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| #Year | Season | Gender | GP | Birth Season | Fleet | Age-0 | Age-1 | ... |
| 1971 | 1 | 1 | 1 | 1 | 1 | 0.0128586 | 0.13718 | 0.432243 |
| 1971 | 1 | 1 | 1 | 1 | 2 | ... | ... | ... |
| 1971 | 1 | 1 | 1 | 1 | 0 | ... | ... | ... |

where:

* Fleet = -2 is age-specific fecundity\*maturity, so time-varying fecundity is possible to implement
* Fleet = -1 is population wt-at-age at middle of the season
* Fleet = 0 is population wt-at-age at the beginning of the season
* There must be an entry for each fleet for fecundity\*maturity, wt-at-age at the middle of the season, and wt-at-age at the beginning of the season.
* GP and birthseas probably will never be used, but are included for completeness
* A negative value for year will fill the table from that year through the ending year of the forecast, overwriting anything that has already been read for those years.
* Judicious use of negative years in the right order will allow user to enter blocks without having to enter a row of info for each year
* N ages here equal to maxage specified with the data file, , and N ages +1 columns are required because of age 0 fish.
* If N ages in this table is greater than Maxage in the model, the extra wt-at-age values are ignored.
* If N ages in this table is less than Maxage in the model, the wt-at-age for N ages is filled in for all unread ages out to Maxage.
* There is no internal error checking to verify that weight-at-age has been read for every

fleet and every year.

* Fleets that do not use biomass do not need to have wt-at-age assigned
* The values entered for endyr+1 will be used for the benchmark calculations and for the forecast; this aspect needs a bit more checking

CAVEATS:

* SS will still calculate growth curves from the input parameters and can still calculate size-selectivity and can still examine size composition data.
* However, there is no calculation of wt-at-age from the growth input, so no way to compare the input wt-at-age from the wt-at-age derived from the growth parameters.
* If wt-at-age is read and size-selectivity is used, a warning is generated
* If wt-at-age is read and discard/retention is invoked, then a BEWARE warning is generated because of untested consequences for the body wt of discarded fish.
* Warning: age 0 fish seem to need to have weight=0 for spawning biomass calculation (code -2).

TESTING:

* A model was setup with age-maturity (option 2) and only age selectivity.
* The output calculation of wt-at-age and fecundity-at-age was taken from report.sso and put into wtatage.ss (as shown above).
* Re-running SS with this input wt-at-age (Maturity\_Option 5) produced identical results to the run that had generated the weight-at-age from the growth parameters.
  1. **runnumbers.ss**

This file contains a single integer value. It is read when the program starts, incremented by 1, used when processing the profile value inputs (see below), used as an identifier in the batch output, then saved with the incremented value. Note that this incrementation may not occur if a run crashes.

* 1. **profilevalues.ss**

This file contains information for changing the value of selected parameters for each run in a batch. In the ctl file, each parameter that will be subject to modification by profilevalues.ss is designated by setting its phase to –9999 .

The first value in profilevalues.ss is the number of parameters to be batched. This value MUST match the number of parameters with phase set equal to -9999 in the ctl file. The program performs no checks for this equality. If the value is zero in the first field, then nothing else will be read. Otherwise, the model will read runnumber \* Nparameters values and use the last Nparameters of these to replace the initial values of parameters designated with phase = –9999 in the ctl file.

USAGE Note: If one of the batch runs crashes before saving the updated value of runnumber.ss, then the processing of the profilevalue.ss will not proceed as expected. Check the output carefully until a more robust procedure is developed.

1. **Data File**
   1. **Overview of Data File**
      1. Dimensions (years, ages, N fleets, N surveys, etc.)
      2. Fleet and survey names, timing, etc.
      3. Catch biomass
      4. Discard
      5. Mean body weight
      6. Length composition set-up
      7. Length composition
      8. Age composition set-up
      9. Age imprecision definitions
      10. Age composition
      11. Mean length of bodyweight-at-age
      12. Generalized size composition (e.g. weight frequency)
      13. Tag-recapture
      14. Stock composition
      15. Environmental data
   2. **Units of Measure**

The normal units of measure are as follows:

* Catch biomass – metric tons
* Body weight – kilograms
* Body length – usually in cm, weight at length parameters must correspond to the units of body length and body weight.
* Survey abundance – any units if q is freely scaled; metric tons or thousands of fish if q has a quantitative interpretation
* Output biomass – metric tons
* Numbers – thousands of fish, because catch is in mtons and body weight is in kg
* Spawning biomass – metric tons of mature females if eggs/kg = 1 for all weights; otherwise has units that are proportional to egg production
  1. **Time Units**

Year

* Spawning is restricted to happening once per year at a specified time of year (in real months).
* Time-varying parameters are allowed to change annually.
* Rates like growth and mortality are per year.
* All fish advance to the next older integer age on January 1, no matter when they were born during the year

Seasons

* Seasons are the time step during which constant rates apply
* Seasons are the time step for which catch and discard is input and for which F is calculated
* The year can have just 1 annual season, or be subdivided into seasons of unequal length.
* Season duration is input in real months and is converted into fractions of an annum. Annual rate values are multiplied by the per annum season duration.
* If the sum of the input season durations is not close to 12.0, then the input durations is divided by 12. This allows for a special situation in which the year could be only

0.25 in duration (e.g. seasons as years) so that spawning and time-varying parameters can occur more frequently.

* 1. **Data File Syntax**
     1. **Model Dimensions**

**Typical Value Description**

#C data using new survey

Data file comment. Must start with #C to be retained then written to top of various output files. These comments can occur anywhere in the data file, but must have #C in columns 1-2.

1971 Start year

2001 End year

1 Number of seasons per year

12 Vector with N months in each season. These do not need to be integers. Note: If the sum of this vector is close to 12.0, then it is rescaled to sum to 1.0 so that season duration is a fraction of a year. But if the sum is not close to 12.0, then the entered values are simply divided by 12. So with one season per year and 3 months per season, the calculated season duration will be 0.25, which allows a quarterly model to be run as if quarters are years. All rates in SS are now calculated in v3.3 by season (growth, mortality, etc.).

2 The number of subseasons. Entry must be even and the minimum

value is 2. This is for the purpose of finer temporal granularity in calculating and using the length-at-age.

1. Spawning month; spawning biomass is calculated at this time of

year and used as basis for the total recruitment of all settlement events resulting from this spawning.

1. Number of genders

20 Number of ages. The value here will be the plus-group age. SS start age 0.

1. Number of areas
   * 1. **Fleet Definitions**

The catch data input has been modified to improve the user flexibility to add/subtract fishing and survey fleets to a model set-up. The fleet setup input is transposed so each fleet is now a row. Previous versions (3.24 and earlier) required that fishing fleets be listed first followed by survey only fleets. In version 3.30 all fleets now have the same status within the model structure and each has a specified fleet type. Available types are: catch fleet, bycatch only, or survey.

Inputs that define the fishing and survey fleets:

1. #Number of fleets which includes survey in any order

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| #Fleet | Timing | Area | Catch | Eq. Catch | Catch | Catch | Fleet |
| Type |  |  | Units | SE | SE | Mult. | Name |
| 1 | -1 | 1 | 1 | 0.01 | 0.01 | 0 | FISHERY1 |
| 1 | -1 | 1 | 2 | 0.01 | 0.01 | 0 | SURVEY1 |

**Fleet Type**

* + 1 = fleet with input retained catch
  + 2 = bycatch fleet
  + 3 = survey
  + 4 = ignored (not yet implemented)

**Timing**

Carryover from 3.24 approach, now superseded by real month input for data observations.

* + 0.50 = now ignored in v3.30
  + -1 = treat as catch from whole season

**Area**

An integer value indicating the area in which a fleet operates.

**Catch Units**

Ignored for survey fleets.

**Equil. Catch SE**

Standard error of the initial equilibrium catch.

**Catch SE**

Standard error of retained catch; ignored for survey fleets and bycatch fleets and with Pope’s F method.

**Catch Multiplier**

Invokes use of a catch multiplier, which is then entered as a parameter in the MG parameter section. The estimated value or fixed value of the catch multiplier is multiplied by the estimated catch before being compared to the observed catch.

* + 0 = no catch multiplier used
  + 1 = Apply a catch multiplier which is defined as an estimatable parameter in the control file after the cohort growth deviation in the biology parameter section. The model’s estimated retained catch will be multiplied by this factor before being compared to the observed retained catch.

After reading the fleet-specific indicators, a list of catch values by fleet and season are read in by the model. The format for the catches is year, season that the catch will be attributed to, fleet, a catch value, and a year specific catch standard error. To include an equilibrium catch value the year should be noted as -999 and be included as the first entry for the associated fleet. There is no longer a need to specify the number of catch records to be read; instead the list is terminated by entering a record with the value of -9999 in the year field. Additionally, initial equilibrium catch is now season specific and can be specified using -999 in the year column.

In addition, it is possible to collapse the number of seasons. So if a season value is greater than the N seasons for a particular model, that catch is added to the catch for N seasons. This is generally to collapse a seasonal model into an annual model. In a seasonal model, use of season=0 will cause SS to distribute the input value of catch equally among the N seasons.

If a bycatch fleet is included the continuous F method must be selected (F\_method = 2) and are excluded from the catch log-likelihood. Bycatch fleets have selectivity and retention functions, so even though they are considered to have unknown catch levels, this does not mena that their calculated retained catch is zero. MSY and yield per recruit are calculated in terms of dead catch, and they currently include catch from bycatch fleets. The F for bycatch only fleets is kept constant in benchmark and forecast calculations, so it is not included in any forecast cap and allocation calculations. It is not part of the acceptable biological catch, but it is still calculated and reported.

* + 1. **Catch**

The new format for version 3.30 for a 2 season model with 2 fisheries looks like the table below. The example is sorted by fleet, but the sort order does not matter. In data.ss\_new, the sort order is fleet, year, season.

#Catches by year, season for every fleet:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # Year | Season | Fleet | Catches | Catch SE |
| -999 | 1 | 1 | 56 | 0.05 |
| -999 | 2 | 1 | 62 | 0.05 |
| 1975 | 1 | 1 | 876 | 0.05 |
| 1975 | 2 | 1 | 343 | 0.05 |
| ... | ... | ... | ... | ... |
| -999 | 1 | 2 | 55 | 0.05 |
| -999 | 2 | 2 | 22 | 0.05 |
| 1975 | 1 | 2 | 555 | 0.05 |
| 1975 | 2 | 2 | 873 | 0.05 |
| ... | ... | ... | ... | ... |
| -9999 | 0 | 0 | 0 | 0.05 |

* + - * Catch can be in terms of biomass or numbers for each fleet.
      * Catch is retained catch. If there is discard also, then it is handled in the discard section

below.

* + - * If there is reason to believe that the retained catch values underestimate the true catch, then it is possible in the retention parameter set up to create the ability for the model to estimate the degree of unrecorded catch. However, this is better handled with the new catch multiplier option.

If a bycatch fleet is used, continuous F (F\_method 2) must be used and are excluded from the catch log likelihood. Bycatch fleets have selectivity and retention functions, so even though they are considered to have unknown catch levels, this does not mean that their retained catch is zero. SS v3.30 will later add the option for bycatch fleets to have retained and discarded catch calculated or have all their catch be assigned to discard. MSY and yield per recruit are calculated in terms of dead catch, and currently include catch from bycatch fleets. Future bycatch fleet options will address this.

* + 1. **Abundance Indices**

For fishing fleets, catch-per-unit-effor (CPUE) is defined in terms of retained catch (biomass or numbers). For fishery independent surveys, retention/discard is not defined so CPUE is implicitly in terms of total CPUE. If a survey has its selectivity mirrored to that of a fishery, only the selectivity is mirrored so the expected CPUE for this mirrored survey is in terms of total catch. Also, fishing effort is related to F, which is the F for total catch.

If the statistical analysis used to create the CPUE index of a fishery has been conducted in such a way that its inherent size/age selectivity differs from the size/age selectivity estimated from the fishery’s size and age composition, then you may want to enter the CPUE as if it was a separate survey and with a selectivity that differs from the fishery’s estimated selectivity. The need for this split arises because the fishery size and age composition should be derived through a catch-weighted approach (to appropriately represent the removals by the fishery) and the CPUE should be derived through an area-weighted GLM (to appropriately serve as if it was a survey of stock abundance.

If the fishery or survey has time-varying selectivity, then this changing selectivity will be taken into account when calculating expected values for the CPUE or survey index.

#CPUE and Suvey Abundance Observations:

#Fleet/Survey Units #Error Distribution

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | 1 | 0 |  | |
| 2  ... | 1  ... | 0  ... |
| #Year | Month | Fleet/Survey | Observation | SE of log(value) |
| 1991 | 7 | 3 | 80000 | 0.056 |
| 1995  ... 2000 | 7.2  ... 7.1 | 3  ... 3 | 65000  ... 42000 | 0.056  ... 0.056 |

**Units**

NOTE: the “effort” option can only be used for a fishing fleet and not for a survey, even if the survey is mirrored to a fishing fleet. The values of these effort data are interpreted as proportional to the level of the fishery F values. No adjustment is made for differentiating between continuous F values versus exploitation rate values coming from Pope’s approximation. A normal error structure is recommended so that the input effort data are compared directly to the model’s calculated F, rather than to loge(F). The resultant proportionality constant has units of 1/Q.

**Error Distribution**

* + - * -1 = normal error
      * 0 = lognormal error
      * >0 = Student’s t-distribution in log space with degrees of freedom equal to this value. For DF>30, results will be nearly identical to that for lognormal distribution. A DF value of about 4 gives a fat-tail to the distribution (see Chen (2003)). The se values entered in the data file must be the standard error in loge space.

Abundance indices typically have a lognormal error structure with units of standard error of loge(index). If the variance of the observations is available only as a CV, then the value

of se can be approximated as p(*log*e(1 + (*CV* )2)) where CV is the standard error of the

observation divided by the mean value of the observation.

For the normal error structure, the entered values for se are interpreted directly as a se in arithmetic space and not as a CV. Thus switching from a lognormal to a normal error structure forces the user to provide different values for the se input in the data file.

If the data exist as a set of normalized Z-scores, you can either: assert a lognormal error structure after entering the data as exp(Z-score) because it will be logged by SS. Preferably, the Z-scores would be entered directly and the normal error structure would be used.

**Data Format**

* + - * Year values that are before start year or after end year are excluded from model, so the easiest way to include provisional data in a data file is to put a negative sign on its year value.
      * Duplicate survey observations are not allowed.
      * Observations can be entered in any order, except if the super-year feature is used.
      * Observations that are to be included in the model but not included in the –logL need to have a negative sign on their fleet ID. Previously the code for not using observations was to enter the observation itself as a negative value. However, that old approach prevented use of a Z-score environmental index as a “survey”.
      * Super-periods are turned on and then turned back off again by putting a negative

sign on the season. Previously, super-periods were started and stopped by entering

-9999 and the -9998 in the se field. See the “Data Super-Period” section of this manual for more information.

**Special Surveys**

Four special kinds of surveys are defined in SS. Here in the survey data section, there is no change in the way in which these survey data are entered. Then in the size-selectivity section of the control file, the selectivity pattern used to generate expected values for these surveys is specified by entering the selectivity pattern as 30, 31, 32, or 33. These four survey “selectivity” pattern options bypass the calculation of survey selectivity from explicit selectivity parameters.

* + - * 30 = spawning biomass (e.g. for an egg and larvae survey)
      * 31 = exp(recruitment deviation), useful for environmental index affecting recruitment
      * 32 = spawning biomass \* exp(recruitment deviation), for a pre-recruit survey occurring before density-dependence
      * 33 = recruitment, age-0 recruits
    1. **Discard**

If discard is not a feature of the model specification, then just a single input is needed:

#Input Description

0 #Number of fleets with discard observations

If discard is being used, the input syntax is:

#Input Description

1. #Number of fleets with discard observations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| #Fleet | Units | Error |  | |
| 1 | 2 | -1 |
| 3  #Year | 2  Season | -1  Fleet | Observation | Error |
| 1980 | 1 | 1 | 0.05 | 0.25 |
| 1991 | 1 | 1 | 0.10 | 0.25 |
| -9999 | 0 | 0 | 0 | 0 |

**Discard Units**

* + 1 = values are amount of discard in either biomass or numbers according to the selection made for retained catch
  + 2 = values are fraction (in biomass or numbers) of total catch discarded; bio/num

selection matches that of retained catch

* + 3 = values are in numbers (thousands) of fish discarded, even if retained catch has units of biomass

**Discard Error Structure**

The four options for discard error are:

* + >= 1 = degrees of freedom for Student’s t-distribution used to scale mean body weight deviations. Value of error in data file in interpreted as CV of the observation.
  + 0 = normal distribution, value of error in data file in interpreted as CV of the observation
  + -1 = normal distribution, value of error in data file is interpreted as standard error of the observation
  + -2 = lognormal distribution, value of error in data file is interpreted as standard error of the observation in log space

**Data Format**

* + Since discard refers to catch, its time units are in seasons, not months.
  + Year values that are before start year or after end year are excluded from model, so the easiest way to include provisional data in a data file is to put a negative sign on its year value.
  + Negative value for fleet causes it to be included in the calculation of expected values, but excluded from the log likelihood.
  + Zero (0.0) is a legitimate discard observation, unless lognormal error structure is used.
  + Duplicate survey observations are not allowed.
  + Observations can be entered in any order, except if the super-period feature is used.

**Cautionary Note**

The use of CV as the measure of variance can cause a small discard value to appear to be overly precise, even with the minimum standard error (std. err.) of the discard observation set to 0.001. In the control file, there is an option to add an extra amount of variance. This amount is added to the standard error, not to the CV, to help correct this problem of underestimated variance.

* + 1. **Mean Body Weight**

This is the overall mean body weight across all selected sizes and ages. This may be useful in situations where individual fish are not measured but mean weight is obtained by counting

the number of fish in a specified sample, e.g. a 25 kg basket. Version 3.24r added the capability to use mean length data by modifying the mean weight data approach. Now observations can be entered in terms of mean length by setting switching the partition code to 10=all, 11=discard, and 12=retained rather than the 0, 1, and 2 typically used with the mean body weight approach.

#Mean Body Weight Data Section

#Degrees of freedom for Student’s t-distribution used to

evaluate mean body weight deviation. This is not a

30 conditional input, must be here even if there are no mean

body weight observations.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| #Year | Month | Fleet | Partition | Value | CV |
| 1990 | 1 | 1 | 0 | 4.0 | 0.95 |
| 1990 | 1 | 1 | 0 | 1.0 | 0.95 |
| -9999 | 0 | 0 | 0 | 0 | 0 |

**Partition**

Mean weight data and composition data require specification of what group the sample originated from (e.g. discard, retained, discard + retained).

* 0 = whole catch in units of weight (discard + retained)
* 1 = discarded catch in units of weight
* 2 = retained catch in units of weight
* 10 = whole catch in units of length (discard + retained)
* 11 = discarded catch in units of weight
* 12 retained catch in units of length

**Value - Units**

Units must correspond to the units of body weight (or mean length in cm), normally in kilograms. The expected value of mean body weight (or mean length) is calculated in a way that incorporates effect of selectivity and retention.

**Error**

Error is entered as the CV of the observed mean body weight (or mean length)

* + 1. **Population Length Bins**

The beginning of the length composition section sets up the bin structure for both the population and for the length composition data.

1 1 = use data bins Length bin method - creates a conditional

2 = generate from bin width min max below

3 = read vector

read situation below.

COND = 1 Selects option 1, no additional input necessary COND = 2 Selects option 2, read 3 additional input values.

2 Bin width

10 Lower size of first bin

82 Lower size of largest bin

The number of bins is then calculated from: (max Lread - min Lread)/(bin width) + 1 COND = 3 Selects option 3 - read 1 value and then read vector of bin boundaries

1. Number of population length bins to be read
2. 28 30 ... Vector containing lower edge of each population size bin

End of conditional inputs for length bin method.

**Notes:**

* For option 2, bin width should be a factor of min size and max size. For options 2 and 3, the population length bins must not be wider than the length data bins, but the boundaries of the bins do not have to align. In SS\_v3.02B and earlier, the data boundaries needed to align with the population boundaries but this requirement has been removed. The transition matrix is output to checkup.sso.
* The mean size at age 0.0 (virtual recruitment age) is set equal to the min size of the first population length bin.
* When using more population length bins than data bins, SS will run slower (more calculations to do), the calculated weights at age will be less aliased by the bin structure, and you may or may not get better fits to your data.
* While exploring the performance of models with finer bin structure, a potentially pathological situation has been identified. When the bin structure is coarse (note that some applications have used 10 cm bin widths for the largest fish), it is possible for a selectivity slope parameter or a retention parameter to become so steep that all of the action occurs within the range of a single size bin. In this case, the model will lose the gradient of the log likelihood with respect to that parameter and convergence will be hampered. A generic guidance to avoid this situation is not yet available.

Specify bin compression and error structure for length composition data:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| #Min Tail | Constant | Combine |  | Compress | Error | Dirichlet |  |
| Compression | added to | males | & | Bins | Distribution | Parameter |
|  | proportions | females |  |  |  | Number |
| 0 | 0.0001 | 0 |  | 0 | 0 | 0 | #Fleet 1 |
| 0 | 0.0001 | 0 |  | 0 | 0 | 0 | #Fleet 2 |

**Minimum Tail Compression**

Compress tails of composition until observed proportion is greater than this value; negative value causes no compression; Advise using no compression if data are very sparse, and especially if the set-up is using agecomp within length bins because of the sparseness of these data.

**Added Constant**

Constant added to observed and expected proportions at length and age to make logL calculations more robust. Tail compression occurs before adding this constant. Proportions are renormalized to sum to 1.0 after constant is added.

**Combine Males & Females**

Combine males into females at or below this bin number. This is useful if the gender determination of very small fish is doubtful so allows the small fish to be treated as combined gender. If CombGender>0, then add males into females for bins 1 thru this number, zero out the males, set male data to start at the first bin above this bin. Note that CombGender is entered as a bin index, not as the size associated with that bin. Comparable option is available for age composition data.

**Error Distribution**

* + 0 = Multinomial Error
  + 1 = Dirichlet Error

**Dirichlet Parameter Number**

If the dirichlet error distribution is selected a number of parameters must be specified.

**Notes:**

* The tail compression and added constant are used in the processing of both the length composition and the age composition data. They do not apply to the generalized size composition data.
* If broad length bins are used, then beware of steep selectivity and retention parameters. An overly steep curve can disappear within the domain of a single length bin, thus causing ADMB to lose track of its gradient.
  + The mean weight-at-length, maturity-at-length and size-selectivity are based on

the mid-length of the population bins. So these quantities will be rougher approximations if broad bins are defined.

* + Provide a wide enough range of population size bins so that the mean body weight-at-age will be calculated correctly for the youngest and oldest fish. If the growth curve extends beyond the largest size bin, then these fish will be assigned a length equal to the mid-bin size for the purpose of calculating their body weight.
  + More bins create a bigger model internal structure and slower run times.
  + When fish recruit at age 0.0, they are assigned a size equal to the lower edge of the smallest population size bin.
  + Fish smaller than the first data bin are placed in the first bin.
    1. **Length Composition Data**

30 #Number of length bins for data

26 28 30 ... 88 90 #Vector of length bins associated with the length data

Example of a single length composition observation:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| #Year | Month | Fleet | Gender | Partition | Nsamp | data vector |
| 1986 | 1 | 1 | 3 | 0 | 20 | <female then male data> |
| ... | ... | ... | ... | ... | ... | ... |
| -9999 | 0 | 0 | 0 | 0 | 0 | 0 |

**Gender**

If model has only one gender defined in the set-up, all observations must have gender set equal to 0 or 1. In a 2 gender model, the data vector always has female data followed by male data, even if only one of the two genders has data that will be used.

* Gender = 0 means combined male and female (must already be combined and information placed in the female portion of the data vector) (entries in male portion of vector must exist and will be ignored).
* Gender = 1 means female only (male entries must exist for correct data reading, then will be ignored).
* Gender = 2 means male only (female entries must exist and will be ignored after being read).
* Gender = 3 means both data from both genders will be used and they are scaled so that they together sum to 1.0

**Partition**

Partition indicates samples from either discards,retained, or combined.

* 0 = combined
* 1 = discard
* 3 = retained

**Excluding Data**

* If the value of year is negative, then that observation is not transferred into the working array. This feature is the easiest way to include observations in a data file but not to use them in a particular model scenario.
* If the value of fleet is negative, then the observation is processed and its logL is

calculated, but this logL is not included in the total logL. This feature allows the user to see the fit to a provisional observation without having that observation affect the model.

**Note:**

* Version 3.30 no longer requires that the number of length composition lines to be read be specified. Entering -9999 at the end of the data matrix will indicate to the model the end of length composition lines to be read.
* Each observation can be stored as one row for ease of data management in a

spreadsheet and for sorting of the observations. However, the 6 header values, the female vector and the male vector could each be on a separate line because ADMB reads values consecutively from the input file and will move to the next line as necessary to read additional values.

* The composition observations can be in any order. However, if the super-period

approach is used, then each super-periods’ observations must be contiguous in the data file.

* + 1. **Age Composition Bin Setup**

The age composition section begins by reading a definition of the age bin structure, then the definition of ageing imprecision, then the age composition data itself. The bins are in terms of observed age (here age’). The ageing imprecision definitions are used to create one or more matrices to translate true age structure into expected age structure in terms of age’.

17 #Number of age’ bins;

#can be equal to 0 if age data not used;

#do not include a vector of agebins if Nage’ bins is set equal to 0.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 20 25

Above is the vector with lower age of age’ bins. The first and last bins work as accumulators. So in this example any age 0 fish that are caught would be accumulated into the age’1 bin.

* + 1. **Ageing Error**

Here, the capability to create a distribution of age’ (e.g. age with possible bias and imprecision) from true age is created. One or many age error definitions can be created. For each, there is input of a vector of mean age’ and stddev of age’. For one definition, the input vectors can be replaced by vectors created from estimable parameters. In the future, capability to read a full age’ – age matrix could be created.

2 # Number of ageing error matrices to generate

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # Age-0 | Age-1 | Age-2 | ... | Max Age |
| -1 | -1 | -1 | ... | -1 |
| 0.001 | 0.001 | 0.001 | ... | 0.001 |
| 0.5 | 1.5 | 2.3 | ... | Max Age + 0.5 |
| 0.5 | 0.65 | 0.67 | ... | 4.3 |

The above table shows the values for the first 3 ages for each of two age transition definitions: the first defines a matrix with no bias and negligible imprecision and the second shows a small negative bias beginning at age 2.

**Note:**

* If no age data, there can be 0 vectors.
* In principle, one could have year or laboratory specific matrices.
* For each matrix, enter a vector with mean age’ for each true age; if there is no ageing bias, then set age’ equal to true age + 0.5. Alternatively, -1 value for mean age’ means to set it equal to true age plus 0.5. The addition of +0.5 is needed so that fish will get assigned to the intended interger age’.
* The length of the input vector is Nage+1, with the first entry being for age 0 fish and the last for fish of age Nage. The following line is a a vector with the standard deviation (stddev) of age’ for each true age.
* SS is able to create one ageing error matrix from parameters, rather than from an input vector. The range of conditions in which this new feature will perform well has not been evaluated, so it should be considered as a preliminary implementation and subject to modification.

**–** To invoke this option, for the selected ageing error vector, set the stddev of ageing error to a negative value for age 0. This will cause creation of an ageing error matrix from parameters and any age or size-at-age data that specify use of this age error pattern will use this matrix. Then in the control file, add 7 parameters below the cohort growth dev parameter. These parameters are described in the control file section of this manual.

Specify bin compression and error structure for age composition data:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| #Min Tail | Constant | Combine |  | Compress | Error | Dirichlet |  |
| Compression | added to | males | & | Bins | Distribution | Parameter |
|  | proportions | females |  |  |  | Number |
| 0 | 0.0001 | 1 |  | 0 | 0 | 0 | #Fleet 1 |
| 0 | 0.0001 | 1 |  | 0 | 0 | 0 | #Fleet 2 |
| 0 | 0.0001 | 1 |  | 0 | 0 | 0 | #Survey 2 |

1 Bin method for age data

1 = value refers to population bin index 2 = value refers to data bin index

3 = value is actual length (which must correspond to population length bin boundary)

An example age composition observation:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| #Year | Month | Fleet | Gender | Partition | AgeErr | Lbin lo | Lbin hi | Nsamp | Data Vector |
| 1987 | 1 | 1 | 3 | 0 | 2 | -1 | -1 | 79 | <enter data values> |
| -9999 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Note:** |  |  |  |  |  |  |  |  |  |

* Syntax for Gender, Partition, and data vector are same as for length.
* Ageerr identifies which ageing error matrix to use to generate expected value for this observation.
* The data vector has female values then male values, just as for the length composition data.
* As with the length comp data, a negative value for year causes the observation to not be read into the working matrix, a negative value for fleetcauses the observation to be included in expected values calculation, but not in contribution to total logL.
* Lbin lo, and Lbin hi are the range of length bins that this age composition observation refers to. Normally these are entered with a value of 1 and Maxbin. Whether these are entered as population bin number, length data bin number, or actual length is controlled by the value of the length bin range method above.
  + Entering value of 0 or –1 for Lbin lo converts Lbin lo to 1;
  + Entering value of 0 or -1 for Lbin hi converts Lbin hi to Maxbin;
  + It is strongly advised to use the “-1” codes to select the full size range. If you use explicit values, then the model could unintentionally exclude information from some size range if the population bin structure is changed.
  + In reporting to the comp\_report.sso, the reported Lbin\_lo and Lbin\_hi values are always converted to actual length.
    1. **Conditional Age’-at-Length**

Use of conditional age’-at-length will greatly increase the total number of age’ composition observations and associated model run time, but it is a superior approach for several reasons. First, it avoids double use of fish for both age’ and size information because the age’ information is considered conditional on the length information. Second, it contains more detailed information about the relationship between size and age so provides stronger ability to estimate growth parameters, especially the variance of size-at-age. Lastly, where age data are collected in a length-stratified program, the conditional age’-at-length approach can directly match the protocols of the sampling program.

In a two gender model, it is best to enter these conditional age’-at-length data as single gender observations (gender =1 for females and = 2 for males), rather than as joint gender observations (gender = 3). In this way, it isolates the age composition data from any gender selectivity as well.

When Lbin\_lo and Lbin\_hi are used to select a subset of the total size range, the expected value for these age’ data is calculated within that specified size range, so is age’ conditional on length.

* + 1. **Sex Ratio-at-Length**

The conditional age’-at-length approach can be used to analyze sex ratio-at-length data. If you have no age data, then the following simple setup will allow entry of sex-ratio at length. Note that it must use the joint gender (code 3) approach.

#Example setup for sex ratio-at-length data:

1 #N age bins so all fish are put into a single "age" bind regardless of their true age

10 #Assigned "age" for this one bin

1 #N of age error definitions

10.5 10.5 10.5 10.5 ... repeat for each true age in model, beginning at age-0

* 1. 0.001 0.001 0.001 ... repeat for each true age in model, beginning at age-0

1 # Lbin method: 1 = population length bins, 2 = data length bins, 3 = lengths

0 #Combine males and females at or below this bin number

#There are 4 females and 8 males in the 25th population length bin

#Yr Month Fleet Gender Part AgeErr Lbinlo Lbinhi Nsamp

1971 1 1 3 0 1 25 25 12 0 4 0 0 8 0 ...

-9999

If you have both real age data and sex ratio at length data, then you will need to set up the number of age bins to match the real age data, define an additional age error type to

use for the sex ratio data, put the sex ratio data into the correct bin. For example:

5 #N age bins so all fish are put into a single "age" bind regardless of their true age

1 2 3

4 5

#Assigned "age" for this one bin

2 #N of age error definitions

-1 1 1 1 ... repeat for each true age in model, beginning at age-0

* 1. 0.4 0.5 0.8 ... repeat for each true age in model, beginning at age-0

3.5 3.5 3.5 3.5 ... repeat for each true age in model, beginning at age-0

0.001 0.001 0.001 0.001 ... repeat for each true age in model, beginning at age-0

1 # Lbin method: 1 = population length bins, 2 = data length bins, 3 = lengths

0 #Combine males and females at or below this bin number

#There are 4 females and 8 males in the 25th population length bin

#Yr Month Fleet Gender Part AgeErr Lbinlo Lbinhi Nsamp

1971 1 1 3 0 1 -1 -1 25 1 2 4 ... #real age

data 5

1971 1 1 3 0 1 25 25 12 0 0 4 ... #sex ratio

in bin 3

-9999

### Mean Length or Body Weight-at-Age

SS also accepts input of mean length-at-age’ or mean bodywt-at-age’. This is done in terms of age’, not true age, to take into account the effects of ageing imprecision on expected mean size-at-age’. If the value of “AgeErr” is positive, then the observation is interpreted as mean length-at-age’. If the value of “AgeErr” is negative, then the observation is interpreted as mean bodywt-at-age’ and the abs(AgeErr) is used as AgeErr.

An example observation:

#Yr Month Fleet Gender Part AgeErr Nsamp Female Male

Female Male

Data

Data N N

1989 1 1 3 0 2 999 <Mean <Mean <N <N

size

size

fish>

fish>

-9999

values>values>

**Note:**

* Nsamp value is ignored if positive, but a negative value will cause the entire observation to be ignore.
* Negatively valued mean size entries with be ignored in fitting.
  + Nfish value of 0 will cause mean size value to be ignored in fitting.
  + Negative value for year causes observation to not be included in the working matrix.
  + Each genders’ data vector and N fish vector has length equal to the number of age’ bins.
  + Where age data are being entered as conditional age’-at-length and growth parameters are being estimated, it may be useful to include a mean length-at-age vector with

nil emphasis to provide another view on the model’s estimates.

### Environmental Data

SS accepts input of time series of environmental data. Parameters can be made to be time-varying by making them a function of one of these environmental time series.

# Parameter values can be a function of an environmental data series:

2 #Number of environmental variables

10 #Number of environmental observations

# Example of 2 environmental observations:

#Year Variable Value

1990 1 0.10

1991 1 0.15

**Note:**

* Any years for which environmental data are not read are assigned a value of 0.0.
* It is permissible to include a year that is one year before the start year in order to assign environmental conditions for the initial equilibrium year. But this works only for recruitment parameters, not biology or selectivity parameters.
* Environmental data can be read for up to 100 years after the end year of the model. Then, if the recruitment-environment link has been activated, the future recruitments will be influenced by any future environmental data. This could be used to create a future “regime shift” by setting historical values of the relevant environmental variable equal to zero and future values equal to 1, in which case the magnitude of the regime shift would be dictated by the value of the environmental linkage parameter. Note that only future recruitment and growth can be modified by the environmental inputs; there are no options to allow environmentally-linked selectivity in the forecast years.

### Generalized Size Composition Data

A new feature with SS\_v3 is a generalized approach to size composition information. It was designed initially to provide a means to include weight frequency data, but was implemented

to provide a generalized capability. The user can define as many size frequency methods as necessary.

* + - * Each method has a specified number of bins.
      * Each method has "units" so the frequencies can be in units of biomass or numbers.
      * Each method has “scale” so the bins can be in terms of weight or length (including ability to convert bin definitions in pounds or inches to kg or cm).
      * The composition data is input as females then males, just like all other composition data in SS. So, in a two-gender model, the new composition data can be combined gender, single gender, or both gender.
      * If a retention function has been defined, then the new composition data can be from the combined discard + retained, discard only or retained only.

Example entry:

|  |  |  |
| --- | --- | --- |
| 2 |  | #N of weight frequency methods |
| 25 | 4 | #Nbins per method |
| 2 | 1 | #Units per each method (1 = biomass, 2 = numbers) |
| 3 | 2 | #Scale per each method (1 = kg, 2 = lbs, 3 = cm, 4 = inches) |
| 0.00001 | -1 | #Min compression to add to each observation (entry for each method) |
| 40 | 5 | #N observations per weight frequency method |

Then enter the lower edge of the bins for each method. The two row vectors shown below contain the bin definitions for methods 1 and 2 respectively:

26 28 30 32 34 36 38 40 42 ... 60 62 64 68 72 76 80 90

1 2.4 4 9 ... ... ... ... ... ... ... ... ... ... ... ... ... 1

**Note:**

* There is no tail compression for generalized size frequency data.
* Super-period capability is enabled for generalized size comps beginning with V3.20.
* There are two options for treating fish that in population size bins that are smaller than the smallest size frequency bin.
* Option 1: By default, these fish are excluded (unlike length composition data where the small fish are automatically accumulated up into the first bin.
* Option 2: If the first size bin is given a negative value, then: accumulation is turned on and the negative of the entered value is used as the lower edge of the first size bin;
  + By choosing units=2 and scale=3, the size comp method can be nearly identical

to the length comp method if the bins are set identically;

* + Bin boundaries can be real numbers so obviously do not have to align with population length bin boundaries, SS interpolates as necessary;
  + Size bins cannot be defined to be narrower than the population binwidth; an untrapped error will occur;
  + Because the transition matrix can depend upon weight-at-length, it is calculated internally for each gender and for each season because weight-at-length can differ between genders and can vary seasonally.

An example observation is below. Note that its format is identical to the length composition data, including gender and partition options, except for the addition of the first column to indicate the size frequency method.

#Method Year Month Fleet Gender Part Sample <composition females then

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | Size | males> |
| 1 | 1975 | 1 | 1 | 3 | 0 | 43 | <data> |

### Tag-Recapture Data

The ability to analyze tag-recapture data has been introduced with SS\_v3. Each released tag group is characterized by an area, time, gender and age at release. Each recapture event is characterized by a time and fleet. Because SS fleet’s each operate in only one area, it is not necessary to record the area of recapture. Inside the model, the tag cohort is apportioned across all growth patterns in that area at that time (with options to apportion to only one gender or to both). The tag cohort x growth pattern then behaves according to the movement and mortality of that growth pattern. The number of tagged fish is modeled as a negligible fraction of the total population. This means that a tagging event does not move fish from an untagged group to a tagged group. Instead it acts as if the tags are seeded into the population with no impact at all on the total population abundance or mortality. The choice to require assignment of a predominant age at release for each tag group is a pragmatic coding and model efficiency choice. By assigning a tag group to a single age, rather than distributing it across all possible ages according to the size composition of the release group, it can be tracked as a single diagonal cohort through the age x time matrix with minimal overhead to the rest of the model. Tags are considered to be released at the beginning of a season (period).

Example set-up for tagging data:

1 #Do tags - if this value is 0, then omit all entries below

COND = 1 All subsequent tag-recapture entries must be omitted if "Do Tags" = 0

3 #Number of tag groups

12 #Number of recapture events

2 #Mixing latency period: N periods to delay before comparing observed to expected recoveries (0 = release period)

10 #Max periods (months) to track recoveries, after which tags enter accumulator

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| #Release Data | | | | | | | | |
|  | #TG | Area | Year | Month | <tfill> | Gender | Age | N |
|  |  |  |  |  |  |  | Release |
| 1 | 1 | 1980 | 1 | 999 | 0 | 24 | 2000 |
| 2 | 1 | 1995 | 1 | 999 | 1 | 24 | 1000 |
| 3 | 1 | 1985 | 1 | 999 | 2 | 24 | 10 |
| #Recapture Data | | | | | | | |
|  | #TG |  | Year |  | Month |  | Fleet | Number |
|  | 1 |  | 1982 |  | 1 |  | 1 | 7 |
|  | 1 |  | 1982 |  | 1 |  | 2 | 5 |
|  | 1 |  | 1985 |  | 1 |  | 2 | 0 |
|  | 2 |  | 1997 |  | 1 |  | 1 | 6 |
|  | 2 |  | 1997 |  | 2 |  | 1 | 4 |
|  | 3 |  | 1986 |  | 1 |  | 1 | 7 |
|  | 3 |  | 1986 |  | 2 |  | 1 | 5 |
| **Note:** |  |  |  |  |  |  |  |  |

* The release data must be enter in TG order.
* <tfill> values are place holders and are replaced by program generated values for model time.

### Stock Composition Data

It is sometimes possible to observe the fraction of a sample that is composed of fish from different stocks. These data could come from genetics, otolith microchemistry, tags or other means. The growth pattern feature in SS allows definition of cohorts of fish that have different biological characteristics and which are independently tracked as they move among areas. SS now incorporates the capability to calculate the expected proportion of a sample of fish that come from different growth patterns. In the inaugural application of this feature, there was a 3 area model with one stock spawning and recruiting in area 1, the other stock in area

3, then seasonally the stocks would move into area 2 where stock composition observations were collected, then they moved back to their natal area later in the year.

Stock composition data can be entered in SS as follows:

1 #Do morphcomp (if zero, then do not enter any further input below) COND = 1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 3 | #Number of observations | |  |  |
| 2 | #Number of stocks |  |  |
| 0.0001 | #Minimum Compression |  |  |
| #Year | Month Fleet Part | Nsamp | Data Vector |
| 1980 | 1 1 0 | 36 | 0.4 0.6 | ... |
| 1981 | 1 1 0 | 40 | 0.44 0.62 | ... |
| 1982 | 1 1 0 | 50 | 0.49 0.50 | ... |
| **Note:** |  |  |  |  |  |

* The N stocks entered with these data must match the N growth patterns in the

control file.

* The expected value is combined across genders.
* The “partition” flag is included here in the data, but cannot be used because the expected value is calculated before the catch is partitioned into discard and retained components.
* Note that there is a specific value of mincomp to add to all values of observed and expected.

End of Data File

999 #End of data file marker

### Excluding Data

Data that are <styr or > retroyr are not moved into the internal working arrays at all. So if you have any alternative observations that are used in some model runs and not in others, you can simply give them a negative year value rather than having to comment them out and revise the observation read counter. The first output to data.ss\_new has the unaltered and complete input data. Subsequent reports to data.ss\_new produce expected values or bootstraps only for the data that are being used. Note that the Nobs values are adjusted accordingly.

Data that are to be included in the calculations of expected values, but excluded from the calculation of negative log likelihood, are flagged by use of a negative value for fleet ID.

### Data Super Periods

The “Super-Period” capability allows the user to introduce data that represent a blend across a set of time steps and to cause the model to create an expected value for this observation that uses the specified set of time steps. The option is available for all types of data and a similar syntax is used. The syntax is revised for SS version 3.23 and higher. Previously, super-periods were started with a -9999 flag in a standard error (se) or Nsamp field and then stopped with a -9998 flag in that field. This was cumbersome and did not allow for super-periods with only 2 time periods. With model version 3.23 and higher, super-periods are started with a negative value for season, and then stopped with a negative value for season, placeholder observations within the super-period are designated with a negative fleet field. The standard error (se) or Nsamp field is now used for weighting of the expected values. An error message will be generated if the old syntax is used. Similarly, negative fleet is the sole allowable flag for omitting observations from the log likelihood calculation. An error message is generated if the super-period does not contain exactly one observation with a positive fleet field.

All super-period observations must be contiguous in the data file. All but one of the observations in the sequence will have a negative value for fleet ID so the data associated with these dummy observations will be ignored. The observed values must be combined outside of the model and then inserted into the data file for the one observation with a positive fleet ID. An expected value for the observation will be computed for each selected time period within in the super-period. Beginning with V3.23b, the expected values are weighted according to the values entered in the se (or Nsamp) field for all observations expect the single observation holding the combined data. The expected value for that year gets a relative weight of 1.0. So in the example below, the relative weights are: 1982, 1.0 (fixed); 1983, 0.85; 1985, 0.4; 1986, 0.4. These weights are summed and rescaled to sum to 1.0, and are output in the echoinput.sso file.

Not all time steps within the extent of a super-period need be included. For example, in a 3 season model a super-period could be set up to combine information from season 2 across 3 years, e.g. skip over the season 1 and season 2 for the purposes of calculating the expected value for the super-period. The key is to create a dummy observation (negative fleet value) for all time steps, except 1, that will be included in the super-period and to include one real observation (positive fleet value; which contains the real combined data from all the specified time steps).

Example:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| #Year | Month | Fleet | Obs | SE | Comment |  |
| 1982 | **-2** | 3 | 34.2 | 0.3 | Start super-period. | This observation has |

positive fleet value, so is expected to contain combined data from all identified periods of the super-period. The se entered here is

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | | | | use as the se of the combined observation.  The expected value for the survey in 1982 will have a relative weight of 1.0 (default) in calculating the combined expected value. |
| 1983 | 2 | **-3** | 55 | 0.3 | In super-period; entered obs is ignored. The expected value for the survey in 1983 will have a relative weight equal to the value in the se field (0.85) in calculating the combined expected value. |
| 1985 | 2 | **-3** | 88 | 0.40 | Note that 1984 is not included in the supe-rperiod. Relative weight for 1985 is 0.4 |
| 1986 | **-2** | **-3** | 88 | 0.40 | End super-period |

A time step that is within the time extent of the super-period can still have its own separate observation. In the above example, the survey observation in 1984 could be entered as a separate observation, but it must not be entered inside of the contiguous block of super-period observations. For composition data (which allow for replicate observations), a particular time steps observations could be entered as a member of a super-period and as a separate observation.

The super-period concept can also be used to combine seasons within a year with multiple seasons. This usage could be preferred if fish are growing rapidly within the year so their effective age selectivity is changing within year as they grow; fish are growing within the year so fishery data collected year round have a broader size-at-age modes than a mid-year model approximation can produce; and it could be useful in situations with very high fishing mortality.

# Control File

## Overview of Control File

These listed model features are denoted in the control file in the following order:

* + 1. Number of growth patterns and sub-morphs
    2. Design matrix for assignment of recruitment to area/season/growth pattern
    3. Design matrix for movement between areas
    4. Definition of time blocks that can be used for time-varying parameters
    5. Specification for growth and fecundity
    6. Natural mortality and growth parameters for each gender x growth pattern
    7. Maturity, fecundity and weight-length for each gender
    8. Recruitment distribution parameters for each area, season, growth pattern
    9. Cohort growth deviation
    10. Catch Multiplier
    11. Environmental link parameters for any mortality-growth (MG) parameters that use a link
    12. Time-varying setup for any MG parameters that use blocks
    13. Seasonal effects on biology parameters
    14. Phase for any MG parameters that use annual deviations
    15. Spawner-recruitment parameters
    16. Recruitment deviations
    17. Method for calculating fishing mortality (F)
    18. Initial equilibrium F for each fleet
    19. Catchability (Q) setup for each fleet and survey
    20. Catchability parameters
    21. Length selectivity, retention, discard mortality setup for each fleet and survey
    22. Age selectivity setup for each fleet and survey
    23. Parameters for length selectivity, retention, discard mortality for each fleet and survey
    24. Parameters for age selectivity for each fleet and survey
    25. Environmental link parameters for any selectivity/retention parameters that use a link
    26. Time-varying setup for any selectivity/retention parameters that use blocks
    27. Phase for any selectivity/retention parameters that use random annual deviation
    28. Tag-recapture parameters
    29. Variance adjustments
    30. Lambdas for likelihood components

## Parameter Line Elements

A primary role of the SS control file is to define the parameters to be used by the model. The general syntax of a parameter line is described here. Parameter lines will be used in three sections of the control file: (1) natural mortality and growth; (2) spawner-recruitment, initial F and catchability; and (3) selectivity. The first seven elements of a parameter line are used in every section and will be referred to as a short parameter line. The remaining elements are used just in sections (1) and (3). Each parameter line contains:

|  |  |  |
| --- | --- | --- |
| Column | Element | Description |
| 1 | LO | Minimum value for the parameter |
| 2 | HI | Maximum value for the parameter |
| 3 | INIT | Initial value for the parameter. If the SS3 PAR file is read, it overwrites these INIT values. |
| 4 | Prior Value | Expected value for the parameter. This value is ignored if the prior type is -1 or 1. |
| 5 | Prior Type | -1 = none, 0 = normal, 1 = symmetric beta, 2 = full beta, 3 = lognormal with bias adjustment, 5 = gamma |
| 5 | Prior StDev | Standard deviation for the prior, used to calculate likelihood of the current parameter value. This value is ignored if prior type is -1. |
| 6 | PHASE | Phase in which parameter begins to be estimated. A negative value causes the parameter to retain its INIT value (or value read from the PAR file). |

Short parameter lines have only the above 7 elements. The full parameter line syntax for the Mortality-Growth and Selectivity sections provides additional controls to give the parameter time-varying properties. These are listed briefly below and described in more detail in the section Time Varying Parameter Options found at the end of the control file syntax section.

|  |  |  |
| --- | --- | --- |
| 8 | ENV | Create a linkage to an input environmental time-series |
| 9 | Use Dev | Invokes use of the deviation vector |
| 10 | Dev min yr | Beginning year for the deviation vector |
| 11 | Dev max yr | Ending year for the deviation vector |
| 12 | Dev StDev | Standard deviation for elements in the deviation vector |
| 13 | USE-BLOCK | Set up blocks or parameter trends |
| 14 | BLOCK-TYPE | Function form for the block offset |

## Control File Syntax

The control file is described here using a rather complex set-up with 2 seasons, 2 areas, 2 growth morphs, 2 genders, and 3 sub-morphs in order to demonstrate the order and interdependence of various factors.

Terminology:

* Where the term “COND” appears in the value column of this documentation (it does not actually appear in the control file), it indicates that the following section is omitted except under certain conditions, or that the factors included in the following section depend upon certain conditions.
* In most cases, the description in the Definition column is the same as the label output to the control.ss\_new file.

Typical Value Description and Options

#C comment Comments beginning with #C at the top of the file will be retained and included in output

1. N growth patterns (GP)
2. Number of sub-morphs within a growth pattern. Permissible values are 1, 3, 5 only. Typical value is 1. Values of 3 or 5 allow exploration of size-dependent survivorship.

COND > 1 Following 2 lines are conditional on N sub-morphs > 1

0.7 Morph between/within stdev ratio. Ratio of the amount of growth variability between sub-morphs to within sub-morphs.

0.2 0.6 0.2 Distribution among sub-morphs. Enter custom vector or enter -1 to first value of vector to get a normal approximation: (0.15, 0.70, 0.15) for 3 sub-morphs, (0.031, 0.237, 0.464, 0.237, 0.031) for 5 sub-morphs.

1 Recruitment distribution method. Options: 1 = use the 3.24 or earlier setup, 2 = main effects for GP, settle timing, and area, 3 = each settle entity, and 4 = none when N GP\*Nsettle=1

1 Number of recruitment settlement assignments. Options: 1 = global, 2 = by area

COND = 1 Only read if recruitment distribution method is set to 1 (3.24 and earlier version)

0 Year x Area x Settlement Event Interaction Requested

1 1 1 Recruitment assignment to GP, season, area (for each settlement event).

COND: If there are multiple GP, season, and areas, specify the additional lines:

Typical Value Description and Options

1. 1 1 Recruitment assignment to GP1, season 1, area 1
2. 1 2 Recruitment assignment to GP1, season 1, area 2

2 1 1 Recruitment assignment to GP2, season 1, area 1

2 2 2 Recruitment assignment to GP2, season 2, area 2 COND: If N areas > 1:

0 Movement: Only read following movement section if N areas > 1 COND > 0 Following lines are conditional if movement is selected:

4 N movement definitions

0.60 First age that moves. Real, not integer age at the beginning of season. This control primarily used to keep new recruits from moving until after their first year.

1 1 1 2 4 10 The four requested movement definitions appear here. Each

1 1 2 1 4 10

1 2 1 2 4 10

1 2 2 1 4 10

definition specifies: season, GP source area, destination area, min age, max age. The rate of movement will be controlled by the movement parameters later. Here the minage and maxage controls specify the range over which the movement parameters are active.

1. Number of block patterns. These patterns can be referred to in the parameter sections to create a separate parameter value for each block.

COND: Following inputs are omitted if N Block patterns equals 0 3 2 1 Blocks per pattern

1975 1985

1986 1990

1995 2001

Beginning and ending years for blocks in design 1; years not assigned to a block period retain the baseline value for a parameter that uses this pattern.

1987 1990

1995 2001

Beginning and ending years for blocks in design 2.

1999 2002 Beginning and ending years for blocks in design 3.

### Biology

This section controls the biology parameters. These include: natural mortality, growth, maturity, fecundity, distribution of recruitment, and movement. Collectively, these are referred to as the MG parameters. The top of the biology section includes several factors

that control the number of parameters to be subsequently read and the method by which SS will use these parameters.

Typical Value Description and Options

0.50 Fraction female - a constant that applies to all growth patterns

1 Natural Mortality Option: 0 = A single parameter

1 = N breakpoints 2 = Lorenzen

3 = Read age specific M and do not do seasonal interpolation

4 = Read age specific and do seasonal interpolation, if appropriate COND = 0 No additional natural mortality controls

COND = 1

4 Number of breakpoints. A value of 2 would correspond to the M pattern as defined in SS V2. Then read a vector of ages for these breakpoints (e.g. corresponding to natM\_amin and natM\_amax in SS V2). Later, per gender x GP, read N parameters for the natural mortality at each breakpoint.

2.0 4.5 9.0

15.0

COND = 2

Vector of age breakpoints

4 Lorenzen Natural Mortality: read one additional value that is the reference age (integer) ([*click here for more information*](#_bookmark48)). Later read one parameter for each gender x GP that will be the M at the reference age. Other ages will have an M scaled to its body size-at-age. However, if sub-morphs are used, all will have the same M a their growth pattern. Lorenzen M calculation will be updated if the starting year growth parameters are active, but if growth parameters vary during the time-series, the M is not further updated. So be careful in using Lorenzen when there is time-varying growth.

COND = 3 or 4 Do not read any natural mortality parameters. With option 2, these M values are held fixed for the integer age (no seasonality or birth season considerations). With option 4, there is seasonal interpolation based on real age, just as in options 1 and 2.

0.20 0.25 ...

Age-specific M values: row 1 is female GP1, row 2 is female 2

0.20 0.23 ... GP2, row 3 is male GP1, etc.

Typical Value Description and Options

1 Growth Model:

1 = von Bertalanffy (2 parameters)

2 = Schnute’s generalized growth curve (aka Richards curve) with 3 parameters

3 = von Bertalanffy with age-specific *k* deviations for specified range of ages

1.66 Growth Amin (A1): Reference age for first size-at-age parameter ([*click here for more information*](#_bookmark50))

25 Growth Amax (A2): Reference age for second size-at-age parameter.

COND = 3 Growth option age-specific *k*

5 Minimum age for age-specific *k*

7 Maximum age for age-specific *k*

0 Standard deviation added to length-at-age: Enter 0.10 to mimic SS2 V1.xx. Recommend using a value of 0.0. [(*click here for more*](#_bookmark50)[*information*)](#_bookmark50)

1. CV Pattern

0: CV=f(LAA), so the 2 parameters are in terms of CV of the distribution of length-at-age and the interpolation between these 2 parameters is a function of mean length-at-age.

1: CV=f(A), so interpolation is a function of age.

2: SD=f(LAA), so parameters define the standard deviations of length-at-age and interpolation is a function of mean length-at-age. 3: SD=f(A)

4: Lognormal distribution of size-at-age. Input parameters will specify the standard deviation of loge size at age. E.g. entered values will typically be between 0.05 and 0.15. A bias adjustment is applied so the lognormal distribution of size-at-age will have the same mean size as when a normal distribution is used.

1. Maturity Option: 1 = length logistic, 2 = age logistic,

3 = read age-maturity for each female GP

4 = read an empirical age-maturity vector for all ages

5 = read empirical age-fecundity and body weight-at-age from separate file, wtatage.ss. Allows for reading time series of input. See section [*Empirical Wt-at-Age*](#_bookmark62)for details. NOTE: need to read 2 parameters even if option 3, 4, or 5 is selected.

Typical Value Description and Options

6 = read an empirical length-maturity vector by population length bin (available in v3.24q)

COND = 3 or 4 Maturity Option

0 0.05 0.10

...

Vector of age-specific maturity or fecundity. One row of length Nages + 1 for each female GP

COND = 6 Maturity Option

0 0.05 0.10

...

Vector of length-specific maturity or fecundity. One row of length of the population length bins for each female GP

1 First Mature Age: Overridden if maturity option is 3, 4, or 5, but still must exist here. Otherwise, all ages below the first mature age will have maturity set to zero.

1 Fecundity Option (irrelevant if maturity option is 4 or 5):

1 = to interpret the 2 egg parameters as linear eggs/kg on body weight (current SS default), so fecundity = *wt∗* (*a* + *b∗wt*), so value

of a=1, b=0 causes eggs to be equivalent to spawning biomass. 2 = to set fecundity= *a ∗ Lb*

3 = to set fecundity= *a∗Wb*, so values of a=1, b=1 causes fecundity

to be equiv to spawning biomass 4 = fecundity = *a* + *b ∗ L*

5 = Eggs = *a* + *b ∗ wt*

0 Hermaphroditisim Option: 0 = no, 1 = invoke female to male transition

COND = 1 Read 2 lines below if herma. is selected; also read 3 parameters after reading the male weight-length parameter

-1 Hermaphroditism Season:

-1 to do transition at the end of each season (after mortality and before movement)

<positive integer> to select just one season

|  |  |  |
| --- | --- | --- |
|  | 1 | Include males in spawning biomass |
|  | 0 = no males in spawning biomass |
|  | 1 = simple addition of males to females |
|  | xx = more options to come later |
| 2 |  | Parameter Offset Method |
|  |  | 1 = direct assignment |
|  |  | 2 = for each GP x gender, parameter defines offset from gender 1, offsets are in exponential terms, so for example, old\_male M = old\_female M \* exp(old\_male parameter) |

Typical Value Description and Options

3 = for each GP x gender, parameter defines offset from GP 1 gender 1. For females, given that “natM option” is breakpoint and there are two breakpoints, parameter defines offset from early age (e.g., old\_female\_M

= young\_female\_M \* exp(old\_female\_M\_parameter). For males, given that “natM option” is breakpoint and there are two breakpoints, parameter is defined as offset from females AND from early age (e.g., old\_male\_M

= young\_female\_M \* exp(young\_male\_M\_parameter) \* exp(old\_male\_M\_parameter)).

1 Time-varying adjustment constraint:

1 = standard parameter adjustments for environmental, block, and deviations are not constrained by bounds

2 = logistic transform - parameter adjustments use a logistic transformation to assure that adjusted parameter value stays within bounds of base parameter

3: standard with no bound check

### Read Mortality-Growth Parameters

Next, SS reads the MG parameters in generally the following order (may vary based on selected options):

Parameter Description

Females Female natural mortality and growth parameters in the following order by GP

natM Natural mortality for female GP1, where the number of natural mortality parameters depends on the option selected.

Lmin Length at Amin (units in cm) for female, GP1

Lmax Length at Amax (units in cm) for female, GP1

VBK Von Bertanlaffy growth coefficient (units are per year) for females, GP1

COND if growth type =2 Richards Coefficient

Only include this parameter if Richards growth function is used. If included, a parameter value of 1.0 will have a null effect and produce a growth curve identical to Bertalanffy.

Parameter Description

COND if growth type =3 Age-Specific K K deviations for first age in rage

K deviations for next age in rage

...

K deviations for last age in rage

CV young Variability for size at age <= AFIX (units are fraction)

for females, GP1. Note that CV cannot vary over time, so do not set up env-link or a dev vector. Also, units are either as CV or as standard deviation, depending on assigned value of CV pattern.

CV old Variability for size at age >= AFIX (units are fraction) for females, GP1. For intermediate ages, do a linear interpolation of CV on means size-at-age. Note that the units for CV will depend on the CV pattern and the value of MGparm as offset.

COND: GP > 1 Repeat female parameters in the above order for GP2 Males Male natural mortality and growth parameters in the following order by GP

natM Natural mortality for male GP1, where the number of natural mortality parameters depends on the option selected.

Lmin Length at Amin (units in cm) for male, GP1

Lmax Length at Amax (units in cm) for male, GP1

VBK Von Bertanlaffy growth coefficient (units are per year) for males, GP1

COND if growth type =2 Richards Coefficient

Only include this parameter if Richards growth function is used. If included, a parameter value of 1.0 will have a null effect and produce a growth curve identical to Bertalanffy.

COND if growth type =3 Age-Specific K K deviations for first age in rage

K deviations for next age in rage

...

K deviations for last age in rage

Parameter Description

CV young Variability for size at age <= AFIX (units are fraction)

for males, GP1. Note that CV cannot vary over time, so do not set up env-link or a dev vector. Also, units are either as CV or as standard deviation, depending on assigned value of CV pattern.

CV old Variability for size at age >= AFIX (units are fraction) for males, GP1. For intermediate ages, do a linear interpolation of CV on means size-at-age. Note that the units for CV will depend on the CV pattern and the value of MGparm as offset.

COND: GP > 1 Repeat male parameters in the above order for GP2 Females Weight length relationship parameters, maturity and

fecundity

WtLen scale Coefficient to convert length in cm to weight in kg for

females

WtLen exp Exponent in to convert length to weight for females Mat-50 Maturity logistic inflection (in cm or years). Where

female maturity-at-length (or age) is a logistic function:

*maturity* = 1*/*(1 + *exp*(*slope ∗* (*size − at − age −*

*inflection*)))

Mat-slope Logistic slope (must have negative value)

Eggs-alpha Two fecundity parameters; usage depends on the

selected fecundity option. Must be included here eve if vector is read in the control section above.

Eggs-beta

COND: GP > 1 Repeat female parameters in the above order for GP2 Males Weight length relationship parameters

WtLen scale Coefficient to convert length in cm to weight in kg for

males

WtLen exp Exponent in to convert length to weight for males COND: GP > 1 Repeat male parameters in the above order for GP2 COND: Hermaphrodism 3 parameters define a normal distribution for the

transition rate of females to males

Inflect Age Hermaphrodite inflection age

StDev Hermaphrodite standard deviation (in age)

Asmp Rate Hermaphrodite asymptotic rate

Recr Dist GP Recruitment apportionment by GP, if multiple GP, multiple entries required

Parameter Description

Recr Dist Area Recruitment apportionment by area, if multiple areas, multiple entries required

Recr Dist Seas Recruitment apportionment by season, if multiple seasons, multiple entries required

COND: If recruitment distribution interaction = 1 (on)

N patterns x N areas x N seasons

Note that the order of recruitment distribution parameters has areas then seasons for main effect, and seasons then areas for interactions.

Cohort growth deviation If no deviations the INIT set equal to 1 2 x N selected movement pairs Movement parameters

COND: The following lines are only required when the associated features are turned on

Ageing Error Turned on in the data file

Catch Multiplier

Turned on in the data file

Example format for MG parameter section:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| LO | HI | INIT | Prior  Value | <other  entries> | Block  Type | Parameter Label |
| 0 | 0.50 | 0.15 | 0.1 | ... | 0 | #NatM\_p\_1\_Fem\_GP\_1 |
| 0 | 45 | 21 | 36 | ... | 0 | #L\_at\_Amin\_Fem\_GP\_1 |
| 40 | 90 | 70 | 70 | ... | 0 | #L\_at\_Amax\_Fem\_GP\_1 |
| 0 | 0.25 | 0.15 | 0.10 | ... | 0 | #VonBert\_K\_Fem\_GP\_1 |
| 0.10 | 0.25 | 0.15 | 0.20 | ... | 0 | #CV\_young\_Fem\_GP\_1 |
| 0.10 | 0.25 | 0.15 | 0.20 | ... | 0 | #CV\_old\_Fem\_GP\_1 |
| -3 | 3 | 2e-6 | 0 | ... | 0 | #Wtlen\_1\_Fem |
| -3 | 4 | 3 | 3 | ... | 0 | #Wtlen\_2\_Fem |
| 50 | 60 | 55 | 55 | ... | 0 | #Mat50%\_Fem |
| -3 | 3 | -0.2 | -0.2 | ... | 0 | #Mat\_slope\_Fem |
| -5 | 5 | 0 | 0 | ... | 0 | #Eggs/kg\_inter\_Fem |
| -50 | 5 | 0 | 0 | ... | 0 | #Eggs/kg\_slope\_wt\_Fem |
| 0 | 0.50 | 0.15 | 0.1 | ... | 0 | #NatM\_p\_1\_Mal\_GP\_1 |
| 0 | 45 | 21 | 36 | ... | 0 | #L\_at\_Amin\_Mal\_GP\_1 |
| 40 | 90 | 70 | 70 | ... | 0 | #L\_at\_Amax\_Mal\_GP\_1 |
| 0 | 0.25 | 0.15 | 0.10 | ... | 0 | #VonBert\_K\_Mal\_GP\_1 |
| 0.10 | 0.25 | 0.15 | 0.20 | ... | 0 | #CV\_young\_Mal\_GP\_1 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| LO | HI | INIT | Prior  Value | <other  entries> | Block  Type | Parameter Label |
| 0.10 | 0.25 | 0.15 | 0.20 | ... | 0 | #CV\_old\_Mal\_GP\_1 |
| -3 | 3 | 2e-6 | 0 | ... | 0 | #Wtlen\_1\_Mal |
| -3 | 4 | 3 | 3 | ... | 0 | #Wtlen\_2\_Mal |

### Natural Mortality Notes

The options for natural mortality have been expanded. In addition, M is now, in most options, calculated according to real age since the beginning of a cohort’s birth season, rather than annual, integer age. So, if M varies by age, M will change by season and cohorts born in early seasons of the year will have different M than late born cohorts.

**Lorenzen Natural Mortality**

Lorenzen natural mortality is based on the concept that natural mortality varies over the life cycle of a fish, which is driven by physiological and ecological processes.

### Growth Notes

When fish recruit at the real age of 0.0 at the beginning of their birth season, they have body size equal to the lower edge of the first population size bin. Previously, they recruited at a size equal to the lower edge of the smallest data size bin. The fish then grow linearly until they reach a real age equal to the input value “growth\_age\_for\_L1” and have a size equal to the parameter value for L1. As they age further, they grow according the Bertalanffy growth equation. The growth curve is calibrated to go through the size L2 when they reach the age “Growth\_age\_for\_L2”.

If “Growth\_age\_for\_L2” is set equal to 999, then the size L2 is used as Linf. If MGparm\_def option ==1 (direct estimate, not offsets), then setting a male growth or natural mortality parameter value to 0.0 and not estimating it will cause SS to use the corresponding female parameter value for the males. This check is done on a parameter, by parameter basis and is probably most useful for setting male L1 equal to female L1, then letting males and females have separate K and Linf parameters.

**Schnute growth function**

The Schnute implementation of a 3-parameter growth function is invoked by entering 2 in the grow\_type field. Then a fourth parameter is read after reading the von Bertalanffy K parameter. When this fourth parameter has a value of 1.0, it is equivalent to the standard von Bertalanffy growth curve. When this function was first introduced in SS, it required that A0 be set to 0.0.

**Age-specific K**

A new growth option, #3, has been introduced in V3.23. This option creates age-specific

K deviations for each age of a user-specified age range, with independent additive deviations for each age in the range and for each growth pattern / gender. Each of these deviations is entered as a full parameter line, so inherits all time-varying capabilities of full parameters. The lower end of this age range cannot extend younger than the specified age for which the first growth parameter applies. This is a beta model feature, so examine output closely to assure you are getting the size-at-age pattern you expect. Beware of using this option in a model with seasons within year because the K deviations are indexed solely by integer age according to birth year. There is no offset for birth season timing effects, nor is there any seasonal interpolation of the age-varying K.

### Growth Patterns (morphs) and Sub-Morphs

The user specifies a number of growth patterns (usually just 1), a number of genders (usually 2), and a number of birth seasons. The collection of Bio\_pattern x Gender x BirthSeas constitute the “morphs”. The number of sub-morphs per morph can be 1, 3, or 5. The fraction of recruits that are female is specified as an input value (not a parameter), and the fraction of recruits assigned to each sub-morph is custom-input or designated to be a normal approximation. When multiple sub-morphs are designated, an additional input is the ratio of between sub-morph to within sub-morph variability in size-at-age. This is used to partition the total growth variability. Growth parameters are read for each growth pattern x gender combination. For the sub-morphs, their size-at-age is calculated as a factor (determined from the between-within variability calculation) times the size-at-age of the central morph which is determined from the growth parameters for the growth pattern x gender.

### Recruitment, Age, and Growth

Recruitment can occur in any season. In older versions of SS one value of spawning biomass was calculated annually at the beginning of one specified spawning season and this spawning biomass produces one annual total recruitment value and this annual recruitment was distributed among seasons, areas, and growth types according to other model parameters. SSv3.3 allows for the spawning biomass in a season to produce recruitment that may vary over the year based on the spawning biomass which associated with the area and growth types according

to the model parameterization. These distribution parameters can be time-varying, so the fraction of the recruits that occur in a particular season can change from year to year. For the recruitment apportionment, the parameter values are the ln(apportionment weight), so should have values ranging from about –4 to +4. The product of all apportionment weights is calculated for each pattern x area x season cell that has been designated to receive recruits in the recruitment design matrix. Then the apportionment weights are scaled to sum to 1.0 (within year, not within season) so that the total annual recruitment is distributed among the cells designated to receive recruitment.

In a seasonal model, all cohorts graduate to the age of 1 when they first reach January 1, even if the seasonal structure of the model has them being born in the fall. In general,

this means that SS operates under the assumption that all age data have been adjusted so that fish graduate to the next age on Jan 1. This can be problematic if the ageing structures deposit a ring at another time of year. Consequently, you may need to add or subtract a year to some of your age data to make it conform to the SS structure, or you may need to define the SS calendar year to start at the beginning of the season at which ring deposition occurs. Talk with your ageing lab about their criteria for seasonal ring deposition!

Seasonal recruitment is coded to work smoothly with growth. If the recruitment occurring in each season is assigned the same growth pattern, then each seasonal cohort’s growth trajectory is simply shifted along the age/time axis. At the end of the year, the early born cohorts will be larger, but all are growing with the same growth parameters so all will converge in size as they approach their common Lmax.

Age 0.0 fish (at beginning of their birth season) are assigned a size equal to the lower edge of the first population size bin and they grow linearly until they reach the age A1. SS generates a warning if the first population length bin is greater than 10 cm as this seems an unreasonably large value for a larval fish. A1 is in terms of real age elapsed since birth. All fish advance to the next integer age on Jan 1, regardless of birth season. For example, consider a 2 season model with some recruitment in each season and with each season’s recruits coming from the same GP. At the end of the first year, the early born fish will be larger but both of the seasonal cohorts will advance to an integer age of 1 on Jan 1 of the next year. The full growth curve is still calculated below A1, but the size-at-age used by SS is the linear replacement. Because the linear growth trajectory can never go negative, there is no need for the additive constant to the stddev (necessary for the growth model used in SS2 V1.x), but the option to add a constant has been retained in the model.

### Cohort Growth Deviation

This parameter must be given a value of 1.0 and be given a negative phase so it is not estimated. Its importance is in serving as a base for blocks or annual devs, which may be estimated, around this base value of 1.0.

### Movement Parameters

There are 2 movement parameters per area pair flagged in the movement design matrix as needing estimable movement parameters. For each, the first parameter is for the movement coefficient for young fish and the second is for old fish (with intermediate ramp calculated using the designated start age and end age. Parameter values are the ln(movement coefficient). For fish that stay in their source area (e.g. move from area 1 to area 1 in season 1), they are given a movement coefficient of ln(1)=0, but this default value is replaced if the stay movement is selected as needed parameters. For each source area, each movement coefficient is exponentiated and then they are scaled to sum to 1.0. At least one needs to not be estimated so that all others are estimated relative to it.

The movement model has been augmented to define movement parameters for each growth pattern. With this capability, it will be possible to have homing of a growth pattern

back to its natal area.

An added feature is the reading of migr\_firstage immediately after reading the do\_migration flag if the do\_migration flag is positive. This value is a real number, not an integer, to allow for an in-year start to movement in a multi-season model. The value is the real age at the beginning of a season, even though movement does not occur until the end of the season.

For example, in a setup with two 6-month seasons: a value of 0.5 will cause the age 0 fish to not move when they complete their first 6 month season of life, and then to move at the end of their second season because they start movement capability when they reach the age of 0.5 years (6 months).

A new feature added in v3.3 allows for a multi-season setup to have a growth pattern (GP) to have some fish recruit in different “birthseasons”. The movement parameters are now specific to GP x birthseason x actual season.

Future Need: augment the capability further to allow sex-specific movement, and also to allow some sort of mirroring so that genders and growth patterns can share the same movement parameters if desired.

The model will allow movement only between source-destination pairs that have an explicit movement definition. For fish that stay in an area, there are two options:

* + - 1. define an explicit movement pattern where the destination area is the same as the source area. This will allow you to control its parameters explicitly;
      2. allow the model to create an implicit stay rate definition equivalent to setting the movement strength parameter to 0 for all ages.

For all explicit definitions requested, there must be 2 parameters included with the MG parameter section. As before, the age-specific movement strength is:

1. constant at P1 below minage, constant at P2 above maxage, and linearly interpolated for intermediate ages;
2. exponentiated so that a movement strength parameter value of 0 becomes 1.0;
3. for movement out of an area, the exponentiated value is multiplied by season duration;
4. for each source area, all movement rates are then summed and divided by this sum so that 100% of the fish are accounted for in the movement calculations;
5. it is best if at least one of the destinations for each source area has a predefined movement strength so that other destinations are estimated relative to the fixed value.

### Recruitment Allocation and Movement Parameters

In a 2 season, 2 area, 2 growth pattern set-up, the recruitment distribution, cohort growth deviation, and movement parameters could be:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| LO | HI | INIT | Prior  Value | <other Block  entries>Type | | Parameter Label |
| -4 | 4 | 0 | 1 | ... | 0 | #RecrDist\_GP\_1 |
| -4 | 4 | 0 | 1 | ... | 0 | #RecrDist\_GP\_2 |
| -4 | 4 | 0 | 1 | ... | 0 | #RecrDist\_Area\_1 |
| -4 | 4 | -4 | 1 | ... | 0 | #RecrDist\_Area\_2 |
| -4 | 4 | 0 | 1 | ... | 0 | #RecrDist\_Seas\_1 |
| -4 | 4 | -4 | 1 | ... | 0 | #RecrDist\_Seas\_2 |
| -4 | 4 | 0 | 1 | ... | 0 | #CohortGrowthDev |
| COND: Only if movement is defined | | | | | | |
| -5 | 5 | -4 | 1 | ... | 0 | #MoveParm\_A\_seas\_1\_GP\_1from\_1to2 |
| -5 | 5 | -4 | 1 | ... | 0 | #MoveParm\_B\_seas\_1\_GP\_1from\_1to2 |
| -5 | 5 | -4 | 1 | ... | 0 | #MoveParm\_A\_seas\_1\_GP\_1from\_2to1 |
| -5 | 5 | -4 | 1 | ... | 0 | #MoveParm\_B\_seas\_1\_GP\_1from\_2to1 |
| -5 | 5 | -4 | 1 | ... | 0 | #MoveParm\_A\_seas\_1\_GP\_2from\_1to2 |
| -5 | 5 | -4 | 1 | ... | 0 | #MoveParm\_B\_seas\_1\_GP\_2from\_1to2 |
| -5 | 5 | -4 | 1 | ... | 0 | #MoveParm\_A\_seas\_1\_GP\_2from\_2to1 |
| -5 | 5 | -4 | 1 | ... | 0 | #MoveParm\_B\_seas\_1\_GP\_2from\_2to1 |

**Note:**

* For the recruitment parameters, there must be a line for each season, area and GP. But only those seasons, areas, and GPs designated to receive recruits in the recruitment design matrix will have the parameter used in the recruitment distribution calculation.
* For both recruitment allocations and movement rates, SS processes the parameter values according to the following equation:

*epi ratei* = ),*N*

*epi*

*j*=1

(3)

* + Set the value of one of these parameters to 0.0 and not estimate it so that other

areas will be estimated relative to that base area.

* + Be sure that estimated parameters are given a min-max of something like -5 and 5 so they have a good range relative to the base area.
  + In order to get a different distribution of recruitments in different years, you will need to make at least one of the recruitment distribution parameters time-varying.

### Catch Multiplier

This parameter line is only included in the control file if the catch multiplier field in the data file is set to 1. A single value may be fixed or estimated where:

*Cobs* = *Cexp ∗ cmult* (4)

where *Cexp* is the expected catch and *cmult* is the catch multiplier. It has year-specific, not season-specific, time-varying capabilities. In the catch likelihood calculation, expected catch is multiplied by the catch multiplier by year and fishery before being compared to the observed retained catch, so value of 1.1 means that the observed catch has overestimated actual catch by 10%.

### Ageing Error Parameters

These 7 parameters are only included in the control file if one of the ageing error definitions in the data file has requested this feature (by putting a negative value for the ageing error of the age zero fish of one ageing error definition. Although these are input with full parameter lines (with inherent time-varying capability), the time-varying updating has not been implemented.

Until a more complete description and examples are developed, here is the code for creation of the vectors of mean age’ and stddev of age’:

INSERT CODE HERE

The 7 parameters are:

* age at which the estimated pattern begins (just linear below this age). This is “start age”
* bias at start age (as additive offset from unbiased age’)
* bias at maxage (as additive offset from unbiased age’)
* power fxn coefficient for interpolating between those 2 values (value of 0.0 produces linear interpolation in the bias)
* stdev at age
* stdev at max age
* power fxn coefficient for interpolating between those 2 values

### Time-Varying Biology Parameters

Any of the parameters defined above can be made time-varying through linkage to an environmental data series, through time blocks, or by setting up annual deviations. The options for making biology and selectivity parameters change over time is detailed in the section labeled Time-Varying Parameters. After reading the biology parameters above, which will include possible instructions to create environmental link, blocks, or dev vectors, then read the following section. Note that all inputs in this section are conditional (COND) on entries in the biology parameter section. So if no biology parameters invoke any time-varying properties, this section is left blank (or completely commented out with #) except for the line with the input of seasonal factors.

When time-varying growth is used, there are some additional considerations to be aware

of:

* Growth deviations propagate into the forecast. The user can select which growth parameters get used during the forecast by setting the end year of the last block. If the last block ends in the model’s endyr, then the grorth parameters in effect during the forecast will revert to the “no-block” baseline level. By setting the end year of the last block to end year (endyr) + 1, the model will continue the last block’s growth parameter levels throughout the forecast.
* The equilibrium benchmark quantities (MSY, F40%, etc.) previously used end year (endyr) body size-at-age, which is a disequilibrium vector. There is a capability to specify a range of years over which to average the size-at-age used in the benchmark calculations.
* An addition issue occurred in versions prior to 3.20. Its description is retained here, but it was resolved with the growth code modification for version 3.20.

**–** Issue for versions prior to 3.20: When the growth reference ages have A1>0 and A2<999, the effect of time-varying K has a non-intuitive aspect. This occurs because the virtual size at age 0.0 and the actual Linf are calculated annually from the current L1, L2 and K parameters. Because these calculated quantities are outside the age range A1, A2, a reduction in K will cause an increase in the calculated size-at-age 0.0 that year. So there is a ripple effect as the block’s growth parameters affect the young cohorts in existence at the time of the change. The workaround for this is to set A1=0 and A2=999. However, this may create another incompatibility because the size-at-age 0.0 cannot be allowed to be negative and should not be allowed to be less than the size of the first population length bin. Therefore, previous use of A1=2 might have implied a virtual size at age 0.0 that was negative (which is ok), but setting A1=0 does not allow the size at age=A1 to be negative.

Control file continued:

Value Description

COND: If any MG parameters use environmental linkage, then read next factor

0 0: Do not use custom environmental linkage setup, read just one parameter line

1: Use custom environmental linkage, so read one parameter line for each MG parameter that uses linkage

<short parameter line(s)>

Read 0, 1 or many short parameter lines as necessary

COND: If any MG parameters use blocks then read next factor

0 0: Do not use custom block setup, read just one parameter line

1: Use custom block setup, so read one parameter line for each MG parameter that uses blocks

<short parameter line(s)>

Read 0, 1 or many short parameter lines as necessary

#Seasonality for selected biology parameters (not a conditional input)

0 0 0 0 0 0 0 0 0 0 Read 10 integers to specify which biology parameters have seasonality: femwtlen1, femwtlen2, mat1, mat2, fec1, fec2, malewtlen1, malewtlen2, L1, K. Reading a positive value selects that factor for seasonality ([*click here for more*](#_bookmark59)[*information*](#_bookmark59))

COND: If any factors have seasonality, then read N seasons parameters that define the seasonal offsets from the base parameter value.

<short parameter line(s)>

Read N seasons short parameter lines for each factor selected for seasonality. The parameter values define an exponential offset from the base parameter value.

COND: If any MG parameters use annual deviations, then read the phase next.

-1 All MG parameters using annual deviations will have the deviations begin estimation in this phase.

### Notes on Seasonal Biology Parameters

SS\_v3 begins to introduce seasonal effects on selected biology parameters. Currently, seasonal option is only available for the four wt-len parameters and for the growth K. Seasonality is not needed for the maturity and fecundity parameters because spawning is only defined to occur in one season. Seasonal L1 may be implemented at a later date. The seasonal parameter values adjust the base parameter value for that season.

*P t* = *P ∗ exp*(*seas*\_*value*) (5)

### Empirical Weight-at-Age (wtatage.ss)

With version 3.04, SS adds the capability to read empirical body weight at age for the population and each fleet, in lieu of generating these weights internally from the growth parameters, weight-at-length, and size-selectivity. Selection of this option is done by setting Maturity\_Option = 5. The values are read from a separate file named, wtatage.ss. This file is only required to exist if this option is selected. See section 8.1 for additional information on file formatting for empirical weight-at-age.

### Spawner-Recruitment

The spawner-recruitment section starts by specification of the functional relationship. The number of parameters needed by each relationship is stored internally (same approach as is used for the number of parameters for each selectivity relationship).

Control file continued:

Value Description

3 Spawner- The options are: Recruitment 1: null

Relationship 2: Ricker (2 parameters)

3: standard Beverton-Holt (2 parameters)

4: ignore steepness and no bias adjustment. Use this in conjunction with very low emphasis on recruitment deviations to get CAGEAN-like unconstrained recruitment estimates. (2 parameters, but only uses the first one.)

5: Hockey stick (3 parameters) for ln(R0), fraction of virgin SSB at which inflection occurs, and the R level at SSB=0.0. 6: Beverton-Holt with flat-top beyond Bzero (2 parameters) 7: Survivorship function (3 parameters). Suitable for sharks and low fecundity stocks to assure recruits are <= pop production

8: Sheperd (3 parameters)

Value Description

Read the required number of short parameter set-up lines (ex. LO HI INIT PRIOR PR\_Type SD PHASE). These parameters are:

log(R0) Log of virgin recruitment level

steepness Steepness of S-R, bound by 0.2 and 1.0 for the Beverton-Holt

COND: If SRR = 5, 7, or 8

3rd Parameter Optional depending on which SRR function is used

sigma-R std.dev. of log recruitment; This parameter has two related roles. It penalizes deviations from the spawner-recruitment curve, and it defines the offset between the arithmetic mean spawner-recruitment curve (as calculated from log(R0) and steepness) and the expected geometric mean (which is the basis from which the deviations are calculated. Thus the value of sigmaR must be selected to approximate the true average recruitment deviation.

env-link environmental linkage coefficient. The recruitment parameters are short parameters, so cannot have the generic block or environmental link options. Instead, this dedicated env-link is provided. It is used to create a multiplicative adjustment to the target parameter, so

*Pyt* = *P ∗ exp*(*env/link ∗ env/datay* ). An alternative that

provides an additive link is under development.

log(R1) Offset for initial equilibrium recruitment to virgin recruitment.

AutoCorrelation Autocorrelation in recruitment

Then read additional spawner-recruitment conditions:

|  |  |  |
| --- | --- | --- |
| 0 | SR\_env\_link | This is the index of the environmental variable that will be used as the basis for adjustment of SR expectations. This works for both the forecast period and for the initial equilibrium (by entering a value for the environmental variable one year before the start of the time series). |
| 3 | SR\_env\_target | This factor determines what aspect of spawner-recruitment is affected by the environmental variable. The options are: |

1: annual deviations

2: R0

3: steepness

|  |  |  |
| --- | --- | --- |
| Value |  | Description |
|  |  | If the application needs to compare the environment to annual recruitment deviations, then the preferred option is to transform the environmental variable into an age 0 pre-recruit survey and enter these as a survey with expected value based on selectivity option #31. Use of SR\_env\_target=1 is discouraged because it interacts with the level of residual recruitment variability and there is no implementation of a bias correction for the variability in recruitment caused by the environmental variable. If the application is investigating regime shifts, then enter an environmental variable with a time series of zeros and ones to describe the regime periods, then use SR\_env\_target of 2 or 3 to adjust the expected level of recruitment according to the regime variable. Note that MSY related quantities will be calculated with the regime in the zero state only. However, the forecast can be responsive to designated regime levels. |
| 1 | Do\_Recr\_Dev | This selects the way in which recruitment deviations are coded: |
|  |  | 0: none (so all recruitments come from S-R curve) |

1971 Main recr devs begin year

1999 Main recr devs end year

3 Main recr dev phase

1 Advanced Options

1: dev vector (previously the only option). Here the deviations are encoded as a dev\_vector, so ADMB enforces a sum-to-zero constraint.

2: simple deviations. Here the deviations do not have an explicit constraint to sum to zero, although they still should end up having close to a zero sum. The difference in model performance between options (1) and (2) has not been fully explored to date.

If begin year is less than the model start year, then the early deviations are used to modify the initial age composition. However, if set to be more than Nages before start year, it is changed to equal Nages before start year.

If recr devs end year is later than retro year, it is reset to equal retro year.

0: Use default values for advanced options 1: Read values for the 11 advanced options

COND = 1 Beginning of advanced options

1950 Early Recruitment Deviation Start Year:

|  |  |  |
| --- | --- | --- |
| Value |  | Description |
|  |  | 0: skip (default) |
|  |  | +year: absolute year (must be less than begin year of main recr devs) |
|  |  | -integer: set relative to main recr dev start year |
|  |  | NOTE: because this is a dev vector, it should be long enough so that recr devs for individual years are not unduly constrained. |
|  | 6 | Early Recruitment Deviation Phase: |
|  |  | Users may want to set to a late phase if there is not much early data; Default: -4 |
|  | 0 | Forecast Recruitment Phase: |
|  |  | Forecast recruitment deviations always begin in the first year after the end of the main recruitment deviations. Setting their phase to 0 causes their phase to be set to max lambda phase +1 (so that they become active after rest of parameters have converged.). However, it is possible here to set an earlier phase for their estimation, or to set a negative phase to keep the forecast recruitment devs at a constant level. Default: 0 |
|  | 1 | Forecast Recruitment Deviations Lambda: |
|  |  | This lambda is for the logL of the forecast recruitment devs that occur before endyr+1. Use a larger value here if solitary, noisy data at end of time series cause unruly recr dev estimation. Default: 1.0 |
|  | 1956 | Last Year With No Bias Adjustment |
|  | 1970 | First Year With Full Bias Adjustment |
|  | 2001 | Last Year With Full Bias Adjustment |
|  | 2002 | First Recent Year With No Bias Adjustment |

Value Description

These four entries control how the bias adjustment is phased in and then phased back out when the model is searching for the maximum logL. Bias adjustment is automatically turned off when in MCMC mode. For intervening years between the first and second years in this list, the amount of bias adjustment that will be applied is linearly phased in. The first year with full bias adjustment should be a few years into the data-rich period so that SS will apply the full bias-correction only to those recruitment deviations that have enough data to inform the model about the full range of recruitment variability. See the recruitment advisory for more information. Defaults for the four year values: Start year – 1000, Start year – Nages, Main recr dev final year, End year

+1.

0.85 Max Bias Adjustment:

Value for the maximum bias adjustment during the MLE mode. Use value of 1.0 for compatibility with previous versions of SS. All estimated recrdevs, even those within a ramped era, switch to maxbias=1.0 during MCMC.

0 Period For Recruitment Cycles:

Use this when SS is configured to model seasons as years and there is a need to impose a periodicity to the expected recruitment level. If value is >0, then read that number of full parameter lines below define the recruitment cycle

-5 Minimum Recruitment Deviation: Min value for recruitment deviation. Default: -5

5 Maximum Recruitment Deviation: Max value for recruitment deviation. Default: 5

2 Number of Explicit Recruitment Deviations to Read:

0: Do not read any recruitment deviations; Integer: read this number of recruitment deviations; Default: 0

END OF ADVANCED OPTIONS

COND = Enter N full parameter lines below if N recruitment cycles is > 0

<parameter line>

Full parameter line for each of the N periods of recruitment cycle

COND = If N explicit recruitment deviations is > 0, then enter N lines below 1977 3.0 Enter Year and Deviation

|  |  |  |
| --- | --- | --- |
| Value |  | Description |
|  | 1984 3.0 | Two example recruitment deviations being read. NOTE: |
|  | | SS will rescale the entire vector of recrdevs after reading |
| these deviations, so by reading two positive values, all other |
| recrdevs will be scaled to a small negative value to achieve a |
| sum to zero condition before starting model estimation |

### Spawner-Recruitment Function

The number of age-0 fish is related to spawning biomass according to a stock-recruitment relationship. SS has the option of the Beverton-Holt, Ricker, Hockey-Stick, and a survival-based stock recruitment relationship.

**Beverton-Holt**

The Beverton-Holt Stock Recruitment curve is calculated as:

*R*

*Ry* = *SB* (1

0

4*hR*0*SBy*

*— h*) + *SBy* (5*h −*

1) *e−*

0*.*5*byσ*2 +*R*˜*y*

*R*˜*y ∼*

*N* (0; *σ*2 ) (6)

where *R*0 is the unfished equilibrium recruitment, *SB*0 is the unfished equilibrium spawning biomass (corresponding to R0), SBy is the spawning biomass at the start of the spawning season during year y, h is the steepness parameter, by is the bias adjustment fraction applied during year y, is the standard deviation among recruitment deviations in log space, and is the lognormal recruitment deviation for year y. The bias-adjustment factor (Methot and Taylor 2011) ensures unbiased estimation of mean recruitment even during data-poor eras in which the maximum likelihood estimate of the is near 0.0.

*R*

**Ricker**

The Ricker Stock Recruitment curve is calculated as:

*R*0*SBy*

*h*(1*−SBy/SB*0)

*−*0*.*5*byσ*2 +*R*˜*y* ˜ 2

**Hockey-Stick**

*Ry* =

*e*

*SB*0

*e R Ry ∼ N* (0; *σR*) (7)

The hockey-stick recruitment curve is calculated as:

*SBy*

*Ry* = *RminR*0 + *hSB*

0

(*R*0 *− Rmin*)(*join*) + *R*0(1 *− join*) (8)

where *Rmin* is the minimum recruitment level predicted at a spawning size of zero and is set by the user in the control file, h is defined as the fraction of *SB*0 below which recruitment declines linearly, and *join* is defined as:

*join* =

1 + *e*1000*∗*

(*SB*0 *−hSB*0 ) 1*−*1

*SB*0

(9)

**Survivorship**

Survival-based recruitment (Taylor et al. 2012) is constrained so that the recruitment rate cannot exceed fecundity:

*Ry* = *e*

( (

*−z*0+(*z*0*−zmin*)

1*−*(*SBy/SB*0)*ρ*

*R*˜*y ∼ N* (0; *σ*2 ) (10)

where *z*0 (P) is the negative log of the pre-recruit mortality rate at unfished equilibrium, *zmin* is the limit of the pre-recruit mortality as relative spawning biomass approaches 0, parameterized as a function of *zfrac* (P) (which represents the reduction in mortality as a fraction of *z*0), and *ρ* (P) is a parameter controlling the shape of density-dependent relationship between relative spawning biomass and pre-recruit survival. The steepness

*R*

1. of the spawner-recruit curve (defined as recruitment relative to R0 at a spawning depletion level of 0.2) is:

*h* = 0*.*2*ez*0*zfrac*(1*−*0*.*2*β* ) (11)

This 3-parameter function was created for use with low fecundity species, but its use of 3-parameters provides a flexibility comparable to the 3-parameter Shepherd function. This survival based spawner-recruitment function defines survival from the egg (e.g. hatched pups) to the recruits stage to be a declining function of the initial number of pups produced (Taylor et al. 2012).

* + Start with the parameter, ln(R\_0), which is the ln(mean number of recruits) that enter the population in unfished conditions.
  + These recruits over their lifetime will produce some total number of eggs (pups), termed Pups\_0, which can be calculated from natural mortality, which defines the numbers at age in the adult population, and fecundity at age.
  + Because the unfished condition is considered to be a stable equilibrium, we can calculate PPR\_0 = Pups\_0/R\_0 and its inverse which is survivorship, which we will define in logarithmic space. So, Z\_0 = ln(R\_0/Pups\_0). Note that there is no explicit time over which this Z acts. Such an explicit time (e.g. the age ar recruitment) may be implemented in the future. For now, this means that the Z is really a Z\*delta t.
  + So, Z\_0 is the survival when the population is at carrying capacity. On the other extreme, the maximum survival is 1.0, so the maximum Z is 0.0.
  + The parameter, S\_frac, defines the level of Z when the population approaches an abundance of 0.0. This has values bounded by 0.0 and 1.0 and creates a Z\_max which is between Z\_0 and 0.0. Z\_max = Z\_0 + S\_frac\*(0.0-Z\_0)
  + Then for the current level of pup production (e.g. total population fecundity, aka “spawning biomass”):
    - *Zy* = (1 *−* (*Pupy/Pups*\_0)*Beta*) *∗* (*Z*\_*max − Z*\_0) + *Z*\_0
    - So *Ry* = *Pupy ∗ exp*(*−Zy* )
    - Where beta is the third parameter and which logically has values between about 0.4 for a left-shifted spawner-recruitment curve, and 3.0 for a right-shifted curve.
  + With the other spawner-recruitment relationships, the mean level of recruits, *Ry*

, serves as the base against which environmental effects and annual lognormal deviations are applied. However, in a survival context, it is possible that a large positive deviation on recruitments could imply survival greater than 1.0, so an alternative approach is needed for this survival approach. Here, the lognormal deviations are applied to Z and the resultant S is constrained to not exceed 1.0.

* + In SS, it is also necessary to be able to calculate the equilibrium level of spawning biomass (pup production) and recruitment for a given level of spawning biomass per recruit (pups per recruit), PPR.

**–** *Pups*\_*equil* = *Pups*\_0 *∗* (1 *−* (*LN* (1*/PPR*) *−Z*\_0)*/*(*Z*\_*max−Z*\_0))(1*/Beta*)

* + - Then, *R*\_*equil* = *Pups*\_*equil ∗ exp*(*−*(1 *−* (*Pups*\_*equil/Pups*\_0)*Beta*) *∗*

(*Z*\_*max − Z*\_0) + *Z*\_0)

* + Some example plots for various levels of S\_frac and beta are shown below:

INSERT IMAGE

**Shepherd**

The Shepherd stock recruit curve is calculated as:

*S By* 5*hR*0*SBc*(1 *−* 0*.*2*c*) 2 2

*Ry* =

*y R*

*SB*0

(1 *−*

*hadj*

0

0*.*2*c*) + (5*h*

*y*

*adj −*

1)*SBc e*

*−*0*.*5*byσR*+*R*˜*y R*˜ *∼ N* (0; *σ* ) (12)

where c is the shape parameter for the stock recruitment curve, and *hadj* is the transformed steepness parameter defined as:

(0*.*2 + (*h −* 0*.*2) (1 *−* 0*.*2(5 *−* 0*.*2*c*)

*hadj* =

### Recruitment Eras

(13)

4 *∗* 0*.*2*c*

Conceptually, SS treats the early, data-poor period, the main data-rich period, and the recent/forecast time period as three eras along a continuum. The user has control of the break year between eras. Each era has its own vector. The early era is defined as a vector (prior to V3.10 this was a dev\_vector) so it can have zeros during the earliest years not informed by data and then a few years with non-zero values without imposing a zero-centering on this collection of deviations. The main era can be a vector of simple deviations, or a dev\_vector but it is normally implemented as a dev\_vector so that the spawner-recruitment function is its central tendency. The last era does not force a zero-centered deviation vector so it can have zeros during the actual forecast and non-zero values in last few years of the time

series. The early and last eras are optional, but their use can help prevent SS from balancing a preponderance of negative deviations in early years against a preponderance of positive deviations in later years. When the 3 eras are used, it would be typically to turn on the main era during an early model phase, turn on the early era during a later phase, then have the last era turn on in the final phase.

### Recruitment Likelihood

In SS2, recruitment log(L) contained a term, + N\_forecast\_rec\_devs\*log(sigmaR). This meant that the total log(L) changed according to how many forecast years were included in the model scenario. Worse, if sigmaR was allowed to be estimated by SS2, then this term would cause all the zero deviations during the forecast period to drag the overall estimated value of sigmaR down. This problem is rectified in SS V3. Now, for each year in the total time series (early, mid, late/forecast) the contribution of that year to the logL is equal

to: devˆ2/(2.0\*sigmaR\*sigmaR)+offset\*log(sigmaR); where offset is the magnitude of the

adjustment between the arithmetic and geometric mean of expected recruitment for that year. With this approach, years with a zero or small offset value do not contribute to the second component. With this approach, sigmaR may be estimable when there is good data to establish the time series of recruitment deviations. In the likegfish example, turning on estimate of sigmaR results in an estimated value that is very close to the root mean squared error (rmse) of the estimated recruitment deviations.

### Recruitment Bias Adjustment

The recruitment bias adjustment implemented in SS is based upon the work being documented in Methot and Taylor (2011) and following the work of Maunder and Deriso (2003). The concept is based upon the following logic. SigmaR represents the true variability of recruitment in the population. It provides the constraining penalty for the estimates of recruitment deviations and it is not affected by data. Where data that are informative about recruitment deviations are available, the total variability in recruitment, sigmaR, is partitioned into a signal (the variability among the recruitment estimates) and the residual, the variance of each recruitment estimate (see eq. below). Where there are no data, no signal can be estimated and the individual recruitment deviations collapse towards 0.0 and the variance of each recruitment deviation approaches sigmaR. Conversely, where there highly informative data about the recruitment deviations, then the variability among the estimated recruitment deviations will approach sigmaR and the variance of each recruitment deviation will approach zero. Perfect data will estimate the recruitment time series signal perfectly. Of course, we never have perfect data so we should always expect the estimated signal (variability among the recruitment deviations) to be less than the true population recruitment variability.

 1

*SE*(*r*ˆ*y* )2 + *SD*(*r*ˆ)2 =  +

*σ*2

1 *−*1*/*22

*σ*2 

 2 2

*R*

*σ*

+

(*σ*2 + *σ*2)1*/*2 

= *σ*2

*R*

(14)

*d R R d*

The correct offset (bias adjustment) to apply to the expected value for recruitment is based on the concept that a time series of estimated recruitments should be mean unbiased, not median unbiased, because the biomass of a stock depends upon the cumulative number of recruits, which is dominated by the large recruitments. The degree of offset depends upon the degree of recruitment signal that can be estimated. Where no recruitment signal can be estimated, the median recruitment is the same as the mean recruitment, so no offset is applied. Where lognormal recruitment signal can be estimated, the mean recruitment will be greater than the median recruitment. The value

( 2

*by* =

*E S D*(*r*ˆ*y* )

2

*σ*

*R*

= 1 *−*

*SE*(*r*ˆ*y* )2

2

*σ*

*R*

(15)

of the offset then depends upon the partitioning of sigmaR into between and within recruitment variability. The most appropriate degree of bias adjustment can be approximated from the relationship among sigmaR, recruitment variability (the signal), and recruitment residual error.

INSERT FIGURE HERE

Because the quantity and quality of data varies during a time series, SS allows the user to control the rate at which the offset is ramped in during the early, data-poor years, and then ramped back to zero for the forecast years. On output to report.sso, SS calculates the mean bias adjustment during the early and main eras and compares it to the rmse of estimated recruitment devs. A warning is generated if the rmse is small and the bias adjustment is larger than 2.0 times the ratio of *rmse*2 to *sigmaR*2.

In MCMC mode, the model still draws recruitment deviations from the lognormal distribution, so the full offset is used such that the expected mean recruitment from this lognormal distribution will stay equal to the mean from the spawner-recruitment curve. When SS reaches the MCMC and MCEVAL phases, all biasadj values are set to 1.0 for all active recruitment deviations because the model is now re-sampling from the full lognormal distribution of each recruitment.

### Recruitment Autocorrelation

The autocorrelation parameter is implemented. It is not performance tested and it has no effect on the calculation of the offsets described in the section above.

### Recruitment Cycle

When SS is configured such that seasons are modeled as years, the concept of season within year disappears. However, there may be reason to still want to model a repeating pattern in expected recruitment to track an actual seasonal cycle in recruitment. If the recruitment cycle factor is set to a positive integer, this value is interpreted as the number of time units in the cycle and this number of full parameter lines will be read. The cyclic effect is modeled as an exp(p) factor times R0, so a parameter value of 0.0 has nil effect. In order to maintain

the same number of total recruits over the duration of the cycle, a penalty is introduced so that the cumulative effect of the cycle produces the same number of recruits as Ncycles \* R0. Because the cyclic factor operates as an exponential, this penalty is different than a penalty that would cause the sum of the cyclic factors to be 0.0. This is done by adding a penalty to the parameter likelihood, where:

*X* = )(*ep*)

*Y* = *Ncycle*

*Penalty* = 100000 *∗* (*X − Y* )2

(16)

### Initial Age Composition

A non-equilibrium initial age composition is achieved by setting the first year of the recruitment deviations before the model start year. These pre-start year recruitment deviations will be applied to the initial equilibrium age composition to adjust this composition before starting the time series. The model first applies the initial F level to an equilibrium age composition to get a preliminary N-at-age vector, then it applies the recruitment deviations for the specified number of younger ages in this vector. If the number of estimated ages in the initial age composition is less than Nages, then the older ages will retain their equilibrium levels. Because the older ages in the initial age composition will have progressively less information from which to estimate their true deviation, the start of the bias adjustment should be set accordingly.

### Fishing Mortality Method

There are now three methods available for calculation of fishing mortality. These are: Pope’s approximation, continuous F with each F as a model parameter, and a hybrid method that does a Pope’s approximation to provide initial values for iterative adjustment of the continuous F values to closely approximate the observed catch. With the hybrid method, the final values are in terms of continuous F, but do not need to be specified as full parameters. In a 2 fishery, low F case, it is just as fast as the Pope approx. and produces identical result. When F is very high, the problem becomes quite stiff for Pope’s and the hybrid method so convergence may slow. It may still be better to use F option 2 (continuous F as full parameters) in these high F cases. F as parameter is also preferred for situations where catch is known imprecisely and you are willing to accept a solution in which the final F values do not reproduce the input catch levels exactly. Option 1 (Pope’s approx) still exists, but my recommendation is to switch to option 3.

Control file continued:

Value Description

0.2 F ballpark

Value Description

This value is compared to the sum of the F’s for the specified year. The sum is over all seasons and areas. The lambda for the comparison goes down by a factor of 10 each phase and goes to 0.0 in the final phase.

-1990 F ballpark year

Negative value disable F ballpark

-3 F Method

1 = Pope’s

2 = Continuous F as a parameter 3 = Hybrid F

* 1. Maximum F

This maximum is applied within each season and area. A value of 0.9 is recommended for F method 1, and a value of about 4 is recommended for F method 2 and 3.

COND: Depending on the F method

COND = 1: No additional input for Pope’s approximation COND = 2: Continuous F

* 1. Starting value for each F. Initializing value for each F parameter.

1 Phase for F parameters becoming active.

For phases prior to this value, SS will use the hybrid option and the F values so calculated become the starting values for the F parameters when this phase is reached.

1 Number of detailed F inputs to read below. COND = 3: Hybrid F

4 Number of tuning iterations in hybrid method. A value of 2 or 3 is sufficient with a single fleet and low Fs. A value of 5 or so may be needed to match the catch near exactly when there are many fleets and high F.

If N for F detail is > 0

1 1980 1 0.20

0.05 4

fleet, year, season, F, SE, phase - these values override the catch se values in the data file and the overall starting F value and phase read just above.

### Initial Fishing Mortality

Read a short parameter setup line for each fishery. The parameters are the fishing mortalities for the initial equilibrium. Do not try to estimate parameters for fisheries with zero initial

equilibrium catch. If there is catch, then give a starting value greater than zero and it generally is best to estimate the parameter in phase 1.

It is possible to use the initial F method to achieve an estimate of the initial equilibrium Z in cases where the initial equilibrium catch is unknown. To do this:

* Include a positive value for the initial equilibrium catch;
* Set the lambda for the logL for initial equilibrium catch to a nil value (hence causing SS to ignore the lack of fit to the input catch level;
* Allow the initial F parameter to be estimated. It will be influenced by the early age and size comps which should have some information about the early levels of Z.

### Catchability

For each fishery and survey, enter a row with these 4 entries as described below:

* + - 1. Do\_Power
         1. 0 = skip, so the survey is directly proportional to abundance (typical)
         2. 1 = establish a parameter for non-linearity in survey-abundance linkage
      2. Do\_Env\_Link
         1. 0 = skip, no environmental on Q (typical)
         2. 1 = establish a parameter to create environmental effect on Q, where the integer is the index of the environmental variable to be linked. The relationship is: *ln*(*qy* ) =

*ln*(*qbase*) + *Qenv*\_*link*\_*para ∗ Env*\_*V aluey* .

* + - 1. Do\_extra SD
         1. 0 = skip (typical)
         2. 1 = estimate a parameter that will contain an additive constant to be added to the input stddev of the survey variability. This extra SD approach is highly redundant with the older code that provided for iterative input of variance adjustment factors. The newer code for extra SD estimation is recommended.
      2. Q Type
         1. <0 = mirror the Q from another (lower numbered survey designated by abs(value))
         2. 0 = set Q as a scaling factor such that the estimate is median unbiased. This is comparable to the old “float” option. This option is not available if a normal error structure is used.
         3. 2 = establish one parameter that will be the ln(Q). Note that Q is in log units even if the error structure is normal.
         4. 3 = establish one parameter that will be the base ln(Q) and a set of additional parameters for each year of the survey that will be deviations in ln(Q). These deviation parameters are full parameters, so each has a prior and variance, so surveys with high uncertainty in their calibration can be given a more diffuse prior to allow a larger deviation. Because each of these Q deviations is coded as a separate parameter, rather than a member of a deviation vector, the contribution of these deviations to the model’s objective function is captured in the parameter prior section. However, because there is no inherent constraint that these deviations have a zero sum, a separate log(L) contribution is calculated from the sum of the

deviations ((1+(),(*devs*))2)2 *−*1) and added to the “parm\_dev\_like” component.

* + - * 1. 4 = establish one parameter that will be the base ln(Q) and used as the Q for the first survey observation. Subsequent N-1 parameters for remaining survey observations will be deviations in random walk of ln(Q). These deviation parameters are otherwise treated identically to those generated by option (3) above, except that the extra contribution for the mean deviation is not calculated.
        2. 5 = This option will calculate the survey Q according to mean unbiased scaling, then assigns this value to the parameter (which must be set up in the control file and be given a negative phase). Advantage is that the calculated Q can now have a prior.

So for a setup with 2 fisheries and 2 surveys, the Q setup matrix could be:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| #Do\_power  (Den\_depend) | Env-Var | Extra SD | Devtype (<0=mirror, 0/1=none  2=cons, 3=rand, 4=randwalk) | |
| 1 | 0 | 1 | 2 | #Fishery 1 |
| 0 | 0 | 1 | 2 | #Fishery 2 |
| 0 | 0 | 0 | 4 | #Survey 1 |
| 0 | 0 | 1 | 2 | #Survey 2 |

COND: If any fishery or survey uses random devs or random walk, there is an option to either read detailed input to set up the deviation, or to just read a template.

|  |  |  |
| --- | --- | --- |
| #Value |  | Label, Description, and Options |
|  | 1 | Read detailed input for random effects |
|  | | 0: read one parameter line and use it as a template to |
| create a time series of parameters for each observation |
| for each fleet/survey that uses random effects. The |
| output to control.ss\_new will be in detailed format |
| even if the input is not detailed. Therefore a simple |
| way to create a detailed setup file is to start with a |
| simple template then edit the control.ss\_new file to |
| create a detailed input for subsequent model runs; |

1: read a parameter line for each observation of each fleet/survey that uses random effects, thus allowing customization. If the Q option for a fleet is 3 (random devs), then read one parameter for each observation. If the Q option is 4, then read (N observations -1) parameters.