

# **User Manual for Stock Synthesis**

**Model Version 3.04**

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## 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 (2006 in prep). SS is programmed using AutoDifferentiation Model Builder (ADMB; Fournier 2001, [admb-project.org](http://admb-project.org)). SS currently is compiled using ADMB version 7.0.1 using the Microsoft C++ compiler version 6.0. The model and a graphical user interface are available from the NOAA Fisheries Stock Assessment Toolbox website: <http://nft.nefsc.noaa.gov/>. An output processor in R is available from: <http://code.google.com/p/r4ss/>

## Evolution to SS version 3

The evolution from SS2 to SS V-3 was motivated by several factors. The experience gained from use of SS2 led to the identification of several model features needing fuller control and more options. The use of SS for more situations with precise catch-at-age data and high levels of fishing mortality also expanded the range of needed options. The possibility of using SS for more tuna assessments led to the need for better control of seasonally varying parameters, addition of weight frequency data, better control of movement parameters, and capability to include tag-recapture data. A fundamental internal change is the separation of the population length bin structure from the length data bin structure. This was necessary to create the new generalized size frequency capability. Now selectivity, weight-at-age, and other properties can be calculated more precisely from finer grained population length bins, while existing length data bins can remain unchanged. The result of these changes has been labeled SS\_V3 to avoid the awkward syntax posed by SS2 V2.xx. For shorthand, just say “SS”.

As the range of model inputs increases, so does the complexity of the input files. With this version of SS, there are several changes to reduce the burden on users and ease the development of input files.

- Input values are echoed to the file “echoinput.sso” so the user can see exactly how SS is reading and interpreting the input files.
- SS now produces four files (\*.ss\_new) that mirror the input files and provide text to describe the range of options available. This text will make it easier for users to take existing files and modify them to meet the conditions they which to invoke.
- All new features and several older features now have conditional inputs. This means that the user no longer needs to provide placeholder inputs for features they are not using. In addition, commented out placeholders for unused features still are output to the ss\_new file so their syntax is visible for future use.
- Some model features are now bundled into collections of advanced features. If the user sets an advanced feature flag to a value of 0, then there is no reading of that set of advanced features, SS assigns appropriate values or null values as necessary, and these assigned values appear as commented out output in the ss\_new file.
- Many more situations that are illegal or not optimal are identified and a warning is output to warning.sso. The total number of warnings is displayed to the screen at the end of the run.

- SS internally creates a text string to label each parameter. These labels are used to identify the parameters in the new control file (control.ss\_new), in the report file (Report.SSO), and in the covariance matrix output (COVAR.SSO) which is now output as a user-friendly database rather than a matrix.
- Comments can be read and stored if they are placed before the first valid input line in each input file and if each comment line begins with the characters #C. Blank lines and lines starting with just a # are ignored. These comment lines are written out at the top of report.sso and at the top of the \*.ss\_new files.

### Conversion from SS2 to SS\_V3

When SS2 V2.0 was created from SS2 V1.0, input for most new features was simply added to the end of starter.ss2 file. Now a more substantial reorganization has been undertaken with movement of some input features between data, control, starter and forecast files. For example, in keeping with the SS concept that the early data-poor period, the data-rich period, and the forecast period are just eras along a time continuum, control of the forecast recruitments is now adjacent to the control of other recruitments in the control file.

All of these changes are handled by a SS2 to SS\_V3 converter program (*SS2\_cvt.exe*). This converter works with any SS2 V2.x file (basically from Jan 2007 onwards). It reads the standard SS2 input files (*starter.ss2*, *forecast.ss2*, etc.) and outputs the translated input in a set of four new files named: *starter.ss*, *forecast.ss*, *control.ss*, and *data.ss*. Within *starter.ss*, it lists *data.ss* and *control.ss* as its linked data and control files. So, at a command prompt, type:

```
SS2_cvt.exe -nohess
```

which does the conversion. Then you can immediately open the new files in the SS GUI or run SS at the command prompt:

```
SS3.exe
```

### File Organization

#### Overview

#### Input Files

1. *STARTER.SS*: required file containing filenames of the data file and the control file plus other run controls.
2. *<datafile>*: file containing model dimensions and the data
3. *<control file>*: file containing set-up for the parameters
4. *SS3.PAR*: previously created parameter file that can be read to overwrite the initial parameter values in the control file (optional)
5. *FORECAST.SS*: file containing specifications for forecasts
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)

## Output Files

1. *SS3.PAR*, *SS3.STD*, *SS3.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).

## Auxiliary Files

1. *SS-OUTPUT.XLS*: Excel file with macros to read *report.sso* and display results
2. *SS2-NUDATA.XLS*: Excel file with macros to read *SS2-NUDATA.DAT* and parses into individual SS2-compatible datafiles with user-specified prefix and sequential suffix. (still needs update for *ss\_v3*).
3. *SELEX-24.XLS*: Excel file to test parameterization of new selectivity options 20 (age) and 24 (length)
4. *PRIOR-TESTER.XLS*: Shows how the various options for defining parameter priors works

## **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, R can search for these keywords and parse the specific information located below that keyword in the text file.

### **Computer Requirements and Recommendations**

SS is compiled to run under DOS with a 32-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.

Starter File

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.

| <b>STARTER.SS</b>            |   |  |
|------------------------------|---|--|
| <b>Typical Value</b>         | <b>Options</b>  | <b>Description</b>   |
| #C this is a starter comment | Must begin with #C then rest of line is free form   | All lines in this file beginning with #C will be retained and written to the top of several output files   |
| NewFeatures.DAT              | NewFeatures.DAT   | Filename of the data file  |
| NewFeatures.ctl              | NewFeatures.ctl   | Filename of the control file   |
| 0                            | <u>Initial parameter values</u><br>0=use values in control file;<br>1=use ss3.par after reading setup in the control file                       | Don't use this if there have been any changes to the control file that would alter the number or order of parameters stored in the SS3.par file.<br><br>Values in SS3.par can be edited, carefully |
| 1                            | <u>Run display detail</u><br>0=none other than ADMB outputs<br>1=one brief line of display for each iteration<br>2=fuller display per iteration | With option 2, the display shows value of each logL component for each iteration and it displays where crash penalties are created   |
| 1                            | <u>Detailed age-structured report in REPORT.SSO</u><br>0 = omit catch-at-age for each fleet and cohort<br>1 = include all output                |  |
| 0                            | <u>Check-up</u><br>0=omit<br>1=write detailed intermediate calculations to CHECKUP.SSO during first call  | This output is largely unformatted and undocumented and is mostly used by the developer.   |

|   |  |   |
|---|--|---|
| 0 | <u>Parameter Trace</u><br>0=omit<br>1=write good iterations and active parms<br>2= write good iterations and all parms;<br>3= write every_iter and all parms<br>4= write every_iter and active parms | This controls the output to PARMTRACE.SSO<br>The contents 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 | <u>Cumulative Report</u><br>0= Omit<br>1= Brief<br>2= Full   | Controls reporting to the file CUMREPORT.SSO.<br>This 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 | <u>Full Priors</u><br>0= only calculate priors for active parameters<br>1= calculate priors for all parameters that have a defined prior   | Turning on this option causes all prior values to be calculated. With this option off, the total logL, which includes the logL for priors, would change between model phases as more parameters became active   |
| 1 | <u>Soft Bounds</u><br>0= omit<br>1= use  | This option creates a weak symmetric beta penalty for 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. |

|     |   |  |
|-----|---|--|
| 1   | Data File Output<br>0= none<br>1= Output an annotated replicate of the input data file;<br>2= Add a second data file containing the model's expected values with no error added<br>3 to N = Add N-2 parametric bootstrap data files | All output files are sequentially output to DATA.SS_new and will need to be parsed by the user into separate data files.<br><br>The output of the input data file makes no changes, so retains the order of the original file<br><br>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   | <u>Turn off estimation</u><br>-1: exit after reading input files<br>0: exit after one call to the calculation routines and production of SSO and SS_New files;<br><positive value>: exit after completing this phase                | The "0" option is useful for (1) quickly reading in a messy set of 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 | <u>Jitter</u>   | A positive value here will add a small random jitter to the initial parameter values   |
| -1  | SD report start<br>-1: begin annual SD report in start year<br><year>: begin Sdreport this year   |  |

|                   |   |   |
|-------------------|---|---|
| -1                | SD report end<br>-1: end annual SD report in end year<br>-2: end annual SD report in last forecast year<br><value>: end SD annual report in this year |   |
| 2                 | Extra SD report years<br>0: none<br><value>: number of years to read  | In a long time series application, the model variance 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. |
| COND<br>1940 1950 | Vector of years for additional SD reporting   |   |
| 0.0001            | <u>Final convergence</u>  | 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                 | <u>Retrospective year</u><br>0: none<br>-X: retrospective year relative to end year   | Adjusts the model end year and disregards data after this year. May not handle time varying parameters completely.  |
| 2                 | <u>Summary biomass min age</u>  | Minimum integer age for inclusion in the summary biomass used for reporting and for calculation of total exploitation rate  |
| 1                 | <u>Depletion basis</u><br>0: skip;<br>1: X*B0;<br>2: X*Bmsy;<br>3: X*B_styr   | Selects the basis for the denominator when calculating degree of depletion in SSB. The calculated values are reported to the SD report  |
| .40               | Fraction (X) for Depletion denominator  | So would calculate the ratio $SSB_y / (0.40 * SSB_0)$   |

|   |   |   |
|---|---|---|
| 1 | <p><u>SPR report basis</u></p> <p>0: skip;<br/> 1: use <math>1-SPR_{target}</math>;<br/> 2: use 1-SPR at MSY;<br/> 3: use 1-SPR at <math>B_{target}</math>;<br/> 4: no denominator, so report actual 1-SPR values</p> | <p>SPR is the equilibrium SSB per recruit that would result 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.</p> <p>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 <math>(1.0 - SPR)</math>.</p> <p>This ratio (and its variance) is reported to the SD report output for the years selected above in the SD report year selection.</p>  |
| 1 | <p><u>F_std report value</u></p> <p>0: skip;<br/> 1: exploitation rate in biomass;<br/> 2: exploitation rate in numbers;<br/> 3: Sum(full F's by fleet)</p>   | <p>In addition to SPR, an additional proxy for annual F can 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.</p> <p>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.</p> <p>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.</p> |
| 1 | <p>F report basis</p> <p>0: not relative, report raw values;</p>  | <p>Selects the denominator to use when reporting the F_std report values. Note that order of these options differs from</p>   |

|     |  |   |
|-----|--|---|
|     | 1: use F_std value corresponding to $SPR_{target}$ ;<br>2: use F_std value corresponding to $F_{msy}$ ;<br>3: use F_std value corresponding to $F_{Btarget}$ | the biomass report basis options  |
| 999 | End of file  | Must be 999 in first 3 columns with no preceding tab or spaces in order to be correctly parsed by the #C comment reader |

[CHECK THIS] The *Jitter* factor works by adding:

random normal deviate \* *Jitter* \* (Parm\_max-Parm\_min)

to the initial value of the parameter. Except, (Parm\_max-Parm\_min) is replaced by the value 4.0 when applying *Jitter* to the recruitment deviation vector.

### Forecast File

The specification of options for forecasts is contained in the mandatory input file named *FORECAST.SS*. The contents of this file are:

| <b>FORECAST.SS</b>   |  |  |
|----------------------|--|--|
| <b>Typical Value</b> | <b>Options</b>   | <b>Description</b>   |
| #C forecast comment  |  | Same syntax and usage as in STARTER file   |
| 1                    | <u>Forecast Method</u><br>0=none;<br>1: F(SPR);<br>2: F(MSY);<br>3: F(Btarget);<br>4: F(endyr);<br>5: Ave recent F (enter yrs) – not yet implemented | Specifies whether or not to do a forecast and which F to use for that forecast.<br>Basis for some additional conditional input |

|                                    |     |  |   |
|------------------------------------|-----|--|---|
|                                    |     | 6: read Fmult – not yet implemented  |   |
| COND:<br>0 - 4                     |     | No additional input for these options  |   |
| COND:<br>5                         | -4  | First year for recent ave F relative to end year   | Read a range of years for calculation of recent average F (not yet implemented)   |
|                                    | 0   | Last year for recent ave F   | Will be used to calculate an average F multiplier for each fleet over a range of years  |
| COND:<br>6                         | 0.6 | F multiplier for option 6 (not yet implemented)  |   |
|                                    |     |  |   |
| End of conditional Forecast inputs |     |  |   |
| 2000                               |     | <u>Average Selectivity Begin</u><br>>0: absolute year<br><=0: year relative to end year                        | First year to use for averaging selectivity to use in forecast  |
| -1                                 |     | <u>Average Selectivity End</u><br>>0: absolute year<br><=0: year relative to end year                          | Last year to use for averaging selectivity to use in forecast   |
| 1                                  |     | <u>Benchmarks</u><br>0: omit;<br>1: calc F_spr, F_btgt, and F_msy  | SS checks for consistency of the Forecast specification and the benchmark specification. It will turn benchmarks on if necessary and report a warning.  |
| 2                                  |     | <u>Calculate MSY</u><br>1: set to F(SPR);<br>2: search for F(MSY);<br>3: set to F(Btgt);<br>4: set to F(endyr) | This input is ignored in benchmarks are turned off, but its existence is not conditional on benchmark switch. If Benchmarks are on, then F_spr and FBtgt are calculated. This MSY switch determines whether F_MSY is also calculated or is set to one of these other quantities |
| 0.45                               |     | <u>SPR<sub>target</sub></u>  | SS searches for F multiplier that will produce this level of spawning biomass (Reproductive output) per recruit relative to unfished value.   |
| 0.40                               |     | <u>Biomass<sub>target</sub></u>  | 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 |
| 10      | <u>N forecast years</u>  |  |
| 1       | <u>Advanced forecast options</u><br>0: use defaults<br>1: Read 10 inputs below                                   | Following 10 entries are conditional on this choice  |
| COND: 0 | No additional input for this option  |  |
| COND: 1 | Following 10 lines are included if advanced options is selected  |  |
| 0       | <u>Rebuilder</u><br>0: omit West Coast rebuilder output<br>1: do rebuilder output                                |  |
| -1      | <u>Rebuilder first year (Y declared)</u><br>>0: First year catch could have been set to zero;<br>-1: set to 1999 | SS will output the age composition at the beginning of this year.  |
| 2004    | <u>Rebuilder start year (Y initial)</u><br>>0: year for current age structure;<br>-1: set to endyear+1           | SS will output the age composition at the beginning of this year in addition to the age composition for Y declared..               |
| 2       | <u>Forecast Control Rule</u><br>1: west coast adjust catch;<br>2: adjust F                                       | In the forecast, either catch itself, or the F, can be a function of SSB   |
| 0.4     | <u>Control Rule Upper Limit</u><br>Biomass level (as fraction of B0) above which F is constant                   |  |
| 0.1     | <u>Control Rule Lower Limit</u><br>Biomass level (as fraction of B0) below which F is set to 0.0                 |  |
| 0.75    | <u>Control Rule Buffer</u><br>Multiplier applied to forecast F before calculating                                |  |

|                         |   |  |
|-------------------------|---|--|
|                         | catch   |  |
| 1                       | <u>Maximum Forecast Catch</u><br>0: omit;<br>1: cap in terms of retained catch biomass;<br>2: cap in terms of total catch biomass;<br>3: cap in terms of total catch numbers;<br>4: cap in terms of retained catch numbers; | This option is incompletely implemented. Currently, when the cap is encountered it will cause a problem with variance of forecast catch.<br>When this option is selected, then read the forecast catch cap values below, |
| 0                       | Reserved for future use as implementation error in forecast   |  |
| End of input for COND 1 |   |  |
| COND                    | If Maximum Forecast Catch flag is selected, then read the catch values next. Rows are seasons and columns are areas. A negative value signifies that no maximum is used for that season/area.                               |  |
| 600 -1                  | Max catch of 600 mt for season 1, area 1 and no max for area 2  |  |
| -1 300                  | Max catch values for season 2, areas 1 and 2  |  |
|                         |   |  |
| 1                       | Relative F Method<br>1: set relative F between fleets to the end year values<br>2: read allocation values below   |  |
| COND: 1                 | No additional input for option 1  |  |
| COND: 2                 | Read relative F by fleet  | Values will be rescaled to sum to 1.0 before being used in calculation of benchmark F multiplier and forecasts   |
| 0.2 0.3<br>0.4 0.1      | rows are seasons, columns are fleets  |  |
| End of relative F input |   |  |

|             |                   |  |  |
|-------------|-------------------|--|--|
| 2           |                   | Number of forecast catch levels to input (others will be calculated from forecast F) |  |
| COND:<br>0  |                   | No additional input if there are no forecast catch inputs                            |  |
| COND:<br>>0 | 1                 | basis for input forecatch<br>1: retained catch;<br>2: total dead catch               |  |
|             | 2008 1<br>1 785.  | Year Seas Fleet Catch  |  |
|             | 2008 1<br>2 3010. | Year Seas Fleet Catch  |  |
| 999         |                   | End file flag for forecast file  |  |

### Optional Input Files

#### RUNNUMBER.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.

#### 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.

## Data File

### *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. Ageing imprecision definitions
10. Age composition
11. Mean length-at-age
12. Generalized size composition (e.g. weight frequency)
13. Tag-recapture
14. Stock composition
15. Environmental data

### *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  $\text{eggs/kg} = 1$  for all weights; otherwise has units that are proportional to egg production.

Data File Syntax

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   | N 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.   |
| 1   | Spawning season; spawning biomass is calculated at the beginning of this season and used as basis for the total annual recruitment.  |
| 2   | N fishing fleets   |
| 2   | N surveys; These become numbered sequentially following the fisheries. With 2 fisheries and 2 surveys, the surveys will be fleet (aka "type") 3 and 4.   |
| 1   | Number of areas  |
| Comm_Fish%Recr_Fish<br>%Trawl_survey%Recruits | String containing names for each fishery and survey, delimited by the "%" character  |
| -0.7 0.5 0.6 0.75                             | Sample Timing: A vector containing the timing of each fishery and survey for the sole purpose of specifying the amount of age-specific mortality that occurs before the expected values are calculated.<br>Values are the fraction of the season elapsed before the CPUE is measured or the survey conducted. In a multiple season setup, this timing fraction is the same in each season. This fraction affects only the timing of the numbers at age calculation, the size-at-age is always calculated just at the midpoint of the season.<br>For the fishery data, this timing based approach means that the catch-at-age sampled will be |

|                  |  |
|------------------|--|
|                  | <p>different than the actual catch-at-age. The timing approach is a straightforward exponential calculation with continuous F and a timing value can be selected that will closely approximation the catch-at-age according to the standard catch equation.</p> <p>For Pope's the actual catch-at-age is calculated after <math>e^{-M*0.5*seasdur}</math> has occurred so is not at all responsive to catch that occurs within the season. The timing approach was implemented in SS so the fishery catch-at-age sample with Pope's would approximate the catch-at-age sample from continuous F. The downside is that the sample catch-at-age with Pope's diverges from the actual catch-at-age in that season.</p> <p>A new option is implemented with SS_V3.03. For the sample timing of fishing fleets (but not surveys), a negative value for Sample Timing will cause SS to use the actual catch-at-age and not a timed sample of catch-at-age.</p> |
| <b>1 2 1 1</b>   | Vector with area assignment for each fishery and survey  |
| <b>1 2</b>       | Vector with units of catch for each fleet (but not entered for the surveys)<br>1: biomass; 2: numbers  |
| <b>0.01 0.10</b> | Vector with std.err. of log(catch) for each fleet.<br>These values are used only in calculating the logL for the initial equilibrium catch and for the catch deviations if the F_Method is 2 or 3.<br>If year-specific std.err. values are needed, then use the advanced set-up in the control file.   |
| <b>2</b>         | Number of genders (1/2); females are gender 1  |
| <b>40</b>        | Accumulator age. This should be large enough so that fish at this age will be a very large (say 99%) of Linfinity. It also is important that this age be larger than the maximum age bin for the age data so that misaged old fish will principally have an assigned age that is still within the oldest age data bin.<br>Note: SS always starts at age 0.   |

### Catch

The catch data input has been modified to make it possible to maintain a long time series of catch data and then use just a subset for a particular model run. This requires explicitly reading a date field for each catch record. After reading the initial equil catch, read an integer with the number of catch input lines. Then read that number of input lines where each line has a vector of catch by fleet followed by the year and the season. Records that are before startyear or after endyr are dropped from the catch table used in the model.

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.

Previously, the input of catch units (biomass vs. numbers) for each fleet did not occur until the setup of the catchability characteristics for each fleet's CPUE. It was easily overlooked in that location. Now, a vector of Catch\_Units for fleets (not surveys) is read right after reading season timing in the data file. Not that this is separate from the units specified in the catchability section, so it would be possible to specify a fleet's catch in biomass and CPUE in numbers.

After reading fleet-specific catch\_units, read fleet-specific catch standard error. These values were implicitly set to 0.01 in SS2. In SS V3, they are used when calculating the likelihood for the initial equilibrium catch and for calculating the likelihood for catch when using F\_method 2 or F\_method 3. The catch stderr is meaningless when using Pope's approximation because the harvest rate is calculated to match the catch exactly.

|                 |   |
|-----------------|---|
| <b>100 1250</b> | Initial equilibrium catch for each fishery.<br>Enter annual values even if model has >1 season. If there are more than 1 seasons, then model will use first season body size and selectivity in calculating expected catch. |
| 96              | Number of catch records to read below<br>Any records that are outside the year range, start year to end year, are ignored   |
| 10 30 1950 1    | Fishery 1 catch, fishery 2 catch, year, season  |
| Etc.            |   |

- Catch can in terms of biomass or numbers for each fleet.
- Catch is retained catch. If there is discard data 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 an ability for the model to estimate the degree of unrecorded catch.

Abundance Indices

|           |   |
|-----------|---|
| <b>16</b> | N observations (Need to do manual count and enter N here) |
|-----------|---|

| Year | Seas | Fleet/Survey | Value | Std.err. of log(value) |
|------|------|--------------|-------|------------------------|
|------|------|--------------|-------|------------------------|

|             |          |          |              |              |
|-------------|----------|----------|--------------|--------------|
| <b>1991</b> | <b>1</b> | <b>3</b> | <b>80000</b> | <b>0.056</b> |
| <b>1995</b> | <b>1</b> | <b>3</b> | <b>65000</b> | <b>0.056</b> |
| .....       |          |          |              |              |
| <b>2000</b> | <b>1</b> | <b>4</b> | <b>42000</b> | <b>0.056</b> |

- Concept
  - Can be the CPUE of a fishery fleet, or can be a separate fishery
  - 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.
- Format
  - Fishing fleets and surveys are consecutively numbered
  - 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.
- Error distribution - There is some interaction between the information entered here and the information about error structure entered later in the control file.
  - Abundance indices typically have a lognormal error structure with units of standard error of  $\log_e(\text{index})$ . If the variance of the observations is available only as a CV, then the value of s.e. can be approximated as  $\sqrt{\log_e(1+CV^2)}$ , where CV is the standard error of the observation divided by the mean value of the observation.
  - When this lognormal error structure is used, then observations with a value less than or equal to zero are excluded from the logL calculation, but still included in the calculation of expected values.

- A new error structure introduced with version 3.03 is a normal error. **NOTE:** In this case 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 in the control file forces the user to provide different values for the se input in the data file.
- With the normal error structure, observations that are less than or equal to 0.0 are allowed as valid observations
- If the data exist as a set of normalized Z-scores, you can either: assert a lognormal error structure after entering the data as  $\exp(\text{Z-score})$  because it will be logged by SS. Alternatively, the Z-scores can be entered directly and the normal error structure can be used.
- **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.

| Pattern Number | Expected Value equals:     | Description  |
|----------------|----------------------------|--|
| 30             | Spawning Biomass           | Spawning biomass: e.g. for a egg&larvae survey               |
| 31             | Exp(Recruitment deviation) | useful for environmental index affecting recruitment         |
| 32             | SpawnBio * Exp(RecrDev)    | For a pre-recruit survey occurring before density-dependence |
| 33             | Recruitment                | Age 0 recruits   |

### Discard

|             |  |          |            |             |
|-------------|--|----------|------------|-------------|
| <b>2</b>    | Units<br>1: values are amount of discard;<br>2: values are fraction of total catch discarded |          |            |             |
| <b>2</b>    | N observations   |          |            |             |
| Year        | Seas   | Type     | Value      | Std_in      |
| <b>1980</b> | <b>1</b>   | <b>1</b> | <b>.05</b> | <b>0.25</b> |

|             |          |          |             |             |
|-------------|----------|----------|-------------|-------------|
| <b>1991</b> | <b>1</b> | <b>1</b> | <b>0.10</b> | <b>0.25</b> |
|-------------|----------|----------|-------------|-------------|

- Format
  - Type is sequential with the fishery fleet types
  - 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 datum causes it to be included in the calculation of expected values, but excluded from the logL
  - 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-year feature is used.

### Discard Error Structure

This is specified in the DF\_disc value near the end of the control file (sorry about that; later it will be moved into this data section). The selected option determines how the Std\_in is processed and used. The four options for DF\_disc are:

- >=1: T-distribution with degrees of freedom equal to the input value; Std\_in is interpreted as the CV of the observation;
- 0: Normal distribution; Std\_in is interpreted as the CV of the observation;
- -1: Normal distribution; Std\_in is interpreted as the standard error of the observation;
- -2: Lognormal distribution; Std\_in is interpreted as the standard error (in log space) of the observation;
- 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 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 std.err., not to the CV, to help correct this problem of underestimated variance.

### Mean Body Weight

|          |                |
|----------|----------------|
| <b>2</b> | N observations |
|----------|----------------|

| Year        | Seas     | Type     | Partition | Value     | CV          |
|-------------|----------|----------|-----------|-----------|-------------|
| <b>1990</b> | <b>1</b> | <b>1</b> | <b>0</b>  | <b>4.</b> | <b>0.95</b> |
| <b>1990</b> | <b>1</b> | <b>1</b> | <b>1</b>  | <b>1.</b> | <b>0.95</b> |

- Units must correspond to the units of body weight, normally kilograms.
- Mean bodywt observations have a normal error structure.
- Variance is entered as the coefficient of variation (CV) of the observed mean bodywt.
- Expected value of mean bodywt is calculated in a way that incorporates effect of selectivity and retention
- New specification that first appears here is “Partition”, where:
  - 0 means whole catch (discard+retained)
  - 1 means discarded catch
  - 2 means retained catch

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.

|              |  |    |
|--------------|--|----|
|              | Length bin method. This creates a Conditional read situation below:<br>1=use databins;<br>2=generate from binwidth,min,max below<br>3=read vector                    |    |
| COND 1       |  |    |
| 1            | Selects option 1; No additional input necessary  |    |
| COND 2       |  |    |
| 2            | Selects option 2;Read 3 additional input values  |    |
| 2            | 26   | 84 |
|              | Binwidth, lower size of first bin, lower size of largest bin.<br>The number of bins is then calculated from: $(\max L_{read} - \min L_{read}) / \text{binwidth} + 1$ |    |
| COND 3       |  |    |
| 3            | Selects option 3; Read 1 value, then read vector of bin boundaries   |    |
| 25           | number of population length bins to be read  |    |
| 26 28 30 ... | Vector containing lower edge of each population size bin   |    |
|              | <b>End of Conditional inputs for Length Bin Method</b>   |    |

Notes:

For option 2, binwidth 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.

Note that in SS2, the minimum size of fish in the population was defined to be equal to the smallest data size bin. If the growth curve defined any smaller fish, these were simply assigned to this first size bin. Also, size selectivity for the smallest fish was calculated on the basis of the first size bin and, implicitly, any smaller fish would have the same selectivity. Now, population size composition and size-selectivity are defined for size bins that may be smaller than the smallest size data bin. This could cause some change in the details of the fit for previously constructed SS models. The selectivity pattern #24 has been modified (see below) to reduce this effect.

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 logL with respect to that parameter and convergence will be hampered. A generic guidance to avoid this situation is not yet available.

### Length Composition

|                |   |
|----------------|---|
| <b>-0.0001</b> | 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 |
| <b>0.0001</b>  | Constant added to observed and expected proportions at length and age to make logL calculation more robust; Tail compression occurs before adding this constant<br>Proportions are renormalized to sum to 1.0 after constant is added   |

|                  |   |
|------------------|---|
| <b>0</b>         | 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. |
| <b>22</b>        | N bins in the length composition data   |
| <b>32 34 ...</b> | Vector containing lower edge of length bins. The last length bin will have same width as next lower bin   |

- Bin width does not need to be uniform for either the population (with option 3) or length composition data
- 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.
- SS will compare the population bin boundaries to the length data bin boundaries and will create a fatal error if there is any misalignment. However, for the generalize size composition data (see below), there is no need for alignment because SS will interpolate as necessary.
- 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.

|           |                            |
|-----------|----------------------------|
| <b>30</b> | N Length comp observations |
|-----------|----------------------------|

Example of a single length composition observation:

|      |      |       |        |           |       |             |
|------|------|-------|--------|-----------|-------|-------------|
| Year | Seas | Fleet | Gender | Partition | Nsamp | data vector |
|------|------|-------|--------|-----------|-------|-------------|

|      |   |   |   |   |    |                         |
|------|---|---|---|---|----|-------------------------|
| 1986 | 1 | 1 | 3 | 0 | 20 | <female then male data> |
|------|---|---|---|---|----|-------------------------|

- 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 (see “gender” note below).
- 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 and are re-sorted by time within fleet after being read. However, if the super-year approach is used, then these observations must be read in chronological order within fleet.
- Gender Flag: If model has only one gender defined in the set-up, all observations must have gender set equal to 0 or 1.
- Gender flag in 2 gender model:
  - 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 indicates discard vs. retained (0=combined; 1=discard; 2=retained)
- 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 Nsamp 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.

### Age Composition

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 | N age' bins; |
|----|--------------|

|  |   |
|--|---|
|  | can be equal to 0 if age data not used;<br>do not include a vector of agebins if Nage'bins is set equal to 0; |
|--|---|

|          |          |          |          |          |          |          |          |          |           |           |           |           |           |           |           |           |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b> | <b>9</b> | <b>10</b> | <b>11</b> | <b>12</b> | <b>13</b> | <b>14</b> | <b>15</b> | <b>20</b> | <b>25</b> |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|

- 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.

|          |   |
|----------|---|
| <b>2</b> | Number of ageing error matrices to generate |
|----------|---|

- In principle, one could have year, or laboratory specific matrices
- If no age data, there can be 0 vectors
- 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 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.
- Followed by a vector with the stddev of age' for each true age
- Setting the stddev <=0.0 will generate a warning and reset the stddev to a value of 0.001, which generates negligible dispersion of age' at age..
- The following table shows the values for the first 5 ages for each of two age transition definitions:

| <b>For age 0</b> | <b>Age 1</b> | <b>Age 2</b> | <b>Age 3</b> | <b>Age 4. Etc.</b> |
|------------------|--------------|--------------|--------------|--------------------|
| <b>-1</b>        | <b>-1</b>    | <b>-1</b>    | <b>-1</b>    | <b>-1</b>          |
| <b>0.001</b>     | <b>0.001</b> | <b>0.001</b> | <b>0.001</b> | <b>0.001</b>       |
| <b>0.5</b>       | <b>1.5</b>   | <b>2.5</b>   | <b>3.5</b>   | <b>4.3</b>         |
| <b>0.5</b>       | <b>0.65</b>  | <b>0.67</b>  | <b>0.7</b>   | <b>0.8</b>         |

|           |   |
|-----------|---|
| <b>26</b> | N age observations  |
| <b>1</b>  | Length bin range method for Lbin_lo and Lbin_hi:<br>1 = value refers to population length bin index<br>2 = value refers to length data bin index<br>3 = value is an actual length (which must correspond to a population length bin boundary) |

|          |   |
|----------|---|
| <b>1</b> | Combine males into females below this age bin number. Note this is in terms of age' bins, not true age. |
|----------|---|

An example age composition observation

| Year        | Seas     | Fleet    | Gender   | Partition | ageerr   | Lbin<br>lo | Lbin<br>hi | Nsamp     | data<br>vector |
|-------------|----------|----------|----------|-----------|----------|------------|------------|-----------|----------------|
| <b>1987</b> | <b>1</b> | <b>1</b> | <b>3</b> | <b>0</b>  | <b>2</b> | <b>-1</b>  | <b>-1</b>  | <b>79</b> | values         |

- 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 Nsamp causes 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.

**Conditional Age'-at-Length:**

- 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.
- 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.
- 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 because it:
  - Avoids double use of fish for both age' and size information because the age' information is considered conditional on the length information;

- 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;
- 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.

### 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.

```
1 #_N_age_bins # so all fish are put into a single "age" bin regardless of their true age
10 # assigned "age" for this one bin
1 #_N_ageerror_definitions
10.5 10.5 10.5 10.5 10.5 10.5 repeat for each true age in model, beginning at age 0
0.001 0.001 0.001 0.001 0.001 0.001 ... repeat for each true age in model, beginning at age 0
```

```
1 #_N_Agecomp_obs
1 #_Lbin_method: 1=poplenbins; 2=datalenbins; 3=lengths
0 #_combine males into females at or below this bin number
# There are 4 females and 8 males in the 25th population length bin
```

| #Yr  | Seas | Flt/Svy | Gender | Part | Ageerr | Lbin_lo | Lbin_hi | Nsamp |   |   |   |   |   |   |   |   |   |   |
|------|------|---------|--------|------|--------|---------|---------|-------|---|---|---|---|---|---|---|---|---|---|
| 1971 | 1    | 1       | 3      | 0    | 1      | 25      | 25      | 12    | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 8 | 0 | 0 |

If you have both real age data and sex ratio at length data, then you will need to set up the N\_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
1 2 3 4 5 # "age" bins
2 #_N_ageerror_definitions
-1 -1 -1 -1 -1 extend for each true age in model, beginning at age 0
.2 .4 .5 .8 1 extend for each true age in model, beginning at age 0
```

3.5 3.5 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 0.001 0.001 ... repeat for each true age in model, beginning at age 0  
 2 #\_N\_Agecomp\_obs  
 1 #\_Lbin\_method: 1=poplenbins; 2=datalenbins; 3=lengths  
 0 #\_combine males into females at or below this bin number

| #Yr  | Seas | Flt/Svy | Gender | Part | Ageerr | Lbin_lo | Lbin_hi | Nsamp |   |   |   |   |   |   |   |   |   |   |                      |
|------|------|---------|--------|------|--------|---------|---------|-------|---|---|---|---|---|---|---|---|---|---|----------------------|
| 1971 | 1    | 1       | 3      | 0    | 1      | -1      | -1      | 25    | 1 | 2 | 4 | 7 | 4 | 0 | 2 | 3 | 6 | 3 | #real age data       |
| 1971 | 1    | 1       | 3      | 0    | 2      | 25      | 25      | 12    | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | # sex ratio in bin 3 |

Mean Length-at-age

SS also accepts input of mean length-at-age' observations. 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'.

|          |                          |
|----------|--------------------------|
| <b>1</b> | N size@age' observations |
|----------|--------------------------|

An example observation appears below.

| Year        | Seas     | Fleet    | Gender   | Partition | AgeErr   | Nsamp    | Female Data             | Male Data               | Female N      | Male N        |
|-------------|----------|----------|----------|-----------|----------|----------|-------------------------|-------------------------|---------------|---------------|
| <b>1989</b> | <b>1</b> | <b>1</b> | <b>3</b> | <b>0</b>  | <b>2</b> | <b>2</b> | <b>Mean size values</b> | <b>Mean size values</b> | <b>N fish</b> | <b>N fish</b> |

- Nsamp value is ignored if positive, but a negative value cause the entire observation to be ignored
- Negatively valued mean size entries will 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 gender's 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

|           |                              |
|-----------|------------------------------|
| <b>2</b>  | N environmental variables    |
| <b>10</b> | N environmental observations |

Example of 2 environmental observations

| Year        | Variable | Value       |
|-------------|----------|-------------|
| <b>1990</b> | <b>1</b> | <b>0.1</b>  |
| <b>1991</b> | <b>1</b> | <b>0.15</b> |

- 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 biomass units or numbers units.

- 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.

|            |  |
|------------|--|
| 2          | # N WtFreq 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 | mincomp to add to each obs (entry for each method)   |
| 40 5       | N observations per wtFreq 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 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 68 | 72 | 76 | 80 | 90 |
| 1  | 2.5 | 4  | 9  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

- There is no tail compression option for generalized size frequency data;
- Super-year capability is also not enabled for generalized size comps
- 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 | Yr   | seas | Fleet | Gender | Partition | samplesize | <composition females then 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).

|   |   |
|---|---|
| 1 | Do_Tags If this value is 0, then omit all entries below |
|---|---|

All subsequent tag-recapture entries must be omitted if Do\_Tags = 0.

|    |   |
|----|---|
| 3  | N tag groups  |
| 12 | N recap events  |
| 2  | Mixing latency period: N periods to delay before comparing observed to expected recoveries (0 = release period) |
| 10 | Max periods (seasons) to track recoveries, after which tags enter accumulator                                   |

Release data

| TG | area | yr   | season | <tfill> | gender | Age | Nrelease |
|----|------|------|--------|---------|--------|-----|----------|
| 1  | 1    | 1980 | 1      | 999     | 0      | 24  | 2000     |
| 2  | 1    | 1995 | 1      | 999     | 1      | 24  | 1000     |
| 3  | 1    | 1985 | 1      | 999     | 2      | 24  | 10       |

Note: the release data must be entered in TG order.

Note: <tfill> values are placeholders and are replaced by program generated values for model time.

Recapture data

| TG | year | season | fleet | Number |
|----|------|--------|-------|--------|
| 1  | 1982 | 1      | 1     | 7      |
| 1  | 1982 | 1      | 2     | 5      |
| 1  | 1983 | 1      | 1     | 4      |
| 1  | 1983 | 1      | 2     | 3      |
| 1  | 1984 | 1      | 1     | 2      |
| 1  | 1984 | 1      | 2     | 1      |
| 1  | 1985 | 1      | 1     | 1      |
| 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      |

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) |
| 3       | N observations  |
| 2       | N stocks  |
| 0.00001 | Mincomp   |

| Year | Seas | Fleet | partition | Nsamp | datavector |
|------|------|-------|-----------|-------|------------|
| 1980 | 1    | 1     | 0         | 36    | .4 .6      |
| 1981 | 1    | 1     | 0         | 40    | .44 .62    |
| 1982 | 1    | 1     | 0         | 50    | .49 .5     |

- 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

|            |                          |
|------------|--------------------------|
| <b>999</b> | #end of data file marker |
|------------|--------------------------|

## Excluding data

Revise pre-processing of the data and writing of data to the data.ss\_new file to make it robust to using negative year as a way to ignore 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; previously the Nobs values could have been incorrect in data.ss\_new if some data were being screened out.

## Data Super Years

The “Super-Year” capability allows the user to introduce data that represent a blend across multiple years and to cause the model to create a expected value for this observation that uses the same blend of years. The option is available for all types of data and a similar syntax is used. For length comp obs:

A Nsamp value of -9999 denotes the first year of the superyear.

A Nsamp value of -9998 ends the superyear sequence.

All superyear observations must be contiguous in the data file, but not all years in the sequence need to be included. Typically, all but one of the years in the sequence will have a negative value for the Nsamp field so the data associated with these negative Nsamp observations will be ignored. The observed values must be combined outside of the model and then inserted into the data file. Only the info for the observation assigned a positive Nsamp value matters.

An expected length comp will be computed for each time period in the super year sequence. All of these expected compositions will have equal weight in the calculation of the expected super year value (that is, they are not weighted by the absolute value of the Nsamps). Any observations in the super year sequence with a positive Nsamp value must contain real data to be compared to the blended super year expected value.

It is tricky to create a super year with only 2 obs since one must start and one must end the sequence, so there is none to contain a positive Nsamp with the real data. So you'll need to create a 4 observation sequence. The first will have the starting superyr code, the second will be a dummy obs and must have the same year as the first, the third will hold the positive Nsamp value and have the same year as the ending obs, and fourth obs to have the ending Nsamp code. So the first year and the second year are equally represented in the super year sequence, so the expected value will be properly balanced across the two years.

For Survey Index super years, use the same syntax as for lengthcomp except use the -9999 and -9998 start-stop values in the CV field. The obs itself must have a negative value (ignore) for the obs that store the codes.

For Discard Obs, same as for survey index obs

For Agecomp Obs, same as for lengthcomp

For Length-at-Age Obs, same as for lengthcomp - put the code in the sample size field which is otherwise unused. Note that only the expected mean size is blended across years, the expected value for the se of meansize is calculated for each year individually.

The Super-year concept can also be used within year for a model setup with multiple seasons. For example, enter the -9999 for a season 1 pseudo-observation, put the actual annual data in a season 2 observation and put the -9998 in season 3 to end the super-season sequence. 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 (but note that all seasons get equal weight in the super-season combination process).



## Control File

### *Overview of Control File*

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. Specifications for mortality, 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. Environmental link parameters for any MG parameters that use a link
11. Time-varying setup for any MG parms that use blocks
12. Seasonal effects on biology parameters (new in v3)
13. Phase for any MG parms that use annual deviations
  
14. Spawner-Recruitment parameters
15. Recruitment deviations (much revised in v3)
  
16. Method for calculating fishing mortality (F)
17. Initial equilibrium F for each fleet
  
18. Catchability (Q) setup for each fleet and survey (expanded options for random devs in v3)
19. Catchability parameters
  
20. Length selectivity, retention, discard mortality setup for each fleet and survey
21. Age selectivity setup for each fleet and survey
22. Parameters for length selectivity, retention, discard mortality for each fleet and survey
23. Parameters for age selectivity for each fleet and survey
24. Environmental link parameters for any selectivity/retention parameters that use a link
25. Time-varying setup for any selectivity/retention parameters that use blocks
26. Phase for any selectivity/retention parameters that use random annual deviations
  
27. Tag-recapture parameters
  
28. Variance adjustments
29. Error structure for discard and mean body weight
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:

| <u>Column</u>   | <u>Element</u> | <u>Description</u>   |
|---|----------------|--|
| 1   | LO             | Minimum value for the parameter  |
| 2   | HI             | Maximum value for the parameter  |
| 3   | INIT           | Initial value for the parameter. If the SS2.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  |
| 6   | Prior stddev   | Standard deviation for the PRIOR, used to calculate likelihood of the current parameter value. This value is ignored if Prior_type is -1       |
| 7   | PHASE          | Phase in which parameter begins to be estimated. A negative value causes the parameter to retain its INIT value (or value read from 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. |                |  |
| <u>8</u>  | ENV            | Create a linkage to an input environmental time series   |
| <u>9</u>  | USE_Dev        | Invokes use of the dev vector  |
| <u>10</u>   | DEV min yr     | Beginning year for the dev vector  |
| <u>11</u>   | DEV max yr     | Ending year for the dev vector   |
| <u>12</u>   | DEV std.dev.   | Standard deviation for elements in the dev vector.   |
| <u>13</u>   | USE-BLOCK      | Set up blocks or parameter trends  |
| <u>14</u>   | BLOCK-TYPE     | Functional 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
- 

| VALUE       | DESCRIPTION   | Comments and Options   |
|-------------|---|--|
| #C comment  | Comments beginning with #C at top of file will be retained and included in output files |  |
| 2           | N growth patterns (GP)  |  |
| 3           | N sub-morphs within 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        | 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 for first value of vector to get a normal approx:<br>{ 0.15,0.70,0.15} for 3 sub-morphs<br>{ 0.031, 0.237, 0.464, 0.237, 0.031} for 5 sub-morphs |

|              |  |   |
|--------------|--|---|
|              |  |   |
| COND         | Only read recruitment assignment section below if $N\_GP * N\_seas * N\_area > 1$  |   |
| 4            | Number of recruitment assignments  | This specifies which GP, area, seasons have any fraction of the total recruitment assigned. Value here does not affect the required number of recruitment parameter reads below (which must equal $N\_GP + N\_area + N\_seas$ ) |
| 0            | Recruitment interaction requested?   | If value is 1, then also read $N\_GP * N\_area * N\_seas$ parameters  |
| 1 1 1        | Recruitment assignment to GP 1, seas 1, area 1   |   |
| 2 1 2        | Recruitment assignment to GP 2, seas 1, area 2   |   |
| 1 2 1        | Recruitment assignment to GP 1, seas 1, area 1   |   |
| 2 2 2        | Recruitment assignment to GP 2, seas 2, area 2   |   |
|              |  |   |
| COND         | Only read following movement section if $N\_area > 1$  |   |
| 4            | N movement definitions   |   |
| 0.6          | First age that moves   | Real, not integer, age at begin 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 definition specifies:<br>seas, 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 1 2 1 4 10 |  |   |
| 1 2 1 2 4 10 |  |   |
| 1 2 2 1 4 10 |  |   |
|              |  |   |
| 3            | N 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;<br>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.

|        |                             |   |
|--------|-----------------------------|---|
| 0.5    | Fraction female             | A constant that applies to all growth patterns  |
| 1      | natM option                 | 0: For 1Parameter;<br>1: for N_breakpoints;<br>2: for Lorenzen;<br>3: read age specific M and do not do seasonal interpolation;<br>4: read age specific and do seasonal interpolation.<br>Options 1 and 2 also do seasonal interpolation, if appropriate.<br>Each option has different additional inputs below. |
| COND=0 | No additional natM 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             | Vector of age breakpoints   |  |
| COND=2                       |   |  |
| 4                            | Read one additional value that is the reference age (integer) for the Lorenzen function | 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 as 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                  |   | No additional parameters are read. With option 3, 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.   |
| 0.2 0.25 etc<br>0.2 0.23 etc | Age-specific M values   | Row 1 is female, GP1, row 2 is female GP2, row 3 is male GP1, etc.   |
|                              |   |  |
| 1                            | Growth model  | 1: von Bertalanffy (2 parameters);<br>2: Schnute's generalized growth curve (aka Richards curve) with 3 parameters   |
| 1.66                         | Growth_Amin (A1)  | Reference age for first size-at-age parameter .See growth notes below  |
| 25                           | Growth_Amax   | Reference age for second size-at-age parameter   |
| 0                            | SD_add_to_LAA   | Enter 0.1 to mimic SS2 V1.xx. See growth notes. Recommend using a value of 0.0   |

|                   |   |  |
|-------------------|---|--|
| 1                 | CV_Pattern  | 0: for CV=f(LAA);<br>1: for CV=f(A);<br>2: for SD=f(LAA);<br>3: for SD=f(A)  |
| 2                 | Maturity option   | 1: for length logistic;<br>2: for age logistic;<br>3: read age-maturity for each female GP;<br>4: read age-fecundity for each female GP. This is a new option in SS_v3.<br>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 for details.<br>NOTE: need to read 2 parameters even if option 3, 4, or 5 is selected |
| COND              | If Maturity option =3 or =4   |  |
| 0.0 0.05 0.1 .... | vector of age-specific maturity or fecundity  | One row of length Nages+1 for each female GP   |
| 1                 | First Mature Age  | Overridden if maturity option = 3, 4 or 5 but still must exist here  |
| 1                 | Fecundity option  | 1: to interpret the 2 egg parameters as linear eggs/gm on body weight (current SS default), so fecundity = wt * (a+b*wt), so value of a=1, b=0 causes eggs to be equiv to spawning biomass<br>2: to set fecundity=a*L^b<br>3: to set fecundity=a*W^b, so values of a=1, b=1 causes fecundity to be equiv to spawning biomass<br>This is overridden if Maturity_Option =4 or 5  |
| 0                 | Hermaphroditism option  | 0 = no; 1 = invoke female to male transition   |
| COND              | Read 2 lines below if herma. is selected;<br>Also read 3 parameters after reading the male weight-length parameters |  |
| -1                | Hermaphroditism season  | -1 to do transition at 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 spawnbio; 1=simple add of males to females; xx – more options to come later   |
| 2 | Offset method                      | 1: direct assignment;<br>2: for each GP x gender, parameter defines offset from GP 1 gender 1;<br>3: offsets same as SS2 V1.xx with natmort old and CV_growth old as offset from young values for that GP x gender    |
| 1 | Time-varying adjustment constraint | 1: parameter adjustments for env, block and dev are not constrained by bounds<br>2: parameter adjustments use a logistic transformation to assure that adjusted parameter value stays within bounds of base parameter |

### Read Mortality-Growth Parameters

Next, SS reads the MG growth parameters.

| Parameters  | Description   |
|---|---|
| N natM parameters,<br>3or 4 growth parameters,<br>2 CV parameters | natural mortality & growth for female, GP1; where the “N” number of natM parameters depends on the option selected. See detailed description of these parameters in section below |
| “   | natural mortality & growth for female, GP2; Note that the order of these blocks of parameters by GP and gender was incorrectly specified in the SS2 user manual.                  |
| “   | natural mortality & growth for male, GP1  |
| “   | natural mortality & growth for male, GP2  |
| 2 wt-len, 2 maturity, 2 fecundity                                 | Female biology  |
| 2 wt-len  | Male biology (if 2 genders exist)   |
| 3 hermaphroditism   | Only if hermaphroditism is selected   |

|                                  |  |
|----------------------------------|--|
| N GP                             | Recruitment apportionment main effect  |
| N areas                          | Recruitment apportionment  |
| N seasons                        | Recruitment apportionment  |
| N patterns x N areas x N seasons | Only if Recr_Dist_Interaction =1 (on).<br>Note that the order of recr_dist parameters has area then seas for main effects, and seas then area for interactions |
| 1                                | Cohort growth deviation  |
| 2 x N selected movement pairs    | Movement parameters  |

The biology parameters are:

|                      |  |
|----------------------|--|
| Natmort_young        | Natural mortality for ages $\leq$ NMyoung (units are per year)   |
| Natmort_old          | Natural mortality for ages $\geq$ NMold. For intermediate ages, do a linear interpolation of NM on age.  |
| Lmin                 | Body length at Amin (units in cm)  |
| Lmax                 | Body length at Amax (units in cm)  |
| VBK                  | Von Bertalanffy growth coefficient (units are per year)  |
| 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.  |
| CV-young             | Variability for size at age at age $\leq$ AFIX (units are fraction). Note that CV cannot vary over time, so do not set up an env-link or a dev vector. Also, units are either as CV or as stddev, depending on assigned value of CV_pattern. |
| CV-old               | Variability for size at age at age $\geq$ AFIX2. For intermediate ages, do a linear interpolation of CV on mean size-at-age. Note that the units for CV will depend on the CV_pattern and the value of Mgparm_as_offset.                     |
| Female_scale         | coefficient to convert L in cm to Wt in kg   |
| Female_exp           | Exponent in female L-W conversion  |

|   |  |
|---|--|
| Mat_inflect                               | Maturity logistic inflection (in cm or years). Where Female Maturity-at-length (or age) is a logistic function:<br>$mat=1/(1 + \exp(\text{slope}*(\text{<size or age>}-\text{inflection})))$ |
| Mat_slope                                 | Logistic slope (must have a negative value)  |
| Alpha                                     | Two fecundity parameters; usage depends on the selected Fecundity option. Must be included here even if vector is read in the control section above  |
| Beta                                      |  |
| Male_scale                                | Male body weight at length parameters. Only include these in a 2 gender model.   |
| Male_exp                                  |  |
| Hermaphrodite inflection age              | 3 parameters that define a normal distribution for the transition rate of females to males. Only include if hermaphroditism is selected.   |
| Hermaphrodite standard deviation (in age) |  |
| Hermaphrodite asymptotic rate             |  |

### 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.

### Growth Notes

A new growth function has been implemented and there are placeholders for some others to be implemented. In the control file, SS now reads *grow\_type*. A value of 1 is equivalent to the Bertalanffy growth function used in SS2. A value of 2 invokes use of an additional parameter for a generalized growth function as defined by Schnute. The fourth parameter is read after reading the Bertalanffy K parameter. When this fourth parameter has a value of 1.0, it is equivalent to the standard von B growth curve. Additional growth types that are planned are the von B parameterized directly with A0 and Linf parameters, and a capability to use an empirical vector of mean lengths-at-age. When the generalized function is used and the Richards coefficient is estimated, the AFIX age should be set to 0.0 to avoid problems with the gradient calculation.

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”.

New feature: If “Growth\_age\_for\_L2” is set equal to 999, then the size L2 is used as  $L_{inf}$ .

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  $L_{inf}$  parameters.

### **Growth patterns (morphs) and sub-morphs**

The user specifies a number of growth patterns (usually just 1) and a number of genders (usually 2), and the number of sub-morphs per gender (1, 3, or 5 are permissible values). 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 in Seasonal Model**

Recruitment can occur in any season. There still is just one value of spawning biomass calculated annually at the beginning of one specified spawning season and this spawning biomass produces one annual total recruitment value. This annual recruitment is distributed among seasons, areas, and growth types according to other model parameters. 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  $\ln(\text{apportionment weight})$ , 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  $\ln(\text{movement coefficient})$ ). 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).

Note that in developing the firststage capability, a related and currently unresolved logic conflict became apparent. In a multi-season setup, it is possible to allow a growth pattern (GP) to have some fish recruit in different “birthseasons”. However, age-specific movement rates are interpolated using integer age, not real age, and movement parameters are common to the entire GP, not to birthseason within GP. Also, movement parameters are explicitly season-specific. Because movement is season-specific, it does not make sense to have movement rates change according to the advancement of real age between seasons. The fix will probably involve making movement parameters be 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:

- a. 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;
- b. 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:

- a. constant at P1 below minage, constant at P2 above maxage, and linearly interpolated for intermediate ages;

- b. exponentiated so that a movement strength parameter value of 0 becomes 1.0;
- c. for movement out of an area, the exponentiated value is multiplied by season duration;
- d. 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;
- e. 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:

| Min | Max | Val | Per standard format..... |    |    |    |   |   |   |   |     |   |   |   |                                  |
|-----|-----|-----|--------------------------|----|----|----|---|---|---|---|-----|---|---|---|----------------------------------|
| -4  | 4   | 0   | 1                        | -1 | 99 | -3 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | RecrDist_GP_1                    |
| -4  | 4   | 0   | 1                        | -1 | 99 | -3 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | RecrDist_GP_2                    |
| -4  | 4   | 0   | 1                        | -1 | 99 | -3 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | RecrDist_Area_1                  |
| -4  | 4   | -4  | 1                        | -1 | 99 | 3  | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | RecrDist_Area_2                  |
| -4  | 4   | 0   | 1                        | -1 | 99 | -3 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | RecrDist_Seas_1                  |
| -4  | 4   | -4  | 1                        | -1 | 99 | -3 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | RecrDist_Seas_2                  |
| -1  | 2   | 1   | 1                        | -1 | 99 | -3 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | CohortGrowDev                    |
| -5  | 5   | -4  | 0                        | 0  | 99 | -5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | MoveParm_A_seas_1_GP_1from_1to_2 |
| -5  | 5   | -4  | 0                        | 0  | 99 | -5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | MoveParm_B_seas_1_GP_1from_1to_2 |
| -5  | 5   | -4  | 0                        | 0  | 99 | -5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | MoveParm_A_seas_1_GP_1from_2to_1 |
| -5  | 5   | -4  | 0                        | 0  | 99 | -5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | MoveParm_B_seas_1_GP_1from_2to_1 |
| -5  | 5   | -4  | 0                        | 0  | 99 | -5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | MoveParm_A_seas_1_GP_2from_1to_2 |

|    |   |    |   |   |    |    |   |   |   |   |     |   |   |   |                                  |
|----|---|----|---|---|----|----|---|---|---|---|-----|---|---|---|----------------------------------|
| -5 | 5 | -4 | 0 | 0 | 99 | -5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | MoveParm_B_seas_1_GP_2from_1to_2 |
| -5 | 5 | -4 | 0 | 0 | 99 | -5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | MoveParm_A_seas_1_GP_2from_2to_1 |
| -5 | 5 | -4 | 0 | 0 | 99 | -5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | # | MoveParm_B_seas_1_GP_2from_2to_1 |

- 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:

$$\text{rate}_i = e^{p_i} / \sum_{j=1}^N e^{p_j}$$

- 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.

### 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.

### Time-varying growth caution

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 growth parameters in effect during the forecast will revert to the "no-block" baseline level. By setting the end year of the last block to endyr+1, the model will continue the last block's growth parameter levels throughout the forecast.
- The equilibrium benchmark quantities (MSY, F40%, etc.) currently use the endyr body size-at-age. This is a disequilibrium vector of body size-at-age, the age-specific values of which are dependent on the timing of growth parameter changes. There is not a recalculation of equilibrium size-at-age according to a specific set of growth parameters. Future model upgrades will address this issue.
- 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  $L_{inf}$  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.

| 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<br><br>1: Use custom environmental linkage, so read one parameter line for each MG parameter that uses linkage |
| <short | Read 0, 1, or many short parameter lines as necessary   |

|                                 |  |
|---------------------------------|--|
| parameter<br>line(s)>           |  |
| COND                            | If any MG parameters use blocks, then read next factor   |
| 0                               | 0: Do not use custom block setup, read just one parameter line<br>1: Use custom block setup, so read one parameter line for each MG parameter that uses blocks   |
| <short<br>parameter<br>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<br>0 0 0 0 0          | Read 10 integers to specify which biology parameters have seasonality:<br>femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K<br>Reading a positive value selects that factor for seasonality. See notes below. |
| COND                            | If any factors have seasonality, then read N seasons parameters that define the seasonal offsets from the base parameter value.  |
| <short<br>parameter<br>line(s)> | Read N seasons short parameter lines for each factor selected for seasonality.<br>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.

$$P' = P * \exp(\text{seas\_value})$$

### Empirical Weight-at-Age

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. The format of this input file is:

# syntax for optional input file: wtatage.ss

10 #N rows

40 #N ages

| #yr   | seas | gender | GP | birthseas | fleet | age 0     | age 1   | .....    |
|-------|------|--------|----|-----------|-------|-----------|---------|----------|
| -1971 | 1    | 1      | 1  | 1         | 1     | 0.0128586 | 0.13718 | 0.432243 |

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 season

Fleet = 0 is population wt-at-age at beginning of 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 is the maxage being read from this table

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.

#### 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

Spawner-Recruitment

With SS\_v3, there has been significant rearrangement and augmentation of the control of recruitment deviations. The deviations themselves are now organized into three eras: early, main, and forecast and separate controls are available for each era.

|   |  |
|---|--|
| 3 | spawner-recruitment function form. The 4 forms are:<br>1: Beverton-Holt with flat-top beyond Bzero<br>2: Ricker<br>3: standard Beverton-Holt<br>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. |
|---|--|

read 6 short parameter set-up lines. These parameters are:

|           |   |
|-----------|---|
| log(R0)   | log of virgin recruitment level   |
| steepness | steepness of S-R; bound by 0.2 and 1.0 for Beverton-Holt  |
| sigma-r   | std.dev. of log recruitment;<br>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.<br>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 $P_y' = P * \exp(\text{env\_link} * \text{env\_data}_y)$ . An alternative that provides an additive link is under development.  |
| log(R1)   | offset for initial equilibrium recruitment relative to virgin recruitment.  |

|                 |                                |
|-----------------|--------------------------------|
| autocorrelation | Autocorrelation in recruitment |
|-----------------|--------------------------------|

Then read additional spawner-recruitment conditions:

| Value | Label         | Description and Options  |
|-------|---------------|--|
| 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 | <p>This factor determines what aspect of spawner-recruitment is affected by the environmental variable. The options are:</p> <ul style="list-style-type: none"> <li>1: annual deviations</li> <li>2: R0</li> <li>3: steepness</li> </ul> <p>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.</p> <p>If the application is investigating regime shifts, then enter an environmental variable with a time series of zeroes 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.</p> |
| 1     | Do_recr_dev   | This selects the way in which recruitment deviations are coded:  |

|      |                           |   |
|------|---------------------------|---|
|      |                           | <p>0: none (so all recruitments come from S-R curve)</p> <p>1: devvector (previously the only option). Here the deviations are encoded as a dev_vector, so ADMB enforces a sum-to-zero constraint.</p> <p>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.</p> |
| 1971 | Main recr devs begin year | <p>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</p>   |
| 1999 | Main recr devs end year   | <p>If recr devs end year is later than retro year, it is reset to equal retro year.</p>   |
| 3    | Main recr dev phase       |   |
|      |                           |   |
| 1    | Advanced Options          | <p>0: Use default values for advanced options;</p> <p>1: Read values for the 11 advanced options</p>  |
| COND |                           | Beginning of advanced options   |
| 1950 | Early recr dev start year | <p>0: skip;</p> <p>+year: absolute year (must be less than begin year of main recr devs)</p> <p>-integer: set relative to main recr dev start year</p> <p>NOTE: because this is a dev vector, it should be long enough so that recr devs for individual years are not unduly constrained.</p> <p>Default: 0</p>   |

|      |   |   |
|------|---|---|
| 6    | Early recr dev phase                      | Users may want to set to a late phase if there is not much early data;<br>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.<br>Default: 0   |
| 1.   | Forecast recr devs 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.<br>Default: 1.0   |
| 1956 | Last year with no bias adjustment         | 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.<br>Defaults for the four year values:<br>Start year – 1000.<br>Start year – Nages<br>Main recr dev final year |
| 1970 | First year with full bias adjustment      |   |
| 2001 | Last year with full bias adjustment       |   |
| 2002 | First recent year with no bias adjustment |   |

|      |  |  |
|------|--|--|
|      |  | End year +1.   |
| -5   | Min recr dev   | Min value for recruitment deviation;<br>Default: -5  |
| 5    | Max recr dev   | Max value for recruitment deviation;<br>Default: +5  |
| 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   |
| 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 |
| 2    | N explicit recr devs to read   | 0: Do not read any recruitment deviations;<br>Integer: read this number of recruitment deviations;<br>Default: 0   |
|      | End of advanced options  |  |
| COND |  | Enter N full parameter lines below if N recruitment cycles is >0   |
|      | <full (e.g. 14 element) parameter line for each of the N periods of recruitment cycle> |  |
| COND |  | If N explicit recr devs is >0, then enter N lines below  |
| 1977 | Year,  | First of two recruitment deviations being read.  |

|             |                    |  |
|-------------|--------------------|--|
| 3.0         | deviation          | 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 |
| 1984<br>3.0 | Year,<br>deviation |  |

## Recruitment eras

Conceptually, SS treats the early, data-poor time period, the main data-rich time 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 first is always defined as a zero-centered dev\_vector. The second can be a vector of simple deviations, or a dev\_vector. The last era does not force a zero-centered dev 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 devs in early years against a preponderance of positive devs 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,  $+ N\_forecast\_rec\_devs * \log(\sigma_R)$ . This meant that the total  $\log(L)$  changed according to how many forecast years were included in the model scenario. Worse, if  $\sigma_R$  was allowed to be estimated by SS2, then this term would cause all the zero devs during the forecast period to drag the overall estimated value of  $\sigma_R$  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  $\log L$  is equal to:  $dev^2 / (2.0 * \sigma_R * \sigma_R) + offset * \log(\sigma_R)$ ; 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,  $\sigma_R$  may be estimable when there is good data to establish the time series of recruitment deviations. In the likefish example, turning on estimate of  $\sigma_R$  results in an estimated value that is very close to the root mean squared error (rmse) of the estimated recruitment deviations.

## Recruitment bias adjustment

SS provides substantial flexibility in controlling the amount of offset to apply when setting the expected value for  $\log(\text{recruitment})$  relative to the expected mean value from the spawner-recruitment curve. For years with sufficient data to precisely estimate recruitments, we expect the model to be able to produce a lognormal distribution of annual recruitment deviations, so the expected value for  $\log(\text{recruitment})$  should be offset by nearly the full  $0.5 * \sigma_R^2$  amount. Because we never have perfect data about the recruitment deviations, one should always expect the root mean squared error of the estimated recruitments to be somewhat less than  $\sigma_R$ , even for the most data-rich years. The degree to which the rmse of the recruitment deviations will be less than  $\sigma_R$  depends upon the ratio:  $\sigma_R^2 / (\sigma_R^2 + \text{effective\_data\_variance})$ . This ratio is also the correct value for the magnitude of the maximum bias adjustment. When iteratively tuning  $\sigma_R$  to approach the rmse of the estimated recruitments, the

magnitude of the maximum bias adjustment should guide the expected degree of difference between the sigmaR and the rmse. In practice, one does not know sigmaR aprior and the effective level of “data variance” is not know for a complex model with many types of real data. Work is in progress to provide guidance for setting a reasonable value for the maximum bias adjustment.

In early data-poor years and in forecast years, there are no data to estimate the recruitment deviations, so the estimated deviations collapse to zero in MLE mode, but not in MCMC mode where they get a lognormal distribution. In this case, when operating the model in MLE mode, the offset should be reduced towards zero so that the mean of the distribution of generated recruitments (which all have a deviation of zero) will equal the mean recruitment from the spawner-recruitment curve. But 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. So, the user control allows ramping in the offset during early years and then ramping out the offset in the most recent years. Internally, SS switches the offset fully on for all years when doing MCMC. For further information on use of the spawner-recruitment options, see the Recruitment Issue Advisory section, but as of Sept 2009 it has not been updated with the newest advice on ramping of bias adjustment..

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 to sigmaR.

When SS enters MCMC phase it slowly moves the biasadj values towards 1.0 according to a logistic function. Then when the 1000th MCMC step occurs, biasadj values are set to 1.0 for all active recruitment deviations.

When SS reaches the MCEVAL phase, all biasadj values are set to 1.0 for all active recruitment deviations.

Further work on bias adjustment is underway. In the future, it may become a parameter so that it can change during MLE and MCMC. This would allow it to move from a value near 0.0 before recruitment deviations begin to be estimated, then move towards a value of max\_bias\_adjustment during MLE, then move towards a value of 1.0 during MCMC.

### **Recruitment Autocorrelation**

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

### 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

With SS\_v3, 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 know 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.

| Value | Label           | Description  |
|-------|-----------------|--|
| 0.2   | F ballpark      | 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 disables F ballpark   |

|         |  |   |
|---------|--|---|
| 3       | F Method                                     | 1: Pope's<br>2: Continuous F as parameters<br>3: Hybrid   |
| 0.9     | 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 F Method                        |   |
| COND: 1 | No additional input for Pope's approx.       |   |
| COND: 2 |  |   |
| 0.1     | Starting value for each F                    | Initializing value for each F parameter   |
| 1       | Phase for F parameters becoming active       |   |
| 1       | Number of detailed F inputs to read below    |   |
| COND: 3 |  |   |
| 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. |
| COND    | If N for F detail is >0                      |   |

|                          |                               |   |
|--------------------------|-------------------------------|---|
| 1, 1980, 1, 0.2, 0.05, 4 | fleet, yr, seas, 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.

Catchability and Survey Error Distribution

For each fishery and survey, enter a row with these 6 entries as described below.

1. – Do\_Power

- 0 = skip, so survey is directly proportional to abundance
- 1 = establish a parameter for non-linearity in survey-abundance linkage
- typical = 0

2. – Do\_Env\_Link

- 0 = skip, no environmental effect on Q
- 1 = establish a parameter to create environmental effect on Q
- typical = 0

3. – Do\_extra SD

- 0 = skip
- 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.
- typical = 0

4. – Q type

<0=mirror the Q from another (lower numbered) survey designated by abs(value)

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.

1 = set Q as a scaling factor such that the estimate is mean unbiased. This option is not available if a normal error structure is used.

2 = establish one parameter that will be the  $\ln(Q)$ . Note that Q is in log units even if the error structure is normal.

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 dev\_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 devs ( $=\text{square}(1.+ \text{square}(\text{sum\_devs}))-1.$ ) and added to the “parm\_dev\_like” component.

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.

5. – Units – This is used to set both the units for surveys and for catch and discard

0 = numbers

1 = biomass

2 = effort

Default = 1

NOTE: the “effort” option is new with version 3.03. It 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  $\log_e(F)$ . The resultant proportionality constant has units of  $1/Q$ .

6. - Error\_type

-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 (19xx)).

Default = 30 to be like SS2 V1.xx; =4 for a fat-tail

NOTE: the units of se in the input data file need to be in units that correspond to the normal vs. lognormal selection entered here. If normal error is selected here, the s.e. values in the data file must be in the same units as the observations and not as the CV of the observation. If the lognormal or Student's T error structure is selected here, then the s.e. values entered in the data file must be the standard error in log<sub>e</sub> space.

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

| A | B | C | D | E | F |           |
|---|---|---|---|---|---|-----------|
| 1 | 0 | 1 | 2 | 1 | 0 | #Fish_1   |
| 0 | 0 | 1 | 2 | 1 | 0 | #Fish_2   |
| 0 | 0 | 0 | 4 | 1 | 0 | #Survey_1 |
| 0 | 0 | 1 | 2 | 0 | 5 | #Survey_2 |

Where: A=do power, B=env-var, C=extra SD, D=devtype(<0=mirror, 0/1=none, 2=cons, 3=rand, 4=randwalk); E=0=num/1=bio, F=err\_type

| 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 deviations, 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;<br>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. |
|--|--|---|

For each positive element in columns A – D above, read a short parameter setup line.

The order is: fishery 1 through survey N within power transformation, then within environment link, then within extra stddev, then within Q.

If no elements are selected, then there must be no parameter setup lines.

The list of parameters to be read from the above setup would be:

- Fishery 1 power
- Fishery 1 extra SD
- Fishery 2 extra SD
- Survey 2 extra SD
- Fishery 1 base Q
- Fishery 2 base Q
- Survey 1 base Q
- Survey 1 Q randwalk for observation 2
- Survey 1 Q randwalk for observation 3
- Survey 1 Q randwalk for observation 4
- Etc.
- Survey 3 base Q

### Selectivity and Retention

For each fleet and survey, read a definition line for size selectivity and retention. The four values read from each line are:

PATTERN: Valid length selectivity pattern code.

RETENTION: (0/1/2 or -index) If value is 1, then program will read 4 retention parameters after reading the specified number of selectivity parameters. If the value is 2, then the program will read 4 retention parameters and 4 discard mortality parameters. If the value is a negative number, then it will mirror the retention and discard mortality pattern of the lower numbered fleet.

- MALE:** (0/1/2/3) If value is 1, then program will read 4 additional parameters to define the male selectivity relative to the female selectivity. Anytime the male selectivity is caused to be greater than 1.0; the entire male/female matrix of selectivity values is scaled by the max so that the realized max is 1.0. Hopefully this does not cause gradient problems. If the value is 2, then the main selectivity parameters define male selectivity and female selectivity is estimated as an offset from male selectivity. This alternative is preferable if female selectivity is less than male selectivity. The option 3 is only available if the selectivity pattern is 1 or 24 and it causes the male selectivity parameters to be offset from the female parameters, rather than the male selectivity being an offset from the female selectivity.
- SPECIAL:** (0/value). This value is used in different ways depending on the context. If the selectivity type is to mirror another selectivity type, then put the index of that source fleet or survey here. It must refer to a lower numbered fleet/survey. If the selectivity type is 6 (linear segment), then put the number of segments here. If the selectivity type is 7, then put a 1 here to keep selectivity constant above the mean average size for old fish of morph 1.

For each fleet and survey, read a definition line for age selectivity. The 4 values to be read are the same as for the size-selectivity. However, the retention value must be set to 0.

**Selectivity Patterns**

The currently defined selectivity patterns, and corresponding required number of parameters, are:

| Pattern                 | N Parameters    | Description  |
|-------------------------|-----------------|--|
| <b>SIZE SELECTIVITY</b> |                 |  |
| 0                       | 0               | Selex=1.0 for all sizes  |
| 1                       | 2               | Logistic   |
| 2                       | 8               | Double logistic, with defined peak, uses IF joiners. Discontinued. Use pattern #8 instead.   |
| 3                       | 6               | Discontinued.  |
| 4                       | 0               | set size selex=female fecundity. Discontinued. Use pattern #30 instead   |
| 5                       | 2               | mirror another selex. The two parameters select bin range  |
| 6                       | 2+special value | Non-parametric   |
| 7                       | 8               | Double logistic, with defined peak, uses smooth joiners; special=1 causes constant selex above Linf for morph 1. Discontinued. Use pattern #8. |
| 8                       | 8               | Double logistic, with defined peak, uses smooth joiners; special=1 causes constant selex above Linf for morph 1.                               |
| 9                       | 6               | Simple double logistic, no defined peak  |
| 22                      | 4               | Double normal; similar to CASAL  |
| 23                      | 6               | Discontinued. Use pattern #24.   |
| 24                      | 6               | Double normal with defined initial and final selectivity level – Recommended option. Test using SELEX-24.xls. See new notes for SS_v3 below.   |
| 25                      | 3               | Exponential-logistic   |

| <b>SPECIAL SELECTIVITY</b>  |              |  |
|---|--------------|--|
| Pattern   | N Parameters | Description  |
| 30  | 0            | Sets expected survey abundance equal to spawning biomass (population fecundity)  |
| 31  | 0            | Sets expected survey abundance equal to $\exp(\text{recruitment deviation})$ . This is useful if environmental data is used as an index of recruitment variability.  |
| 32  | 0            | Sets expected survey abundance equal to $\exp(\text{recruitment deviation}) * \text{SpawnBiomass}$ . So this is recruitment without density-dependence (for pre-recruit survey) because most ecological logic places the density-dependent stage during the juvenile period following the larval stage that is most sensitive to environmental perturbation. |
| 33  | 0            | Sets expected survey abundance equal to age 0 recruitment.   |
| <p>Do not input any size/age comp for surveys using pattern 30-33.<br/> The “catchability” coefficient for these selectivity patterns 30-33 have all the general properties of the catchability coefficient for real surveys, e.g. they can be time-varying, use power relationship, etc.</p> |              |  |

| AGE SELECTIVITY |              |  |
|-----------------|--------------|--|
| Pattern         | N Parameters | Description  |
| 10              | 0            | Age selex=1.0 for all ages beginning at age 1. If it is desired that age 0 fish be selected, then use pattern #11 and set the minimum age to 0.1 |
| 11              | 2            | Pick min-max age   |
| 12              | 2            | Logistic   |
| 13              | 8            | Double logistic, IF joiners. Discouraged. Use pattern #18  |
| 14              | nages+1      | Each age, value at age is $1/(1+\exp(-x))$   |
| 15              | 0            | Mirror another selex   |
| 16              | 2            | Coleraine single Gaussian  |
| 17              | Nages+1      | Each age as random walk from previous age (New with version 3.0). Selectivity = $\exp(\text{parameter})$   |
| 18              | 8            | Double logistic, with defined peak, uses smooth joiners  |
| 19              | 6            | Simple double logistic, no defined peak  |
| 20              | 6            | Double normal with defined init and final level – Recommended option. Test using SELEX-24.xls  |
| 26              | 3            | Exponential-logistic   |

## Selectivity Details

Parameter usage (also see spreadsheet SS2-ExampleSetups.xls)

Pattern 5 (mirror size) 2 parameters select the min and max Bin number (not min max size) of the source pattern. If first parameter has value  $\leq 0$ , then interpreted as value of 1 (e.g. first bin). If second parameter has value  $\leq 0$ , then interpreted as value of nlength (e.g. last bin). The source pattern must have a lower type number.

Pattern 6 (non-parametric size selectivity) uses a set of linear segments. The first waypoint is at Length = p1 and the last waypoint is at Length=p2. The total number of waypoints is specified by the value of the Special factor in the selectivity set-up, so the N intervals is one less than the number of waypoints. Intermediate waypoints are located at equidistant intervals between p1 and p2. Parameters 3 to N are the selectivity values at the waypoints, entered as logistic, e.g.  $1/(1+\exp(-x))$ . Ramps from -10 to p3 if  $L < p1$ . Constant at pN if  $L > p2$ . Note that prior to version 3.03 the waypoints were specified in terms of bin number, rather than length.

Patterns 1 (size) and 12 (age)

Simple logistic

p1 – size (age) at inflection

p2 – width for 95% selection; a negative width causes a descending curve

Patterns 8 (size) and 18 (age)

Double logistic:

p1 – PEAK: size (age) for peak. Should be an integer and should be at bin boundary and not estimated. But options 7 and 18 may allow estimation

p2 – INIT: selectivity at lengthbin=1 (minL) or age=0

p3 – INFL1: size (age) at which selectivity is halfway between INIT and 1. A logit transform ( $1/(1+\exp(-x))$ ) is used so that the transformed value will be between 0 and 1. So a p1 value of -1.1 will be transformed to 0.25 and used to set the selectivity equal to 0.5 at a size (age) equal to 0.25 of the way between minL and PEAK. (see SS2-selex.xls).

p4 – SLOPE1: log(slope) of left side (ascending) selectivity

p5 – FINAL: logit transform for selectivity at maxL (or maxage)

p6 – INFL2: logit transform for size(age) at right side selectivity equal to half way between PEAK+PEAKWIDTH and maxL  
(or max age)  
p7 – SLOPE2: log(slope) of right side (descending) selex  
p8 – PEAKWIDTH: in width of flattop

Patterns 14 and 17 (age)

Revise Age-selectivity pattern #14 to allow selectivity-at-age to be the same as selectivity at the next younger age. When using this option, the range on each parameter should be approximately -5 to 9 to prevent the parameters from drifting into extreme values with nil gradient

```
case 14:           // separate parm for each age
{
temp=9.-max(sp(1,nages+1)); // forces at least one age to have selex weight equal to 9
for (a=0;a<=nages;a++)
{
if(sp(a+1)>-.999)
{sel_a(y,f,1,a) = 1./(1.+mfexp(-(sp(a+1)+temp)));}
else
{sel_a(y,f,1,a) = sel_a(y,f,1,a-1);}
}
}
}
```

Replace selectivity pattern 17 with a random walk version of selectivity pattern 14. When using pattern 17, it is best to fix the first parameter at a convenient value so that all other selectivities are relative to this. After accumulating the randwalks from this start value, the vector is exponentiated.

```
case 17:           // separate parm for each age as random walk
tempvec(0)=sp(1);
for(a=1;a<=nages;a++) {tempvec(a)=tempvec(a-1)+sp(a+1);}
temp=max(tempvec);
sel_a(y,f,1)=mfexp(tempvec-temp);
break;
```

}

Pattern 9 (size) and 19 (age) – simple double logistic with no defined peak

- p1 – INFL1: ascending inflection size (in cm)
- p2 – SLOPE1: ascending slope
- p3 – INFL2: descending inflection size (in cm)
- p4 – SLOPE2: descending slope
- p5 – first BIN: bin number for the first bin with non-zero selectivity (must be an integer bin number, not a size)
- p6 – offset: enter 0 if P3 is independent of P1; enter 1 if P3 is an offset from P1

Pattern 22 – double normal with plateau

- p1 – PEAK1: beginning size for the plateau (in cm)
- p2 – PEAK2: ending size for the plateau. Calculated as a fraction of the distance between PEAK1 and 99% of the lower edge of the last size bin in the model. Transformed as  $(1/(1+\exp(-p2)))$ . So a value of 0 results in PEAK2 being halfway between PEAK1 and 99% of the last bin
- p3 – upslope:  $\ln(\text{variance})$  on ascending side
- p4 – downslope:  $\ln(\text{variance})$  on descending side

Pattern 24 (recommended double normal).

See spreadsheet SELEX-24.xls

- p1 – PEAK: ascending inflection size (in cm)
- p2 – TOP: width of plateau, as logistic between PEAK and MAXLEN
- p3 – ASC-WIDTH: parameter value is  $\ln(\text{width})$
- p4 – DESC-WIDTH: parameter value is  $\ln(\text{width})$
- p5 – INIT: selectivity at first bin, as logistic between 0 and 1.
- p6 – FINAL: selectivity at last bin, as logistic between 0 and 1.

With SS\_v3's separation of the population bin structure from the data bin structure, the interpretation of parameter P5 needed to change. Now, P5 refers to selex at the first DATA size bin and selex declines below that size according to  $(L/L_{ref})^2$ . Other recent changes include:

For the initial selectivity parameter (#5)

-999 or -1000: ignore the initial selectivity algorithm and simply decay the small fish selectivity according to P3,

< -1000: ignore the initial selectivity algorithm as above and then set selectivity equal to  $1.0e-06$  for size bins 1 through bin = -1001 - value. So a value of -1003 would set selectivity to a nil level for bins 1 through 2 and begin using the modeled selectivity in bin 3.

For the final selectivity parameter (#6),

-999 or -1000: ignore the final selectivity algorithm and simply decay the large fish selectivity according to parameter #4,

< -1000: set selectivity constant for bins greater than bin number = -1000 - value.

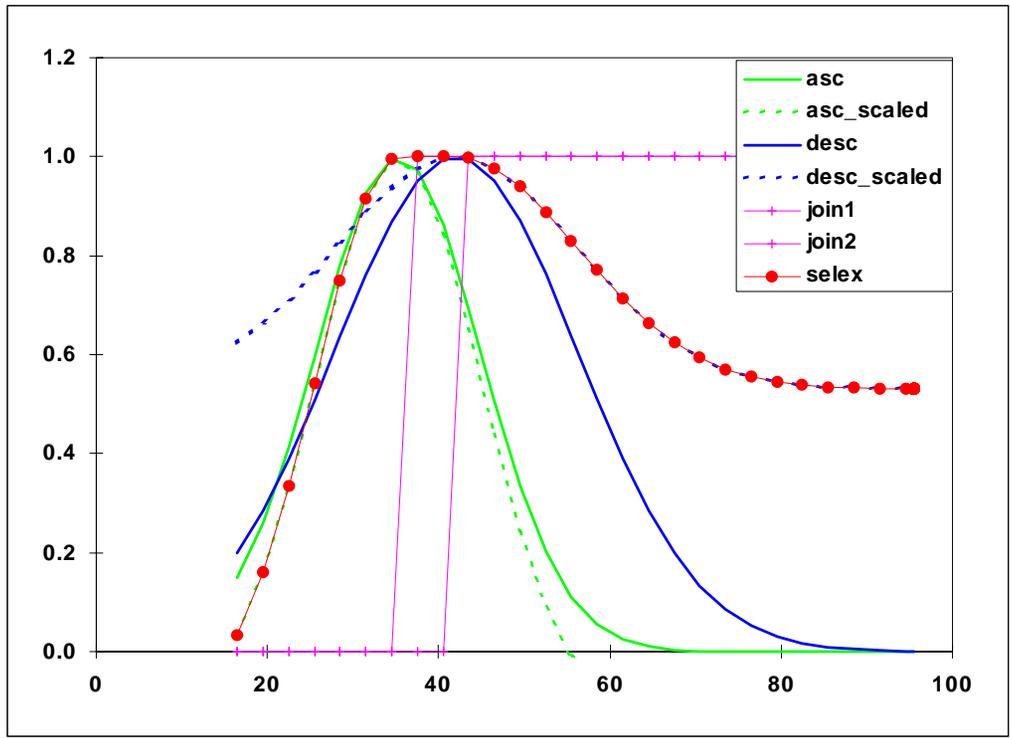


Figure 1 Selectivity pattern 24, double normal, showing sub-functions and steep logistic joiners

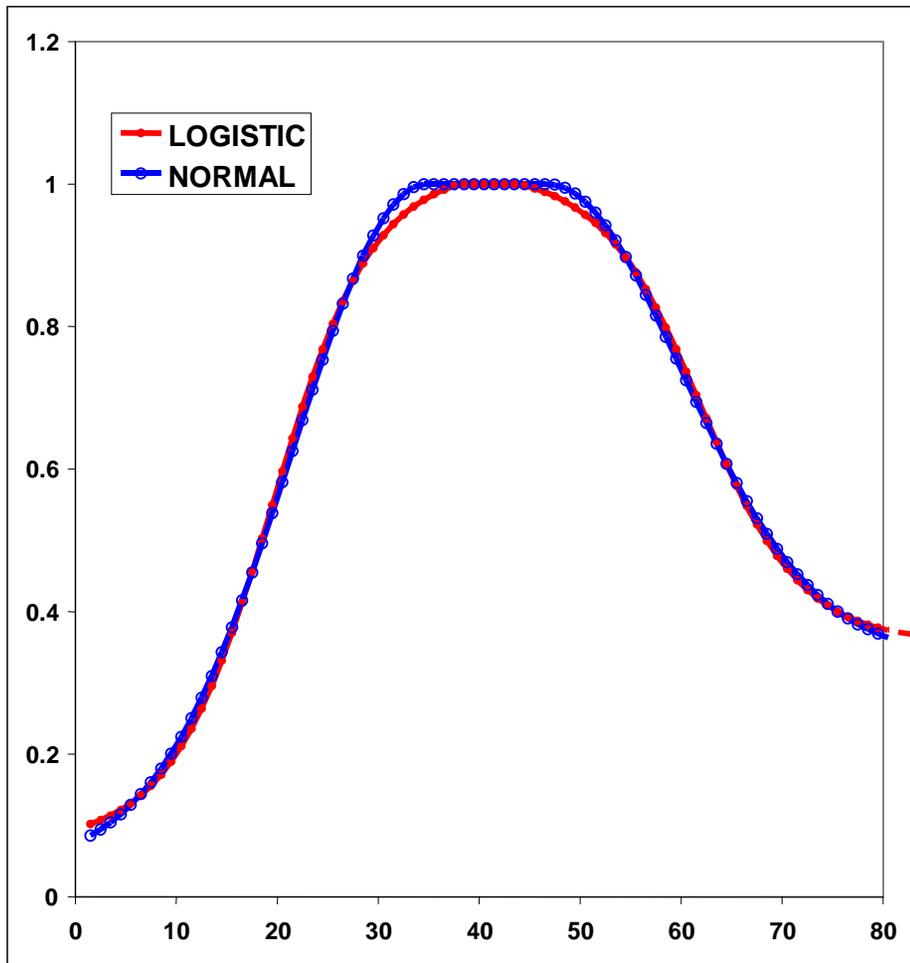


Figure 2. Comparison of 6-parameter double normal with 8-parameter double logistic tuned to match the double normal.

Pattern 15 (mirror age) no parameters. Whole age range is mirrored.

Pattern 16 Gaussian: like Coleraine.

P1 – age below which selectivity declines

P2 – scaling factor for decline

Pattern 9 and 19 (simple double logistic)

p1 – ascending inflection age/size

p2 – ascending slope

p3 – descending inflection age/size

p4 – descending slope

p5 – age or size at first selection; this is a specification parameter, so must not be estimated. Enter integer that is age for pattern 19 and is bin number for pattern 9

p6 – (0/1) where a value of 0 causes the descending inflection to be a standalone parameter, and a value of 1 causes the descending inflection to be interpreted as an offset from the ascending inflection. This is a specification parameter, so must not be estimated.

A value of 1.0e-6 is added to the selectivity for all ages, even those below the minage.

Pattern 25 (size) and 26 (age): Exponential-logistic

p1: ascending rate, min: 0.02, max: 1.0, reasonable start value: 0.1

p2: peak, as fraction of way between min size and max size. Parameter min value: 0.01; max: 0.99; reasonable start value: 0.5

p2': = minsize + p2\*(maxsize-minsize)

p3: descending rate, min: 0.001, max: 0.5?, reasonable start value: 0.01. A value of 0.001 provides a nearly asymptotic curve.

Values above 0.2 provide strongly dome-shaped function in which the p3 and p1 parameters interact strongly.

$$\text{Exp}(P3*P1*(p2'-\text{size}))/((1.0-P3*(1-\text{EXP}(P1*(p2'-\text{size}))))$$

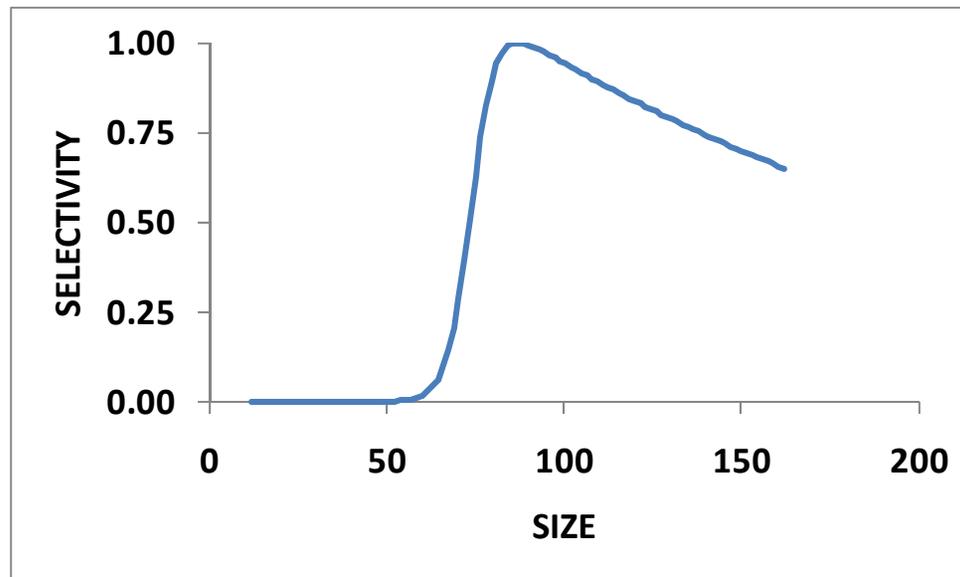


Figure 3. Exponential-logistic selectivity with  $p1=0.3$ ,  $p2=0.5$ ,  $p3=0.02$ .

### Retention

Retention is defined as a logistic function of size. It does not apply to surveys. Four parameters are used:

P1 – inflection

P2 – slope

P3 – asymptotic retention (often a time-varying quantity to match the observed amount of discard)

P4 – male offset to inflection (arithmetic, not multiplicative)

$$\text{Retention} = P3 / (1 + \exp(-(L - (P1 + p4 * \text{male})) / P2)).$$

### **Discard mortality**

Discard mortality is defined as a logistic function of size such that mortality declines from 1.0 to an asymptotic level as fish get larger. It does not apply to surveys and it does not affect the calculation of expected values for discard data. It is applied so that the total mortality rate is:

$$\text{deadfish} = \text{selex} * (\text{retain} + (1.0 - \text{retain}) * \text{discmort}).$$

If discmort is 1.0, all selected fish are dead;

If discmort is 0.0, only the retained fish are dead.

Four parameters are used:

P1 – inflection

P2 – slope

P3 – asymptotic mortality

P4 – male offset to inflection (arithmetic, not multiplicative)

$$\text{Mortality} = 1 - (1 - P3) / (1 + \exp(-(L - (P1 + p4 * \text{male})) / P2)).$$

### **Male Selectivity**

If the “domale” flag is set to 1, then the selectivity parameters define female selectivity and the offset defined below sets male selectivity relative to female selectivity. The two genders switch roles if the “domale” flag is set to 2. Generally it is best to select the domale options so that the dependent gender has lower selectivity, thus obviating the need to rescale for selectivities that are greater than 1.0. Gender specific selectivity is done the same way for all size and age selectivity options.

P1 – size (age) at which a dogleg occurs (set to an integer at a bin boundary and do not estimate)

P2 – log(relative male selectivity) at minL or age=0

P3 – log(relative male selectivity) at the dogleg

P4 – log(relative male selectivity) at maxL or max age.

For intermediate ages, the log values are linearly interpolated on size (age).

If selectivity for the dependent gender is greater than selectivity for the first gender (which always peaks at 1.0), then the male-female selectivity matrix is rescaled to have a maximum of 1.0. Still need to check consequences for gradient calculations.

With SS\_v3, a new male selectivity option (3) has been implemented for size selectivity patterns 1 (logistic) and 24 (double normal). Rather than calc male selectivity as an offset from female selectivity, here the male selectivity is calculated by making the male parameters an offset from the female parameters. If the male\_offset flag is set to 3, then read 4 additional male offset parameters (just as before).

If the size selectivity pattern is 1 (logistic), then

- male parm 1 is added to the first selectivity parm (inflection)
  - male parm 2 is added to the second selectivity parm (width of curve)
  - male parm 3 and 4 are ignored
- note that both offsets are additive, not multiplicative

If the size selectivity pattern is 24 (double normal), then

- male parm 1 is added to the first selectivity parm (peak)
- male parm 2 is added to the third selectivity parm (width of ascending side); then  $\exp(\text{this sum})$  per previous transform
- male parm 3 is added to the fourth selectivity parm (width of descending side); then  $\exp(\text{sum})$  per previous transform
- male parm 4 is added to the sixth selectivity parm (selectivity at final size bin); then  $1/(1+\exp(-\text{sum}))$  per previous transform

Note that the male selectivity offsets currently cannot be time-varying. Because they are offsets from female selectivity, they inherit the time-varying characteristics of the female selectivity.

### **Reading the Selectivity and Retention Parameters**

Read the required number of parameter setup lines as specified by the definition lines above. The complete order of the parameter setup lines is:

Size selectivity for fishery 1

Retention for fishery 1

Male offsets for size selectivity for fishery 1

<repeat for additional fleets and surveys>.

Age selectivity for fishery 1

Male offsets for age selectivity for fishery 1

<repeat for additional fleets and surveys>.

The time-varying options for selectivity parameters are identical to the time-varying options for biology parameters. These options are described below in the Time-Varying Parameter Options section. After reading the selectivity parameters, 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 selectivity parameter section. So if no selectivity parameters invoke any time-varying properties, this section is left blank (or completely commented out with #).

| VALUE   | LABEL              | DESCRIPTION   |
|---|--------------------|---|
| <b>COND</b>   |                    | If any selectivity parameters use environmental linkage, then read next line and associated parameter line(s)   |
| <b>0</b>  | Custom_Env_linkage |   |
| <b>COND</b>   |                    | If custom=0, then read one parameter line below and apply to all env fuctions;<br>If custom>0, then read a setup line for each SEL-parm with Env-var>0.<br>Note that control..ss_new will write out with custom=1 so it can write all the parameter values. |
| Enter proper number of short set-up lines (0, 1, several) for the SEL-parm environmental linkages. Each line will have 7 values: LO, HI, INIT, PRIOR, PR_type, SD, PHASE. |                    |   |
| <b>COND</b>   |                    | If any selectivity parameters use time blocks, then read next line and associated parameter line(s)   |
| <b>0</b>  | Custom_block_setup | If custom=0, then read one setup and apply to all Block fxns;<br>If custom>0, then read a setup line for each SEL-parm with Block>0.  |
| Enter proper number of short set-up lines (0, 1, several) for the SEL-parm block linkages. Each line will have 7 values: LO, HI, INIT, PRIOR, PR_type, SD, PHASE.         |                    |   |

|             |                       |   |
|-------------|-----------------------|---|
| <b>COND</b> |                       | If any selectivity parameters use annual devs, then read value  |
| <b>-4</b>   | Selparm_dev_phase     | Phase in which selparm devs, if any, are estimated  |
| <b>COND</b> |                       | If any selectivity parameters use environmental links, blocks or annual devs, then read value   |
| <b>2</b>    | Selparm_Adjust_Method | 1 = parameter adjustments for env, block and dev are applied directly and resulting value is not compared to base parameter bounds<br>2 = parameter adjustments use a logistic transformation to assure that adjusted parameter value stays within bounds of base parameter |

#### Tag Recapture Parameters

# Tag loss and Tag reporting parameters go next

1 # TG\_custom: 0=no read; 1=read

-10 10 9 9 1 0.001 -4 0 0 0 0 0 0 # TG\_loss\_init\_1  
-10 10 9 9 1 0.001 -4 0 0 0 0 0 0 # TG\_loss\_init\_2  
-10 10 9 9 1 0.001 -4 0 0 0 0 0 0 # TG\_loss\_init\_3  
-10 10 9 9 1 0.001 -4 0 0 0 0 0 0 # TG\_loss\_chronic\_1  
-10 10 9 9 1 0.001 -4 0 0 0 0 0 0 # TG\_loss\_chronic\_2  
-10 10 9 9 1 0.001 -4 0 0 0 0 0 0 # TG\_loss\_chronic\_3  
1 10 2 2 1 0.001 -4 0 0 0 0 0 0 # TG\_overdispersion\_1  
1 10 2 2 1 0.001 -4 0 0 0 0 0 0 # TG\_overdispersion\_2  
1 10 2 2 1 0.001 -4 0 0 0 0 0 0 # TG\_overdispersion\_3  
-10 10 9 9 1 0.001 -4 0 0 0 0 0 0 # TG\_report\_fleet:\_1  
-10 10 9 9 1 0.001 -4 0 0 0 0 0 0 # TG\_report\_fleet:\_2  
-4 0 0 0 0 2 -4 0 0 0 0 0 0 # TG\_rpt\_decay\_fleet:\_1  
-4 0 0 0 0 2 -4 0 0 0 0 0 0 # TG\_rpt\_decay\_fleet:\_2

### Variance Adjustment Factors

When doing iterative reweighting of the input variance factors, it is convenient to do this in the control file, rather than the data file. This section creates that capability. There are six rows and a value for each Fleet&survey on each row.

|                       | Fleet 1 | Fleet 2 | Fleet 3 | Fleet 4 |
|-----------------------|---------|---------|---------|---------|
| Survey CV             | 0       | 0       | 0       | 0       |
| Discard stddev        | 0       | 0       | 0       | 0       |
| Mean bodywt<br>stddev | 0       | 0       | 0       | 0       |
| Length comp           | 1       | 1       | 1       | 1       |
| Age comp              | 1       | 1       | 1       | 1       |
| Size-at-age           | 1       | 1       | 1       | 1       |

Survey CV. The survey input variance (labeled survey CV) is actually the standard deviation of the  $\ln(\text{survey})$ . The variance adjustment is added directly to this standard deviation. Set to 0.0 for no effect. Negative values are OK, but will crash if adjusted value becomes negative.

Discard. The input variance is the CV of the observation. Because this will cause observations of near zero discard to appear overly precise, the variance adjustment is added to the discard standard deviation, not to the CV. Set to 0.0 for no effect.

Mean body wt input variance is in terms of the CV of the observation. Because such data are typically not very noisy, the variance adjustment is added to the CV and then multiplied by the observation to get the adjusted standard deviation of the observation.

Length composition input variance is in terms of an effective sample size. The variance adjustment is multiplied times this sample size. Set variance adjustment to 1.0 for no effect.

Age composition is treated the same way as length composition.

Size-at-age input variance is the sample size for the N observations at each age. The variance adjustment is multiplied times these N values. Set to 1.0 for no effect.

Usage note: the report.sso output file contains information useful for determining if an adjustment of these input values is warranted to better match the scale of the average residual to the input variance scale.

Usage note: because the actual input variance factors are modified, it is these modified variance factors that are used when creating parametric bootstrap data files. So, the control files used to analyze bootstrap generated data files should have the variance adjustment factors reset to null levels.

Error structure for Discard and Mean Body Weight

Note, in a future model release, these values will be moved into the respective data sections.

|    |  |
|----|--|
| 30 | >=1: Degrees of freedom for Student's T distribution used to scale mean body weight deviations. Read value of std_in in data file is interpreted as CV of the observation;<br>0: normal distribution. Read value of std_in in data file is interpreted as CV of the observation;<br>-1: normal distribution. Read value of std_in in data file is interpreted as standard error of the observation;<br>-2: lognormal distribution. Read value of std_in in data file is interpreted as standard error of the observation in log space. |
| 30 | Degrees of freedom for Student's T distribution used to scale mean body weight deviations.   |

Lambdas (emphasis factors)

These values are multiplied by the corresponding likelihood component to calculate the overall negative log likelihood to be minimized.

|   |  |
|---|--|
| 4 | Max_lambda_phase: read this number of lambda values for each element below. The last lambda value is used for all higher numbered phases |
| 1 | sd_offset; value=0 causes log(like) to omit the +log(s) term; value=1 causes   |

|  |   |
|--|---|
|  | log(like) to include the log(s) term for CPUE, discard, meanbodywt, recruitment deviations. |
|--|---|

USAGE Note: If the CV for size-at-age is being estimated and the model contains mean size-at-age data, then the flag for inclusion of the +log(stddev) term in the likelihood must be included. Otherwise, the model will always get a better fit to the mean size-at-age data by increasing the parameter for CV of size-at-age.

The reading of the lambda values has been substantially altered with SS\_v3. Instead of reading a matrix containing all the needed lambda values, SS now just reads those elements that will be given a value other than 1.0. After reading the datafile, SS sets lambda equal to 0.0 if there are no data for a particular fleet/data type, and a value of 1.0 if data exist. So beware if your data files had data but you had set the lambda to 0.0 in a previous version of SS. First read an integer for the number of changes.

|   |   |
|---|---|
| 3 | number of changes to make to default Lambdas (default value is 1.0) |
|---|---|

Then read that number of lines containing the change info:

| Component | fleet/survey | Phase | Lambda | Sizefreq method |
|-----------|--------------|-------|--------|-----------------|
| 1         | 2            | 2     | 1.5    | 1               |
| 4         | 2            | 2     | 10.    | 1               |
| 4         | 2            | 3     | 2.     | 1               |

The codes for component are: 1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch; 9=init\_equ\_catch; 10=recrdev; 11=parm\_prior; 12=parm\_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-comp; 16=Tag-negbin.

On output to control.ss\_new, the full table is written:

```
# lambdas (for info only; columns are phases)
# 0 0 0 0 #_CPUE/survey:_1
# 1 1.5 1.5 1.5 #_CPUE/survey:_2
# 1 1 1 1 #_CPUE/survey:_3
# 1 1 1 1 #_lencomp:_1
```

```

# 1 10. 2. 2. #_lencomp:_2
# 0 0 0 0 #_lencomp:_3
# 1 1 1 1 #_agecomp:_1
# 1 1 1 1 #_agecomp:_2
# 0 0 0 0 #_agecomp:_3
# 1 1 1 1 #_size-age:_1
# 1 1 1 1 #_size-age:_2
# 0 0 0 0 #_size-age:_3
# 1 1 1 1 #_init_equ_catch
# 1 1 1 1 #_recruitments
# 1 1 1 1 #_parameter-priors
# 1 1 1 1 #_parameter-dev-vectors
# 1 1 1 1 #_crashPenLambda

```

Controls for variance of derived quantities

Add option to get variance estimates for one selectivity pattern and for size-at-age. At the end of the control file, just before the "999", add:

|   |  |
|---|--|
| 1 | (0/1) read specs for more stddev reporting |
|---|--|

If the above value is "0", then do not include any more entries. If the above value is "1", then read 9 more integers:

| Fleet | len/age | year | N selex bins | Growth pattern | N growth ages | Area for N_at_age | Year for N_at_age | N ages to report |
|-------|---------|------|--------------|----------------|---------------|-------------------|-------------------|------------------|
| 1     | 1       | -1   | 7            | 1              | 5             | -1                | -1                | 5                |

Where:

- FLEET: is the index of the fleet to be output. A value of zero causes there to be no selectivity variance output;
- LEN/AGE: enter "1" to select length selex or "2" to select age selectivity. There is no option to get the combined age selectivity that incorporates the size selectivity;

- YEAR: enter a value for the selected year, or enter -1 to get the selectivity in the end year
- N Selectivity bins: enter the number of bins for which selectivity will be output. This number controls the number of items to be read below, even if the FLEET is set to zero. In other words, the read occurs even if the effect of the read is disabled.
- GROWTH PATTERN: growth pattern is the number of the growth pattern to be output. Enter "0" to get no variance output for size-at-age. Note that in a multiple season model, SS will output the size-at-age for the last birthseason that gets any recruits within the year. Also, if growth parameters are not estimated, then stddev output of mean size-at-age is disabled.
- N growth bins: Number of ages for which size-at-age variance is requested. This number controls the number of items to be read below, even if the growth pattern selection is set to zero. In other words, the read occurs even if the effect of the read is disabled.
- Area: specifies the area for which output of numbers at age is requested. A value of 0 disables this output. A value of -1 requests that numbers-at-age be summed across all areas. In all cases, numbers-at-age is summed across all growth patterns and sub-morphs and output for each gender.
- Year: specifies the year for which numbers-at-age are output. A value of -1 requests output for year equal to endyear+1, hence the year that starts the forecast period.
  - N numbers-at-age bins: as with the N growth bins.

If the number of selex bins to be output is >0, then read a vector of selex bin numbers. For size selex, these are population bin numbers, For age selex, they refer directly to age. Entering a negative value for the first bin causes SS to self-generate an evenly spaced set.

|                     |  |
|---------------------|--|
| 5 10 16 22 27 38 46 | Vector with selex std bin picks (-1 in first bin to self-generate) |
|---------------------|--|

If the number of growth bins to be output is >0, then read a vector of ages to be output. Entering a negative value for the first bin causes SS to self-generate a set that begins at AFIX, ends at Nages, and is denser at younger ages.

|              |   |
|--------------|---|
| 1 2 14 26 40 | vector with growth std bin picks (-1 in first bin to self-generate) |
|--------------|---|

If the number of numbers-at-age bins to be output is >0, then read a vector of ages to be output. Entering a negative value for the first bin causes SS to self-generate a set that begins at 1, ends at Nages, and is denser at younger ages.

|              |   |
|--------------|---|
| 1 2 14 26 40 | vector with growth std bin picks (-1 in first bin to self-generate) |
|--------------|---|

So a complete input looks like:

```
1 # (0/1) read specs for more stddev reporting
1 1 -1 5 1 5 1 -1 5
5 16 27 38 46 # vector with selex std bin picks (-1 in first bin to self-generate)
1 2 14 26 40 # vector with growth std bin picks (-1 in first bin to self-generate)
1 2 14 26 40 # vector with N-at-age std bin picks (-1 in first bin to self-generate)
```

End Control File

**999** #\_end-of-file

## Time-Varying Parameter Options

Biology parameters and selectivity parameters can vary over time. There are four options for time-varying parameters: blocks, trends, environmental linkage, and annual devs.

Elements 8 through 14 of the full parameter lines are used to setup the time-varying properties. If any parameter of the biology section is made to be time-varying, then one or more conditional inputs at the end of the biology section (or end of the selectivity section) will need to be turned on, and one or more parameter lines will need to be inserted to contain the parameter linkages and offsets that have been selected. This is done separately for the block of biology parameters and then for the selectivity parameters.

With version SS\_v3, the options for time-varying parameters have been expanded to include more additive effects. This is because it is not logical for a parameter whose range spans 0.0 to have a time-varying effect defined in a multiplicative way. This is especially true for those parameters that are exponentiated as they are being used. For example, the parameters that define the allocation of recruitment among areas and seasons should be made time-varying only through an additive function.

The order in which time-varying effects are calculated is: first blocks or trends, then environmental effects, then annual devs.

All time-varying options work on an annual time step, so in a multi-season model the parameters remain constant for the entire year. The exception is for the select biology parameters that have a separate capability to vary seasonally.

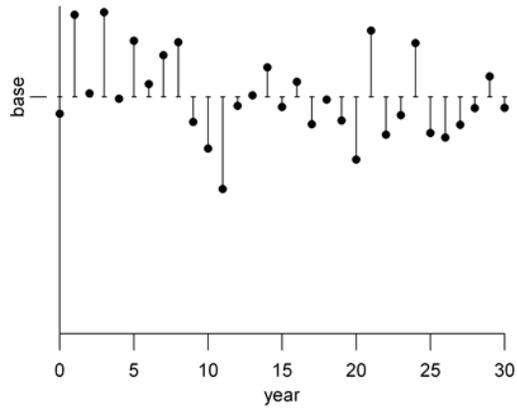
If the parameter adjustment method is set to a value of 2, then each parameter time-varying adjustments has an intermediate logistic transformation so the adjusted parameter stays within the min-max bounds of the parameter being adjusted. With this method, multiplicative adjustments are not implemented and the additive adjustments are in the domain of the logistic transformed base parameter. So, the adjustment coefficients will not have intuitive values.

The available options for time-varying parameters are described in the table below.

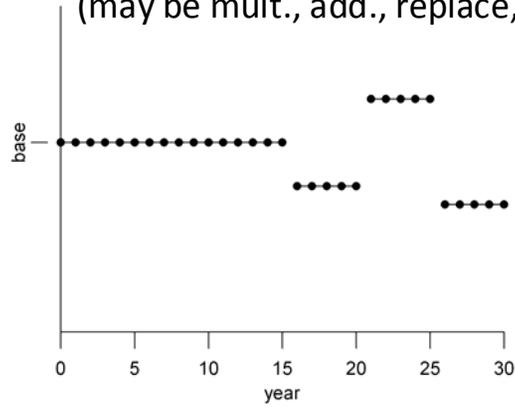
|                 | <b>Environ</b>                                    | <b>Annual Devs</b>                                |                      |                      |                       | <b>Blocks</b>                |   |
|-----------------|---|---|----------------------|----------------------|-----------------------|------------------------------|---|
| <b>NAME:</b>    | <b>Env<br/>Var</b>                                | <b>use<br/>dev</b>                                | <b>dev<br/>minyr</b> | <b>dev<br/>maxyr</b> | <b>dev<br/>stddev</b> | <b>Block</b>                 | <b>Block<br/>Fxn</b>                                |
| <b>ELEMENT:</b> | 8   | 9   | 10                   | 11                   | 12                    | 13                           | 14  |
| <b>OPTIONS:</b> | >0: mult<br><0: additive<br>abs(value): env index | 1: mult<br>2: additive<br>3: additive<br>randwalk | 1973                 | 1985                 | 0.4                   | >0: block index<br><0: trend | 0: mult<br>1: additive<br>2: replace<br>3: randwalk |

# Time-varying parameter options

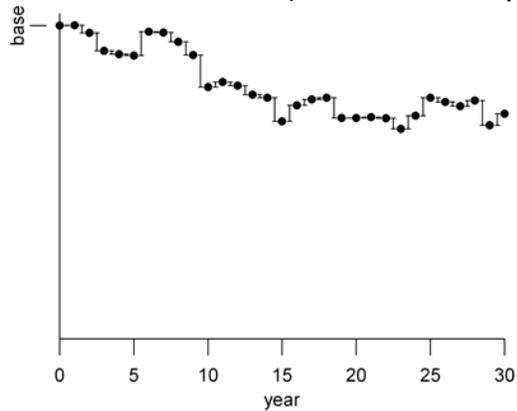
Deviations ( $N$  std. dev. pars.)



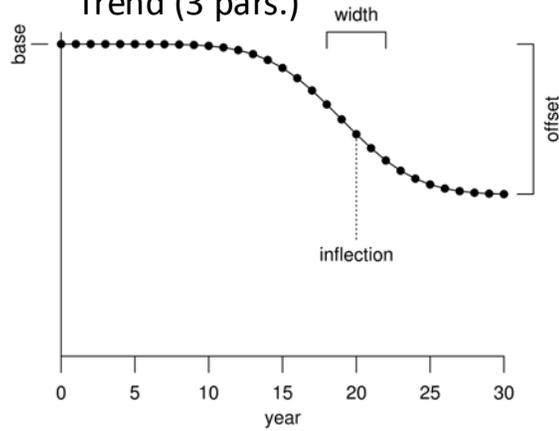
Blocks (1 par. per block)  
(may be mult., add., replace, or walk)



Random walk ( $N - 1$  std. dev. pars.)



Trend (3 pars.)



also: Environmental link

|              |   |
|--------------|---|
| ENV          | <p>A positive value, <math>g</math>, causes SS to set the annual working value of this parameter equal to a multiplicative function of Environmental Variable <math>g</math>:</p> $parm'(y) = parm * exp(link * env(y,g))$ <p>A negative value, <math>g</math>, causes SS to set the annual working value of this parameter equal to a additive function of Environmental Variable <math>g</math>:</p> $parm'(y) = parm + link * env(y,-g)$ <p>Where, <math>link</math> is the environmental link parameter, <math>parm</math> is the base parameter being adjusted, <math>parm'</math> is the value after adjustment, and <math>env(y,-g)</math> is the value of the environmental input <math>g</math> in year <math>y</math>.</p> <p>SS counts the number of parameters that invoke use of an Environmental Variable. After SS finishes reading the section's parameter lines, it then creates/reads additional short parameter line(s) to set up the link parameters. If <math>custom=0</math>, then one short parameter line is used to define the min, max, init, etc, for each of the link parameters. If <math>custom=1</math>, then a separate line is read for each.</p>  |
| USE_Dev      | <p>A value of 1 invokes multiplicative: <math>parm'(y) = parm * exp(dev(y))</math><br/> A value of 2 invokes additive: <math>parm'(y) = parm + dev(y)</math><br/> A value of 3 invokes additive random walk: <math>parm'(y) = parm'(y-1) + dev(y)</math></p> <p>The vector of devs is simply a vector of offsets, there is no inherent sum to zero constraint. However, the fact that they are each penalized by the DEV std.dev. below will tend to make them sum towards 0.0.</p>   |
| DEV min yr   | Beginning year for the dev vector for this parameter  |
| DEV max yr   | Ending year for the dev vector for this parameter   |
| DEV std.dev. | Standard deviation for elements in the dev vector for this parameter  |
| USE-BLOCK    | <p><u>Block</u>: A positive value identifies which block pattern will be used for time changes to a parameter value. Block patterns are simply numbered sequentially as they are defined near the top of the control file, so the index here must be correct for the order in which they are defined. More than one parameter can use the same block definition. The order of generated block parameters is by the order of the parameters that call for creation of the block parameters, then by the order of the blocks within that pattern.</p> <p><u>Trend</u>: A negative value for the Use_Block input causes SS to create a parameter time trend instead of blocks. This time trend requires 3 parameters (instead of the normal one parameter per block). The base parameter is the value for the adjusted parameter in year = start year. For subsequent years, the three parameters define a normal distribution of change over time:</p> <p>P1: parameter value for year = end year. Either as logistic offset from base P (if Use_Block=-1), or as direct usage (if Use_Block=-2)</p> <p>P2: inflection year; if HI value for the base parameter is &gt;1.1, then use as year, else use as fraction of range <math>styr - endyr</math></p> <p>P3: width of change (units of std.dev. of years)</p> |

|            |   |
|------------|---|
|            |   |
| BLOCK-TYPE | <p>This selects the way in which the block parameter creates an offset from the base parameter.</p> <p>0 means that <math>\text{parm}' = \text{baseparm} * \exp(\text{blockparm})</math></p> <p>1 means that <math>\text{parm}' = \text{baseparm} + \text{blockparm}</math></p> <p>2 means that <math>\text{parm}' = \text{blockparm}</math></p> <p>3 means that <math>\text{parm}' =</math> is additive offset from previous block. Note that blocks must be contiguous to use this option properly.</p> |

### Parameter Priors

Priors on parameters fulfill two roles in SS. First, for parameters provided with an informative prior, SS is receiving additional information about the true value of the parameter. This information works with the information in the data through the overall logL function to arrive at the final parameter estimate. Second, diffuse priors provide only weak information about the value of a prior and serve to manage model performance during execution. For example, some selectivity parameters may become unimportant depending upon the values of other parameters of that selectivity function. In the double normal selectivity function, the parameters controlling the width of the peak and the slope of the descending side become redundant if the parameter controlling the final selectivity moves to a value indicating asymptotic selectivity. The width and slope parameters would no longer have any effect on the logL, so they would have no gradient in the logL and would drift aimlessly. A diffuse prior would then steer them towards a central value and avoid them crashing into the bounds. Another benefit of diffuse priors is the control of parameters that are given unnaturally wide bounds. When a parameter is given too

broad of a bound, then early in a model run it could drift into this tail and potentially get into a situation where the gradient with respect that parameter approaches zero even though it is not at its global best value. Here the diffuse prior helps move the parameter back towards the middle of its range where it presumably will be more influential and estimable. The options for parameter priors are:

| PR_Type   | PR_value, Pr | PR_stddev, Psd | Description  |
|---|--------------|----------------|--|
| -1  | NA           | NA             | No prior applied.  |
| 0   | Pr           | Psd            | Normal prior. Note that this function is independent of the parameter bounds.  |
| Prior_Like = 0.5* $\text{square}((\text{Pval}-\text{Pr})/\text{Psd})$ ;   |              |                |  |
| 1   | NA           | Psd            | Symmetric beta prior is scaled between parameter bounds, so imposes larger penalty near bound. Psd=0.05 is very diffuse and a value of 5.0 provides a smooth U-shaped prior. See figure below. |
| $\mu = -(\text{Psd} * (\log((\text{Pmax} + \text{Pmin}) * 0.5 - \text{Pmin}))) - (\text{Psd} * (\log(0.5)))$ ;<br>Prior_Like = $-(\mu + (\text{Psd} * (\log(\text{Pval} - \text{Pmin} + \text{Pconst}))) + (\text{Psd} * (\log(1. - ((\text{Pval} - \text{Pmin} - \text{Pconst}) / (\text{Pmax} - \text{Pmin}))))))$ ;  |              |                |  |
| 2   | Pr           | Psd            | Beta prior   |
| $\mu = (\text{Pr} - \text{Pmin}) / (\text{Pmax} - \text{Pmin})$ ; // CASAL's v<br>$\tau = (\text{Pr} - \text{Pmin}) * (\text{Pmax} - \text{Pr}) / \text{square}(\text{Psd}) - 1.0$ ;<br>Bprior= $\tau * \mu$ ; Aprior= $\tau * (1.0 - \mu)$ ; // CASAL's m and n<br>if(Bprior $\leq$ 1.0    Aprior $\leq$ 1.0) {warning $\ll$ " bad Beta prior " $\ll$ Pval $\ll$ "<br>$\ll$ Pr $\ll$ endl;N_warn++;} |              |                |  |
| Prior_Like = $(1.0 - \text{Bprior}) * \log(\text{Pconst} + \text{Pval} - \text{Pmin}) + (1.0 - \text{Aprior}) * \log(\text{Pconst} + \text{Pmax} - \text{Pval}) - (1.0 - \text{Bprior}) * \log(\text{Pconst} + \text{Pr} - \text{Pmin}) - (1.0 - \text{Aprior}) * \log(\text{Pconst} + \text{Pmax} - \text{Pr})$ ;  |              |                |  |
| 3   | Pr           | Psd            | Lognormal prior. Note that lower bound on the parameter must be >0.0.  |
| Prior_Like = 0.5* $\text{square}((\log(\text{Pval}) - \text{Pr})/\text{Psd})$ ;   |              |                |  |

Where:

Pval is value of the parameter for which a prior is being calculated;

Pmin and Pmax are the bounds on the parameter;

Pr is the value of the parameter prior, or the first of 2 factors controlling the calculation of the prior;

Psd is the value of the prior's standard deviation, or the second of 2 factors controlling the calculation of the prior;

Pconst is a small constant, 0.0001;

Prior\_Like is the calculated value of the prior's contribution to the logL.

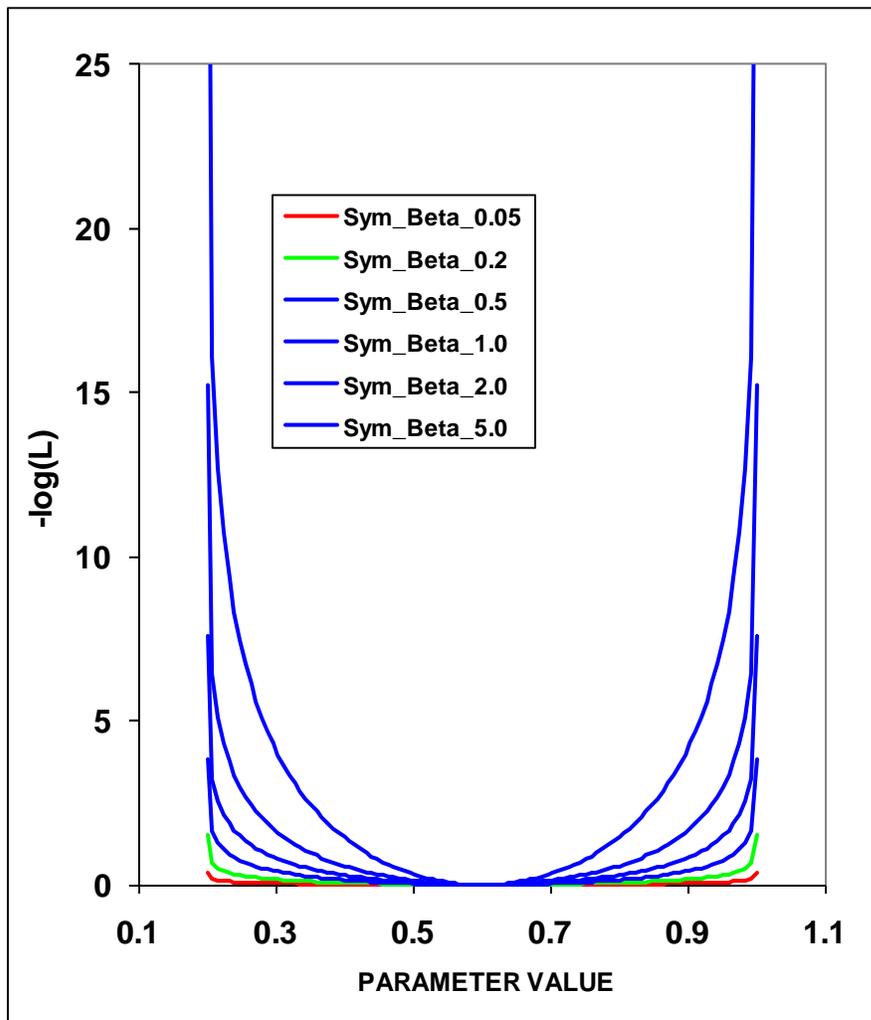


Figure 4. Prior distributions for the symmetric beta distribution.

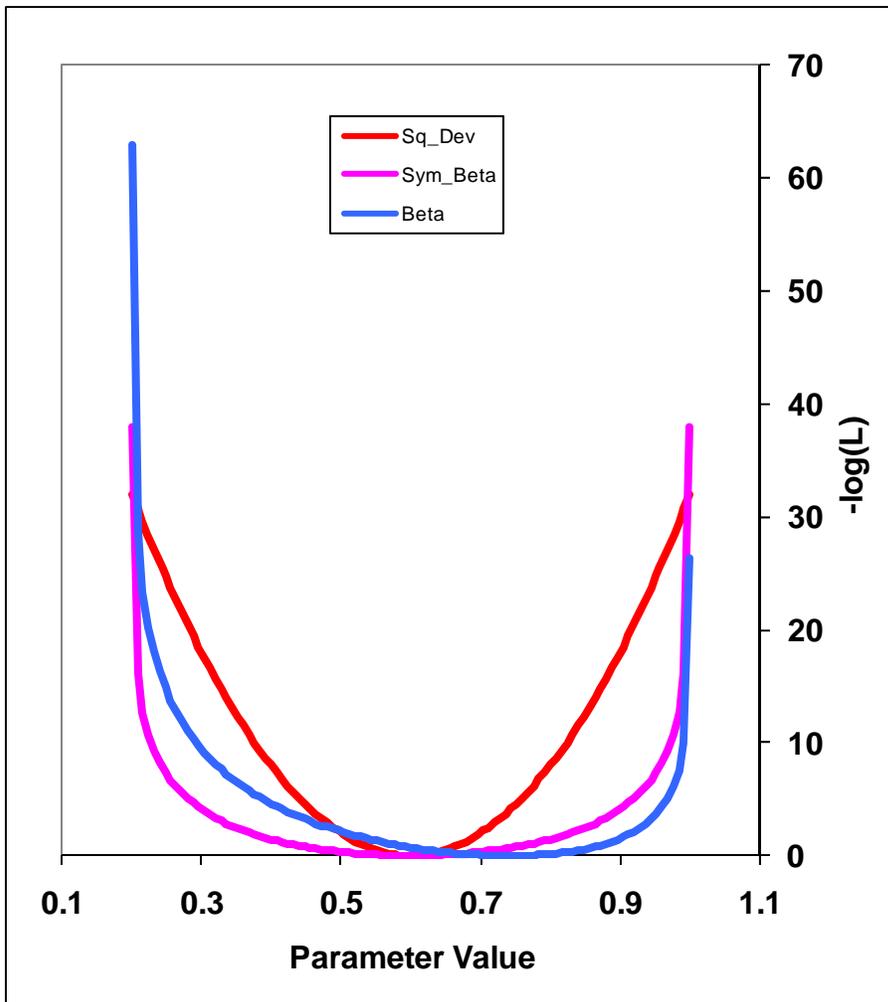


Figure 5 Comparison of parameter prior functions.

## Output Files

### Standard ADMB output files

Standard ADMB files are created by SS. These are:

*SS3.PAR* – This file has the final parameter values. They are listed in the order they are declared in SS. This file can be read back into SS to restart a run with these values (see running SS).

*SS3.STD* – This file has the parameter values and their estimated standard deviation for those parameters that were active during the model run. It also contains the derived quantities declared as sdreport variables. All of this information is also report in the covar.sso. Also, the parameter section of report.sso lists all the parameters with their SS generated names, denotes which were active in the reported run, displays the parameter standard deviations, then displays the derived quantities with their standard deviations.

*SS3.REP* – This report file is created between phases so, unlike report.sso, will be created even if the Hessian fails. It does not contain as much output as shown in report.sso.

*SS3.COR* – This is the standard ADMB report for parameter and sdreport correlations. It is in matrix form and challenging to interpret. This same information is reported in covar.sso.

### Derived Quantities

Before listing the derived quantities reported to the sdreport, there are a couple of topics that deserve further explanation.

#### *Metric for Fishing Mortality*

A generic single metric of annual fishing mortality is difficult to define in a generalized model that admits multiple areas, multiple biological cohorts, dome-shaped selectivity in size and age for each of many fleets. Several separate indices are provided and others could be calculated by a user from the detailed information in report.sso.

Equilibrium SPR – this index focuses on the effect of fishing on the spawning potential of the stock. It is calculated as the ratio of the equilibrium reproductive output per recruit that would occur with the current year's F intensities and biology, to the equilibrium reproductive output per recruit that would occur with the current year's biology and no fishing. Thus it internalizes all seasonality, movement, weird selectivity patterns, and other factors. Because this index moves in the opposite direction than F intensity itself, it is usually reported as 1-SPR. A benefit of this index is that it is a direct measure of common proxies used for Fmsy, such as F40%. A shortcoming of this index is that it does not directly demonstrate the fraction of the stock that is caught each year. The SPR value is also calculated in the benchmarks (see below). The derived quantities report shows an annual SPR statistic. The options, as specified in the starter.ss file, are:

0=skip;

1=(1-SPR)/(1-SPR\_tgt);

2=(1-SPR)/(1-SPR\_MSX);

3=(1-SPR)/(1-SPR\_Btarget);  
 4=rawSPR

F\_std – This index provides a direct measure of fishing mortality. The options are:

0=skip;  
 1=exploitation(Bio);  
 2=exploitation(Num);  
 3=sum(Frates)

The exploitation rates are calculated as the ratio of the total annual catch (in either biomass or numbers as specified) to the summary biomass or summary numbers on Jan 1. The sum of the F rates is simply the sum of all the apical Fs. This makes sense if the F method is in terms of instantaneous F (not Pope’s approximation) and if there are not fleets with widely different size/age at peak selectivity, and if there is no seasonality, and especially if there is only one area. In the derived quantities, there is an annual statistic that is the ratio of the can be annual F\_std value to the corresponding benchmark statistic. The available options for the denominator are:

0=raw;  
 1=F/Fspr;  
 2=F/Fmsy ;  
 3=F/Fbtgt

F-at-Age Because the annual F is so difficult to interpret as a sum of individual F components, an indirect calculation of F-at-age is reported at the end of the report.sso file. This section of the report calculates Z-at-age simply as  $\ln(N_{a+1,t+1}/N_{a,t})$ . This is done on an annual basis and summed over all areas. It is done once using the fishing intensities as estimated (to get Z), and once with the F intensities set to 0.0 to get M-at-age. This latter sequence also provides a measure of dynamic Bzero. The user can then subtract the table of M-at-age/year from the table of Z-at-age/year to get a table of F-at-age/year. From this apical F, average F over a range of ages, or other user-desired statistics could be calculated. Further work within SS with this table of values is anticipated.

*MSY and other Benchhmark Items*

The following quantities are included in the sdreport vector mgmt\_quantities, so obtain estimates of variance. Some additional quantities can be found in the benchmarks section of the forecast\_report.sso.

| Benchmark Item | Description  |
|----------------|--|
| SSB_Unfished   | Unfished reproductive potential (SSB is commonly female mature spawning biomass) |

|                  |   |
|------------------|---|
| TotBio_Unfished  | Total age 0+ biomass on Jan 1   |
| SmryBio_Unfished | Biomass for ages at or above the summary age on Jan 1   |
| Recr_Unfished    | Unfished recruitment  |
| SSB_Btgt         | SSB at user specified SSB target  |
| SPR_Btgt         | Spawner potential ratio (SPR) at F intensity that produces user specified SSB target  |
| Fstd_Btgt        | F statistic at F intensity that produces user specified SSB target  |
| TotYield_Btgt    | Total yield at F intensity that produces user specified SSB target  |
| SSB_SPRtgt       | SSB at user specified SPR target (but taking into account the spawner-recruitment relationship)   |
| Fstd_SPRtgt      | F intensity that produces user specified SPR target   |
| TotYield_SPRtgt  | Total yield at F intensity that produces user specified SPR target  |
| SSB_MS_Y         | SSB at F intensity that is associated with MSY; this F intensity may be directly calculated to produce MSY, or can be mapped to F_SPR or F_Btgt |
| SPR_MS_Y         | Spawner potential ratio (SPR) at F intensity associated with MSY  |
| Fstd_MS_Y        | F statistic at F intensity associated with MSY  |
| TotYield_MS_Y    | Total yield (biomass) at MSY  |
| RetYield_MS_Y    | Retained yield (biomass) at MSY   |

Brief cumulative output

*Cum\_Report.sso*: contains a brief version of the run output, which is appended to current content of file so results of several runs can be collected together. This is especially useful when a batch of runs is being processed. Unless this file is deleted, it will contain a cumulative record of all runs done in that subdirectory. The first column contains the run number. The contents (columns truncated to fit the page) are:

|                 |               |          |                |         |          |          |         | Thu Jan 19    |  |
|-----------------|---------------|----------|----------------|---------|----------|----------|---------|---------------|--|
|                 |               |          |                |         |          |          |         | 13:37:32 2006 |  |
| 40likegfish.dat | likegfish.CTL | 1491.17  | 56792.         | 4530.25 |          |          |         |               |  |
| 40Like-Emph     | Total         |          | 1 Indices      |         | 1        | 1        |         | 1 Discard     |  |
|                 |               |          |                |         |          |          |         | Discard       |  |
|                 |               |          |                |         |          |          |         | _extra_       |  |
| 40Var_adjust    | X             | X        | Index_extra_CV |         | 0        | 0        |         | 0CV           |  |
| 40Like-Value    | 1491.17       | 1491.17  | -7.2568        | 0       | -5.21126 | -2.04554 | 0       |               |  |
| 40Phase         | 1779.45       | 1643.62  | 1503.66        | 1491.17 | 1491.17  |          |         |               |  |
| 40TimeSeries    | Year          | Vir      | Equ            | 1971    | 1972     | 1973     | 1974    |               |  |
| 40Timeseries    | Spbio         | 56792.7  | 56074.3        | 56074.3 | 56071.6  | 56061.6  | 55672.8 |               |  |
| 40Timeseries    | Recruit       | 7699.42  | 7679.07        | 5448.81 | 8278.28  | 6575.76  | 7164.24 |               |  |
| 40Timeseries    | TotBio        | 148714   | 147083         | 146716  | 146599   | 146177   | 144946  |               |  |
| 40Timeseries    | SmryBio-2     | 145430   | 143808         | 143808  | 143808   | 142927   | 142046  |               |  |
| 40Timeseries    | TotCatch      | 0        | 100.002        | 100     | 100      | 1000     | 1000    |               |  |
| 40Timeseries    | RetCatch      | 0        | 0              | 100     | 100      | 1000     | 1000    |               |  |
| 40MG_Parms      | 0.1           | 0        | 36             | 70      | 0.15     | 0.1      | 0.25    |               |  |
| 40SR_Parms      | 8.9489        | 0.401773 | 0.56           | 0       | -0.00265 |          |         |               |  |
| 40Q_Parms       |               |          |                |         |          |          |         |               |  |

|             |         |         |         |         |         |         |         |
|-------------|---------|---------|---------|---------|---------|---------|---------|
| 40Sel_Parms | 52.1741 | 25.8085 | 28.7383 | 3.52001 | 0       | 40      | 0       |
| 40Index:2   | Year    | 1977    | 1980    | 1983    | 1986    | 1989    | 1992    |
| 40Index:2   | VBIO    | 138529  | 123887  | 100056  | 75110.4 | 57039   | 46050.6 |
| 40Index:2   | OBS     | 122005  | 130363  | 67074.8 | 37852.3 | 41481.1 | 82380.5 |
| 40Index:2   | EXP     | 120363  | 107641  | 86935.1 | 65261   | 49559.3 | 40011.8 |
| 40Index:3   | Year    | 1990    | 1991    | 1992    | 1993    | 1994    | 1995    |
| 40Index:3   | VBIO    | 3847.23 | 2824.63 | 1250.02 | 1112.67 | 3819.82 | 3495.18 |
| 40Len:1     | YR      | 1971    | 1972    | 1973    | 1974    | 1975    | 1976    |
| 40Len:1     | effN    | 240.571 | 121.014 | 135.712 | 185.951 | 81.0073 | 151.215 |
| 40Len:2     | YR      | 1977    | 1980    | 1983    | 1986    | 1989    | 1992    |
| 40Len:2     | effN    | 141.151 | 129.342 | 113.115 | 102.136 | 113.378 | 175.735 |
| 40Age:1     | YR      | 1971    | 1972    | 1973    | 1974    | 1975    | 1976    |
| 40Age:1     | effN    | 122.486 | 58.2216 | 64.5374 | 84.8333 | 82.6058 | 114.054 |



## Output for Rebuilder Package

Output filename is REBUILD.DAT

```
#Title # various run summary outputs
SS2_default_rebuild.dat
# Number of sexes
2
# Age range to consider (minimum age; maximum age)
0 40
# Number of fleets
1
# First year of projection (Yinit)
2002
# First Year of rebuilding period (Ydecl)
1999
# Is the maximum age a plus-group (1=Yes;2=No)
1
# Generate future recruitments using historical recruitments (1) historical
recruits/spawner (2) or a stock-recruitment (3)
3
# Constant fishing mortality (1) or constant Catch (2) projections
1
# Fishing mortality based on SPR (1) or actual rate (2)
1
# Pre-specify the year of recovery (or -1) to ignore
-1
# Fecundity-at-age
# 0 1 2 3 4 5 6 7 8 9 10 <deleted values>
0 0.00159008 0.0128943 <deleted values> #female fecundity; weighted by N in year
Y_init across morphs and areas
# Age specific selectivity and weight adjusted for discard and discard mortality
#selex and wt for gender,fleet: 1 1
0.114191 0.174077 0.245545 <deleted values>
0.0248207 0.0707095 0.157683 <deleted values>
#selex and wt for gender,fleet: 2 1
0.114191 0.174077 0.245545 <deleted values>
0.0248207 0.0707095 0.157683 <deleted values>
# M and current age-structure in year Yinit: 2002
# gender = 1
0.1 0.1 0.1 0.1 0.1 <deleted values>
1037.67 696.042 1468.49 <deleted values>
# gender = 2
0.1 0.1 0.1 0.1 <deleted values>
1037.67 696.042 1468.49 <deleted values>
# Age-structure at Ydecl= 1999
```

```

902.589 668.071 1145.47 537.282 <deleted values>
902.589 668.071 1145.47 537.282 <deleted values>
# Year for Tmin Age-structure (set to Ydecl by SS2)
1999
# Number of simulations
1000
# recruitment and biomass
# Number of historical assessment years
93
# Historical data
# year recruitment spawner in B0 in R project in R/S project
1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 <deleted values> 2001 2002
#years (with first value representing R0)
8853.43 8658.22 8651.96 8645.41 8638.43 8630.75 <deleted values> 1594.53 2075.34
#recruits; first value is R0 (virgin)
63679.5 63679.5 63679.3 63678.3 63673.9 63661.6 <deleted values> 8614.18 7313.2
#spbio; first value is S0 (virgin)
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 <deleted values> 0 0 # in Bzero
0 1 1 1 1 1 <deleted values> 1 1 0 0 0 # in R project
0 1 1 1 1 1 <deleted values> 1 1 0 0 0 # in R/S project
# Number of years with pre-specified catches
0
# catches for years with pre-specified catches go next
# Number of future recruitments to override
0
# Process for overriding (-1 for average otherwise index in data list)
# Which probability to product detailed results for (1=0.5; 2=0.6; etc.)
3
# Steepness sigma-R Auto-correlation
0.371059 0.5 0
# Target SPR rate (FMSY Proxy); manually change to SPR_MSX if not using
SPR_target
0.5
# Target SPR information: Use (1=Yes) and power
0 20
# Discount rate (for cumulative catch)
0.1
# Truncate the series when 0.4B0 is reached (1=Yes)
0
# Set F to FMSY once 0.4B0 is reached (1=Yes)
0
# Percentage of FMSY which defines Ftarget
0.75
# Maximum possible F for projection (-1 to set to FMSY)
-1
# Conduct MacCall transition policy (1=Yes)

```

```

0
# Defintion of recovery (1=now only;2=now or before)
2
# Results for rec probs by Tmax (1) or 0.5 prob for various Ttargets (2)
1
# Definition of the 40-10 rule
10 40
# Produce the risk-reward plots (1=Yes)
0
# Calculate coefficients of variation (1=Yes)
0
# Number of replicates to use
10
# Random number seed
-99004
# Conduct projections for multiple starting values (0=No;else yes)
0
# File with multiple parameter vectors
rebuild.ss2
# Number of parameter vectors: value is placeholder only, user needs to change it
1
# User-specific projection (1=Yes); Output replaced (1->9)
0 5 0 0.1
# Catches and Fs (Year; 1/2/3 (F or C or SPR); value); Final row is -1
2002 1 1
-1 -1 -1
# Split of Fs
2002 0.6
-1 99
# Time varying weight-at-age (1=Yes;0=No)
0
# File with time series of weight-at-age data
none
# Use bisection (0) or linear interpolation (1)
1
# Target Depletion
0.4
# Project with Historical recruitments when computing Tmin (1=Yes)
0
# CV of implementation error
0

```

### Bootstrap data files

*Data.ss\_new*: contains a user-specified number of datafiles, generated through a parametric bootstrap procedure, and written sequentially to this file. These can be parsed into individual data files and re-run with the model. The first output provides the unaltered input data file (with annotations added). The second provides the expected values for only the data elements used in the model run. The third and subsequent outputs provide parametric bootstraps around the expected values.

### Updated control file

*Control.ss\_new*: Updated version of the control file with final parameter values replacing the Init parameter values. Note that, at this time, the dev vectors are not written to this file.

### Forecast and reference points

*FORECAST-REPORT.sso*: This file contains output of fishery reference points and forecasts. It is designed to meet the needs of the Pacific Fishery Management Council's Groundfish Fishery Management Plan, but it should be quite feasible to develop other regionally specific variants of this output.

The vector of forecast recruitment deviations is estimated during an additional model estimation phase. This vector includes any years after the end of the recrdev time series and before or at the endyear. When this vector starts before the ending year of the time series, then the estimates of these recruitments will be influenced by the data in these final years. This is problematic, because the original reason for not estimating these recruitments at the end of the time series was the poor signal/noise ratio in the available data. It is not that these data are worse than data from earlier in the time series, but the low amount of data accumulated for each cohort allows an individual datum to dominate the model's fit. Thus, an additional control is provided so that forecast recruitment deviations during these years can receive an extra weighting in order to counter-balance the influence of noisy data at the end of the time series.

An additional control is provided for the fraction of the log-bias adjustment to apply to the forecast recruitments. Recall that  $R$  is the expected mean level of recruitment for a particular year as specified by the spawner-recruitment curve and  $R'$  is the geometric mean recruitment level calculated by discounting  $R$  with the log-bias correction factor  $e^{-0.5s^2}$ . Thus a lognormal distribution of recruitment deviations centered on  $R'$  will produce a mean level of recruitment equal to  $R$ . During the modeled time series, the virgin recruitment level and any recruitments prior to the first year of recruitment deviations are set at the level of  $R$ , and the lognormal recruitment deviations are centered on the  $R'$  level. For the forecast recruitments, the fraction control can be set to 1.0 so that 100% of the log-bias correction is applied and the forecast recruitment deviations will be based on the  $R'$  level. This is certainly the configuration to use when the model is in MCMC mode. Setting the fraction to 0.0 during maximum likelihood forecasts would center the recruitment deviations, which all have a value of 0.0 in ML mode, on  $R$ . Thus would provide a mean forecast that would be more comparable to the mean of the ensemble of forecasts produced in MCMC mode. Further work on this topic is underway.

### Note:

1. Cohorts continue growing according to their specific growth parameters in the forecast period rather than staying static at the endyr values.
2. Environmental data entered for future years can be used to adjust expected recruitment levels. However, environmental data will not affect growth or selectivity parameters in the forecast.

The top of this file shows the search for  $F_{spr}$  and the search for  $F_{msy}$  so the user can verify convergence. Note: if the STD file shows aberrant results, such as all the

standard deviations being the same value for all recruitments, then check the Fmsy search for convergence.

The Fmsy can be calculated, or set equal to one of the other F reference points per the selection made in STARTER.SS.

The reference point output is shown in the table below:

| <b>Management_report</b>                  |                           |            |          |         |            |         |
|---|---------------------------|------------|----------|---------|------------|---------|
|   | Value                     | B_per_Recr | B_per_R0 | B_Total | N_per_Recr | N_total |
| Steepness_R0_S0                           | 0.371                     | 8853       | 63680    |         |            |         |
| +   | (B_in_mT;_N_in_thousands) |            |          |         |            |         |
| Element                                   | Value                     | B_per_Recr | B_per_R0 | B_Total | N_per_Recr | N_total |
| Recr_unfished(R0)                         | --                        | 1.000      | 1.000    | 8853    |            |         |
| SPB_unfished(S0)                          | --                        | 7.193      | 7.193    | 63680   |            |         |
| BIO_Smry_unfished                         | --                        | 18.493     | 18.493   | 163727  |            |         |
| +   | +                         | +          | +        | +       |            |         |
| SPR_target                                | 0.500                     |            |          |         |            |         |
| SPR_calc                                  | 0.500                     |            |          |         |            |         |
| Fmult                                     | 0.261                     |            |          |         |            |         |
| Exploit(Y/Bsmry)                          | 0.052                     |            |          |         |            |         |
| Recruit                                   | --                        | --         | 0.265    | 2343    |            |         |
| SPBio                                     | --                        | 3.596      | --       | 8426    |            |         |
| YPR_encountered                           | --                        | 0.550      | --       | 1289    |            |         |
| YPR_dead                                  | --                        | 0.550      | --       | 1289    | 0.257      | 602     |
| YPR_retain                                | --                        | 0.550      | --       | 1289    |            |         |
| Biomass_Smry                              | --                        | 10.517     | --       | 24641   |            |         |
| +   | +                         | +          | +        | +       |            |         |
| Btarget_rel_to_S0                         | 0.500                     |            |          |         |            |         |
| Btgt_calc                                 | 0.500                     |            |          |         |            |         |
| SPR                                       | 0.712                     |            |          |         |            |         |
| Fmult                                     | 0.116                     |            |          |         |            |         |
| Exploit(Y/Bsmry)                          | 0.024                     |            |          |         |            |         |
| Recruit                                   | --                        | --         | 0.702    | 6218    |            |         |
| SPBio                                     | --                        | 5.120      | --       | 31840   |            |         |
| YPR_encountered                           | --                        | 0.335      | --       | 2085    |            |         |
| YPR_dead                                  | --                        | 0.335      | --       | 2085    | 0.141      | 880     |
| YPR_retain                                | --                        | 0.335      | --       | 2085    |            |         |
| Biomass_Smry                              | --                        | 13.947     | --       | 86730   |            |         |
| +   | +                         | +          | +        | +       |            |         |
| calculate_FMSY                            |                           |            |          |         |            |         |
| SPR                                       | 0.660                     |            |          |         |            |         |
| Fmult                                     | 0.144                     |            |          |         |            |         |
| Exploit(Y/Bsmry)                          | 0.030                     |            |          |         |            |         |
| Recruits                                  | --                        | --         | 0.622    | 5506    |            |         |
| SPBio                                     | --                        | 4.750      | --       | 26157   |            |         |
| SPBmsy/SPBzero(using_S0)                  | --                        | 0.411      | --       | --      |            |         |
| SPBmsy/SPBzero(using_endyear_LifeHistory) | --                        | 0.411      | --       | --      |            |         |
| MSY_for_optimize                          | --                        | 0.391      | --       | 2151    |            |         |
| MSY_encountered                           | --                        | 0.391      | --       | 2151    |            |         |
| MSY_dead                                  | --                        | 0.391      | --       | 2151    | 0.168      | 927     |
| MSY_retain                                | --                        | 0.391      | --       | 2151    |            |         |
| Biomass_Smry                              | --                        | 13.124     | --       | 72263   |            |         |

The forecast is done once using the Target SPR and once using the adjustments specified in the 40:10 section of forecast.ss2 input. Each section contains a time series of seasonal biomass and catch, followed by a time series of population numbers-at-age for each morph.

| <b>Forecast using Fspr</b>   |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
|--|------------------|----------|-----------|----------|--------------|----------|-----------|-----------|--------------|------------|--------------|------------|---------|-----|------|--|
| Allocation_Pattern_as_in_endyear   |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| Harvest_Rates_by_Season&Fleet_(equals_selected_forecast_Fmult*_Allocation_pattern) |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| Season   | fleet:1          |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| 1  | 0.0802           |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| +  |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| Forecast_recruitments_use_this_fraction_of_logbias_adj_before_endyr+1:             |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
|  | 1                |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| and_this_value_after_endyr:  |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
|  | 0                |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| Extra_emphasis_on_forecast_recruits_before_endyr+1:                                |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
|  | 1                |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| N_forecast_yrs;_and_with_stddev:   |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
|  | 6                | 6        |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| OY_Control:  |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
|  | Top;             | Bottom;  | Scale     |          |              |          |           |           |              |            |              |            |         |     |      |  |
| +  | 0.4              | 0.1      | 1         |          |              |          |           |           |              |            |              |            |         |     |      |  |
| +  |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| FORECAST:_Without_40:10  |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| pop  | year             | season   | 4010      | bio-all  | bio-Smry     | SpawnBio | Depletion | recruit-0 | dead_cat_B-1 | retain_B-1 | dead_cat_N-1 | retain_N-1 | Hrate-1 | opt | ABC  |  |
| 1  | 2002             | 1        | 1         | 22361    | 21634        | 7313     | 0.115     | 2075      | 1116         | 1116       | 533          | 533        | 0.0802  | R   | 1116 |  |
| 1  | 2003             | 1        | 1         | 22472    | 21613        | 7341     | 0.115     | 2082      | 1123         | 1123       | 534          | 534        | 0.0802  | R   | 1123 |  |
| +  |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| Forecast-NUMBERS_AT_AGE  |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
|  | <not shown here> |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| +  |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| FORECAST:_with_40:10_Adjustmen   |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
|  | 0.4              | 0.1      | 1         |          |              |          |           |           |              |            |              |            |         |     |      |  |
| pop  | year             | season   | 4010      | bio-all  | bio-Smry     | SpawnBio | Depletion | recruit-0 | dead_cat_B-1 | retain_B-1 | dead_cat_N-1 | retain_N-1 | Hrate-1 | opt | ABC  |  |
| 1  | 2002             | 1        | 0.17242   | 22361    | 21634        | 7313     | 0.115     | 2075      | 192          | 192        | 92           | 92         | 0.0138  | R   | 1116 |  |
| 1  | 2003             | 1        | 0.226996  | 23357    | 22481        | 7674     | 0.121     | 2163      | 266          | 266        | 125          | 125        | 0.0182  | R   | 1171 |  |
| +  |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| Annual_all_area_values_stored_in_sreport_vector_'depletion'_beginning_in_element_6 |                  |          |           |          |              |          |           |           |              |            |              |            |         |     |      |  |
| Year   | Spbio            | Recruits | Depletion | Catch_or | Exploitation |          |           |           |              |            |              |            |         |     |      |  |
| 2002   | 7313             | 2075     | 0.115     | 192.4    | 0.0089       |          |           |           |              |            |              |            |         |     |      |  |
| 2003   | 7674             | 2163     | 0.121     | 265.8    | 0.0118       |          |           |           |              |            |              |            |         |     |      |  |



Where:

40:10 is the magnitude of the adjustment of harvest multiplier to implement the OY policy

bio-all is the biomass of all ages

bio-smry is the biomass for ages at or above the summary age

Spawnbio is the female spawning output

Depletion is the spawnbio divided by the unfished spawnbio

Recruit-0 is the recruitment of age-0 fish in this year

Dead\_cat\_B-1 is the total dead (retained plus dead discard) catch in MT for fleet 1;

Retain\_B-1 is fleet 1's retained catch in MT

Equivalent catch in numbers is then reported.

Hrate-1 is the harvest rate, as adjusted by the 40:10 policy. The units will depend on the F method selected (Pope's method giving mid-year harvest rate or the continuous F.

Opt=C means that the rate was calculated from an input catch level (and crashed means that this caused an excessive harvest rate.

Opt=R means that the catch was calculated from the target harvest rate.

ABC is equal to the Total-Catch when the 40:10 option is not used (upper portion of table). When the 40:10 is on (lower table), the ABC is the catch level corresponding to no 40:10 adjustment after accounting for catch in previous year's from the 40:10.

The time series output described above is detailed by season, area, morph and fishery. It is usually more convenient to have annual values summed across areas, morphs and fisheries. This is done for the 40:10 output and a subset of these values are replicated in the depletion vector in the sd\_report so that variance estimates can be obtained. The elements of the depletion vector in the sd\_report are:

1. depletion level in end year
2. depletion level in end year+1
3. MSY (if calculated, else spbio in endyr-1)
4. BMSY (if calculated, else spbio in endyr)
5. SPRMSY (if calculated, else spbio in endyr+1)

then the time series of:

- a. Spawning biomass
- b. Recruitment

- c. depletion level
- d. total catch (if forecast calculated catch from rates) or sum of fishery-specific harvest rates (if forecast is based on fixed input catch level in this year)
- e. Total exploitation rate (total dead catch / summary biomass at beginning of year).

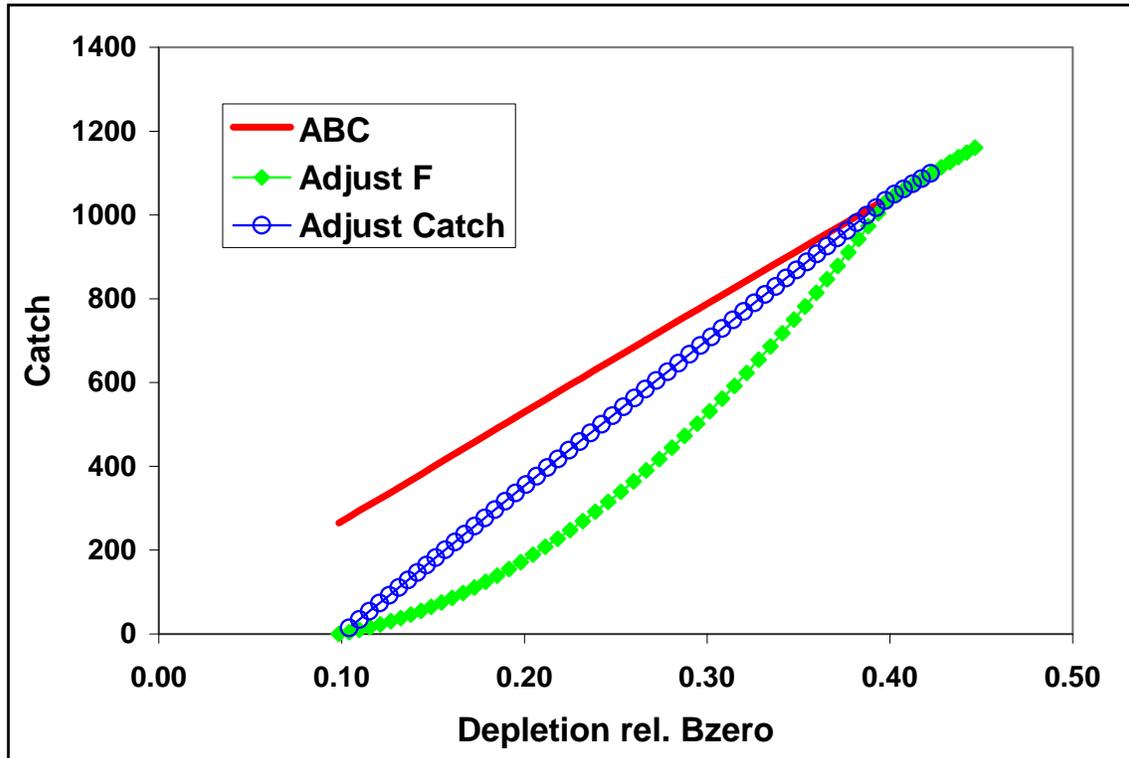


Figure 6. Two examples of harvest forecast adjustment: one adjusts catch and the other adjusts F.

### Main output file, report.sso

*Report.sso*: This is the primary output file. Its major sections are listed below. Each has an associated label. The Excel spreadsheet *ss2-output.xls* reads this *ss2.rep* file, searches for labels in the first column, and copies the adjacent information into specific worksheets for detailed display. Similar capability has been built using R routines and has been included in the GUI.

Content below has not yet been updated for *ss\_v3*.

### LIKELIHOOD

Final values of the negative log(likelihood) are presented.

### PARAMETERS

The parameters are listed here. For the estimated parameters, the display shows: Value, Phase, Min, Max, Init, Prior, PR\_type, SD, Active\_Cnt, Prior\_Like, and Bound. The Active\_Cnt entry is a count of the parameters in the same order they would appear in the *ss2.cor* file.

### MGParm\_Block\_Assignments

#### Selex\_Block\_Assignments

If parameter time blocks are used, then for each base parameter that uses blocks, the parameter number of the block offset is shown for each year of the time series. A value of zero means that the base parameter retains its value for that year.

### RECR\_DIST

This block shows the distribution of recruitment across growth patterns, genders, birthseasons, and areas in the endyr of the model.

### SUBMORPHDIST

This block shows a vector with the distribution of recruitment among sub-morphs within each growth pattern x gender x birthseason x area.

### MGparm\_By\_Year\_after\_adjustments

This block shows the time series of Mgparms by year after adjustment by environmental links, blocks and deviations.

### SELparm(Size)\_By\_Year\_after\_adjustments

This block shows the size selectivity parameters, after adjustment, for each year in which a change occurs.

### SELparm(Age)\_By\_Year\_after\_adjustments

This block shows the age selectivity parameters, after adjustment, for each year in which a change occurs.

## EXPLOITATION

This block shows the harvest rate (if Pope's approximation is used) or F by year and fleet.

## TIME\_SERIES

This section reports the time series of abundance, recruitment and catch for each of the areas (populations). It extends into the forecast period.

## SPR\_series

This section reports on the annual yield per recruit and biomass per recruit calculations. The level of recruitment used for the calculations is R0, the virgin recruitment level. Reported values are the levels that would occur if life history remained at the current year's values and fishery intensity and selectivity remained at the current year's levels. The report contains: Bio\_all (fished total biomass at R0); Bio\_Smry (fished summary biomass at R0); SPBzero (unfished spawning biomass at R0 and current year's life history); SPBfished (fished spawning biomass at R0 and current year's life history); SPBfished/R (fished spawning biomass per recruit); SPR (spawning potential ratio equal to SPBfished/SPBzero); Y/R (yield per recruit); GenTime (unfished generation time equal to mean age weighted by fecundity at age). Additional exploitation statistics are the AveF (average F across ages beginning at the summary age) for each gender, and the maxF (simply Z-M) among ages for each gender. This report section extends into the forecast period.

## SPAWN\_RECRUIT

This section shows the relationship among the steps to calculating recruitment. The column "exp-recr" shows the level estimated by the spawner-recruitment curve. The column "with-env" adjusts this value according to the inputted environmental conditions for that year. The column "bias-adj" adjusts the expected value downwards to the expected geometric mean to serve as the point of central tendency for the log-scale deviations. Finally, the column "pred-recr" shows the value used in the model after adjusting for the year specific recruitment deviation. Early years (prior to start of the recruitment deviations), including the virgin recruitment level, use the "exp-recr" level of recruitment. If the recruitment deviations stop before the ending year, then recruitment deviations for those years can be estimated as forecast recruitment deviations and will be labeled with "forecast" in this output. The root mean squared error of the recruitment deviations (not including deviations from the forecast vector) is shown below the time series.

## INDEX\_1

This section lists the options used for processing the abundance index data.

## INDEX\_2

This section reports the observed and expected values for each index. All are reported in one list with index number included as a selection field. At the bottom of this section, the root mean squared error of the fit to each index is compared to the mean input error level to assist the user in gauging the goodness-of-fit and potentially adjusting the input level of imprecision.

#### INDEX\_3

This section shows the parameter number assigned to each parameter used in this section.

#### DISCARD

This is the list of observed and expected values for the amount (or fraction) discard.

#### MEAN\_BODY\_WT

This is the list of observed and expected values for the mean body weight.

#### FIT\_LEN\_COMPS

This is the list of the goodness of fit to the length compositions. The input and output levels of effective sample size are shown as a guide to adjusting the input levels to better match the model's ability to replicate these observations.

#### FIT\_AGE\_COMPS

This has the same format as the length composition section.

#### LEN\_SELEX

Here is reported the time series of length selectivity for each fishery and survey.

#### RETENTION

#### DISCARD\_MORT

KEEPERS – combination of length selectivity and retention

DEADFISH – this is  $sel * (retain + (1 - retain) * discmort)$

#### AGE\_SELEX

Here is reported the time series of age selectivity for each fishery and survey.

#### AGE\_SELEX\_IN\_ENDYEAR\_FROM\_SIZE\_SELEX

This section shows the combination of length selectivity and the age-length key in the ending year. The overall age selectivity is the product of direct age selectivity and this age selectivity derived from length selectivity.

#### ENVIRONMENTAL\_DATA

The input values of environmental data are echoed here. In the future, the summary biomass in the previous year will be mirrored into environmental column -2 and that the age zero recruitment deviation into environmental column -1.

#### NUMBERS\_AT\_AGE

The output is shown for each morph in each area.

#### CATCH\_AT\_AGE

The output is shown for each morph by each fleet. It is not necessary to show by area because each fleet operates in only one area.

#### BIOLOGY

The first biology section shows the length-specific quantities in the ending year of the time series only. The derived quantity spawn is the product of female body weight, maturity and fecundity per weight.

The second biology section shows the derived age-specific quantities for the population and, by taking into account size-selectivity, each fishery and survey.

#### Growth\_Parameters

This section shows the growth parameters, and associated derived quantities, for each year in which a change is estimated.

#### MEAN\_BODY\_WT(begin)

This section reports the time series of mean body weight for each morph. Values shown are for the beginning of each season of each year.

#### MEAN\_SIZE\_TIMESERIES

This section shows the time series of mean length-at-age for each morph.

#### AGE\_LENGTH\_KEY

This is reported for the midpoint of each season in the ending year.

#### AGE\_AGE\_KEY

This is the calculated distribution of observed ages for each true age for each of the defined ageing keys.

#### Composition\_Database

This section contains the length composition, age composition, and mean length-at-age observed and expected values. It is arranged in a database format, rather than an array of vectors. Software to filter the output allows display of subsets of the database.

Selectivity\_Database.

This section contains the selectivities organized as a database, rather than as a set of vectors.

### **Running SS**

SS can be run from a DOS window in a directory containing the file SS3.EXE (or a path to SS3.EXE) and the necessary input files. Simply type SS3 at the DOS prompt. This will start the executable and the first step will be to open and read the file named *starter.ss* which contains necessary run information.

As with all ADMB-based programs, switches are typed immediately after a space. For example,

```
SS3 -nohess
```

would run SS3 without calculating the Hessian matrix.

### Example of DOS batch input file

A DOS batch file (e.g. SS.bat) might contain some explicit ADMB commands, some implicit commands, and some DOS commands:

```
c:\mymodel\ss3.exe -cbs 5000000000 -gbs 500000000000 %1 %2 %3 %4  
del ss3.r0*  
del ss3.p0*  
del ss3.b0*
```

The example below renames a file to *starter.ss*, calls *SS3.exe*, and then copies one of the output files to save it from being overwritten. This sequence is repeated 3 times here and can be repeated an unlimited number of times. The batch file can have any name with the .bat extension, and there is no particular limit to the DOS commands invoked. Note that brief output from each run will be appended to *cumreport.sso* (see below).

### *Simple batch*

This first example relies upon having a set of prototype files that can be renamed to *starter.ss* and then used to direct the running of SS

```
del ss3.cor  
del ss3.std  
copy starter.r01 starter.ss  
c:\admodel\ss\ss3.exe -sdonly  
copy ss3.std ss-std01.txt  
  
copy starter.r01 starter.ss  
c:\admodel\ss\ss3.exe -sdonly  
copy ss3.std ss-std02.txt
```

### *Complicated batch*

This second example processes 25 dat files from a different directory, each time using the same ctl and nam file. The loop index is used in the file names, and the output is searched for particular keywords to accumulate a few key results into the file *SUMMARY.TXT*. Comparable batch processing can be accomplished by using R or other script processing programs.

```
del summary.txt
del ss2-report.txt
copy /Y runnumber.zero runnumber.ss2

FOR /L %%i IN (1,1,25) DO (
copy /Y ..\MakeData\A1-D1-%%i.dat Asel.dat
del ss3.std
del ss3.cor
del ss3.par
c:\admodel\ss\ss3.exe
copy /Y ss3.par A1-D1-A1-%%i.par
copy /Y ss3.std A1-D1-A1-%%i.std
find "Number" A1-D1-A1-%%i.par >> Summary.txt
find "hessian" ss3.cor >> Summary.txt)
```

### *Batch using PROFILEVALUES.SS*

This example will run a profile on natural mortality and spawner-recruitment steepness, of course.

Edit the control file so that the natural mortality parameter and steepness parameter lines have the phase set to -9999

Edit *STARTER.SS* to refer to this control file and the appropriate data file

### Create a PROFILEVALUES.SS file

```
2      # number of parameters using profile feature
0.16  # value for first selected parameter when runnumber equals 1
0.35  # value for second selected parameter when runnumber equals 1
0.16  # value for first selected parameter when runnumber equals 2
0.40  # value for second selected parameter when runnumber equals 2
0.18  # value for first selected parameter when runnumber equals 3
0.40  # value for second selected parameter when runnumber equals 3
etc.; make it as long as you like.
```

Create a batch file that looks something like this. Or make it more complicated as in the example above.

```
del cumreport.sso
copy /Y runnumber.zero runnumber.ss      % so you will start with runnumber=0
C:\SS2\ss3.exe
C:\SS2\ss3.exe
```

C:\SS2\ss3.exe

C:\SS2\ss3.exe

Repeat as many times as you have set up conditions in the PROFILEVALUES.SS file.

The summary results will all be collected in the cumreport.sso file. Each step of the profile will have a unique Runnumber and its output will include the values of the natmort and steepness parameters for that run.

#### Re-starting a Run

SS model runs can be restarted from a previously estimated set of parameter values. In the *starter.ss* file, enter a value of 1 on the first numeric input line. This will cause SS to read the file *ss3.par* and use these parameter values in place of the initial values in the control file. This option only works if the number of parameters to be estimated in the new run is the same as the number of parameters in the previous run because only actively estimated parameters are saved to the file *ss3.par*. The file *ss3.par* can be edited with a text editor, so values can be changed and rows can be added or deleted. However, if the resulting number of elements does not match the setup in the control file, then unpredictable results will occur. Because *ss3.par* is a text file, the values stored in it will not give exactly the same initial results as the run just completed. To achieve greater numerical accuracy, SS can also restart from *ss3.bar* which is the binary version of *ss3.par*. In order to do this, the user must make the change described above to the *starter.ss* file and must also enter **-binp ss3.bar** as one of the command line options.

## Graphical Interface

<Note: This section on the GUI has not been updated for SS\_v3.>

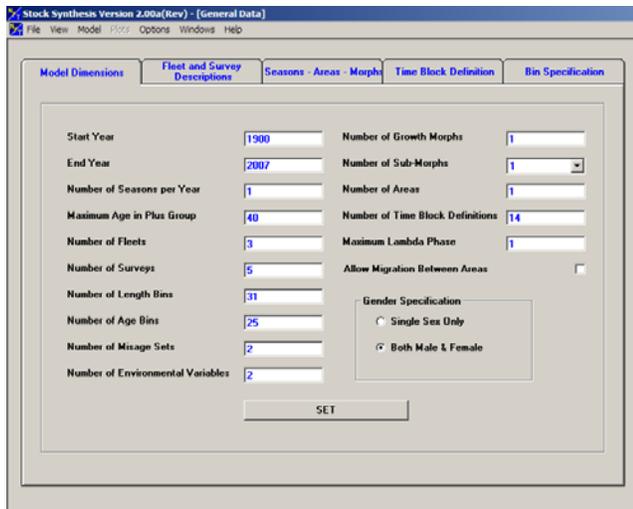
The SS graphical interface uses the same general approach as other stock assessment models in the NOAA Fisheries Assessment Toolbox. The GUI reads and writes DOS text files that are identical in content to the text files described in this document. When the GUI is started, the user sees the Input Files screen. Click on File-Open Existing SS File, navigate to the folder containing the target files, and open STARTER.SS. The GUI opens all necessary files



After reading the files, the user can then select one of the 5 windows for reviewing and editing input information. These windows are:

1. Starter file
2. General data (basically model dimensions)
3. Forecast specifications
4. Observed data (most information from the dat file)
5. Control parameters (most information from the ctl file).

Each window contains a multiple document interface with different tabs for different categories of information.



The GUI contains an internal editing window that allows for editing a cell, or continuously editing within a row or column. Marking a block of cells or clicking on a row or column header calls up a cut – paste option. In addition, blocks of information can be cut from external text editors or spreadsheets and pasted into the GUI cells, but only if the size of the block conforms. Also the user can resize the width of columns to allow viewing the most relevant columns more easily.

If you give the GUI a command that results in resizing arrays (such as changing the selectivity pattern to be used for a particular fishery so that the required number of parameters is changed) then the set of new parameters will be set to blank. The user could then select a block of control specifications from SS2-examples.xls for the newly invoked selectivity function and paste them into this blank area.

When the user is ready to run the program, select Model – Run. The GUI will then save all the input files, run the program, return to the GUI, scan the output files, and return control to the user for viewing the output.

Before using the GUI, it is wise to save a back-up copy of all input files. This is because all custom comments you have placed in these text files will be lost when they are read and rewritten by the GUI. Also, possible GUI crashes may cause loss of some information when the input files are being written.

Future developments with the GUI may include more internal business rules to check for illegal or illogical combinations of input choices, more context-sensitive help, scanning of more output files, etc.

### Debugging Tips

When SS input files are causing the program to crash or fail to produce sensible results, there are a few steps that can be taken to diagnose the problem. Before trying the steps below, examine the ECHOINPUT.SSO file. It is highly annotated, so you should be able to see if SS is interpreting your input files as you intended.

- a. set the turn\_off\_phase switch to 0 in the STARTER.SS file. This will cause the mode to not attempt to adjust any parameters and simply converges a dummy

parameter. It will still produce a REPORT.SSO file, which can be examined to see what has been calculated from the initial parameter values.

b. turn the verbosity level to 2 in the STARTER.SS file. This will cause the program to display the value of each likelihood component to the screen on each iteration. So if the program is creating an illegal computation (e.g. divide by zero), it may show you which likelihood component contains the problematic calculation. If the program is producing a REPORT.SSO file, you may then see which observation is causing the illegal calculation.

c. run the program with the command `SS3 >>SSpipe.txt`. This will cause all screen display to go to the specified text file (note, delete this file before running because it will be appended to). Examination of this file will show detailed statements produced during the reading and preprocessing of input files.

d. *CHECKUP.SSO*: This file can be written during the first iteration of the program. It contains details of selectivity and other calculations as an aid to debugging model problems.

e. If SS fails to achieve a proper Hessian it exits without writing the detailed outputs in the FINAL\_SECTION. If this happens, you can do a run with the `-nohess` option so you can view the report.sso to attempt to diagnose the problem.

### Keyboard Tips

Typing "N" during a run will cause ADMB to immediately advance to the next phase of estimation.

Typing "Q" during a run will cause ADMB to immediately go to the final phase. This bypasses estimation of the Hessian and will produce all of the SS outputs, which are coded in the FINAL\_SECTION.

### Running MCMC

#### 1. Run SS3

- This gives MPD estimates, report file, Hessian matrix and the .cor file
- (Recommended) Look for parameters stuck on bounds which will degrade efficiency of MCMC implementation
- (Recommended) Look for very high correlations that may degrade the efficiency of MCMC implementation

#### 2. Run SS3 with arguments `-mcmc xxxx -mcsave yyyy`

- Where: xxxx is the number of iterations for the chain, and yyyy is the thinning interval (1000 is a good place to start)
- MCMC chain starts at the MPD values
- (Recommended) Remove existing .psv files in run directory to generate a new chain.
- (Recommended) Set DOS run detail switch in starter file to 0; reporting to screen will dramatically slow MCMC progress
- (Optional) Add `-nohess` to use the existing Hessian file without re-estimating
- (Optional) Add `-noest -nohess -mcpin myfile.xxx` starts the MCMC chain from any values you want (file name "myfile.xxx" matching exactly the .par file format)

- (Optional) Add -noest -nohess and modify starter file so that run will now start from the converged (or modified) parameter estimates in "ss3.par"

3. Run SS3 with argument -mceval

- This generates the posterior output files.
- (Optional) Modify starter file entries to add a burn-in and thinning interval above and beyond the ADMB thinning interval applied at run time.
- (Recommended) MCMC always begins with the MPD values and so a burn-in >0 should always be used.
- This step can be repeated for alternate forecast options (e.g. catch levels) without repeating step 2.

4. (Optional) Run SS3 with arguments -mcr -mcmc xxxx -mcsave yyyy ...

- This restarts and extends an uninterrupted chain previously completed (note that any intermediate runs without the -mcr command in the same directory will break this option).

NOTES:

When SS switches to MCMC or MCEVAL mode, it sets all the bias adjustment factors to 1.0 for any years with recruitment deviations defined.

SS does not create a report file after completing MCMC because it would show values based on the last MCMC step.

## Special Set-ups

### Continuous seasonal recruitment

It is awkward in SS to set up a seasonal model such that recruitment can occur with similar and independent probability in any season of any year. Consequently, some users have attempted to setup SS so that each quarter appears as a year. They have set up all the data and parameters to treat quarters as if they were years (i.e. each still has a duration of 1.0 time step). This can work, but requires that all rate parameters be re-scaled to be correct for the quarters being treated as years.

Another option is available. If there is one season per year and the season duration is set to 3 (rather than the normal 12), then the season duration is calculated to be 3/12 or 0.25. This means that the rate parameters can stay in their normal per year scaling and this shorter season duration makes the necessary adjustments internally. Some other adjustments to make when doing quarters as years include:

- re-index all "year seas" inputs to be in terms of quarter-year because all are now season 1; increase endyr value in sync with this
- increase max age because age is now in quarters
- in the age error definitions, increase the number of entries in accord with new max age
- in the age error definitions, recode so that each quarter-age gets assigned to the correct agebin; This is because the age data are still in terms of agebins; i.e. the first 4 entries for quarter-ages 1 through 4 will all be assigned to agebin 1.5; the next four to agebin 2.5; you cannot accomplish the same result by editing the age bin values because the stddev of ageing error is in terms of agebin
- in the control file, multiple the natM age breakpoints and growth AFIX values by 1/seasdur
- decrease the R0 parameter starting value because it is now the average number of recruitments per qtryear
- edit the rec\_dev start and endyrs to be in terms of qtryear
- edit any age selectivity parameters that refer to age to now refer to qtrage
- if there needs to be some degree of seasonality to recruitment or some parameter, then you could create a cyclic pattern in the environmental input and make recruitment or some other parameter a function of this cyclic pattern

A good test showing comparability of the 3 approaches to setting up a quarterly model should be done.

## Special Issues

### Recruitment Variability and Bias Corrections

NOTE: April 2009 – the section below needs to be updated to address the capability to have a phase-in of the bias adjustment and the capability to set a max bias adjustment that is less than 1.0. Because the data are never perfectly informative about the recruitment

deviations, it is normal for  $\sigma_R$  to be greater than the rmse of the estimated recruitments.

Recruitments in SS are defined as lognormal deviates around a log-bias adjusted spawner-recruitment curve. The magnitude of the log-bias adjustment is calculated from the level of  $\sigma_R$ , which is the standard deviation of the recruitment deviations (in log-space). There are 5 segments of the time series in which to consider the effect of the log-bias adjustment: virgin; initial equilibrium; early data-poor period; data-rich period; very-recent/forecast.

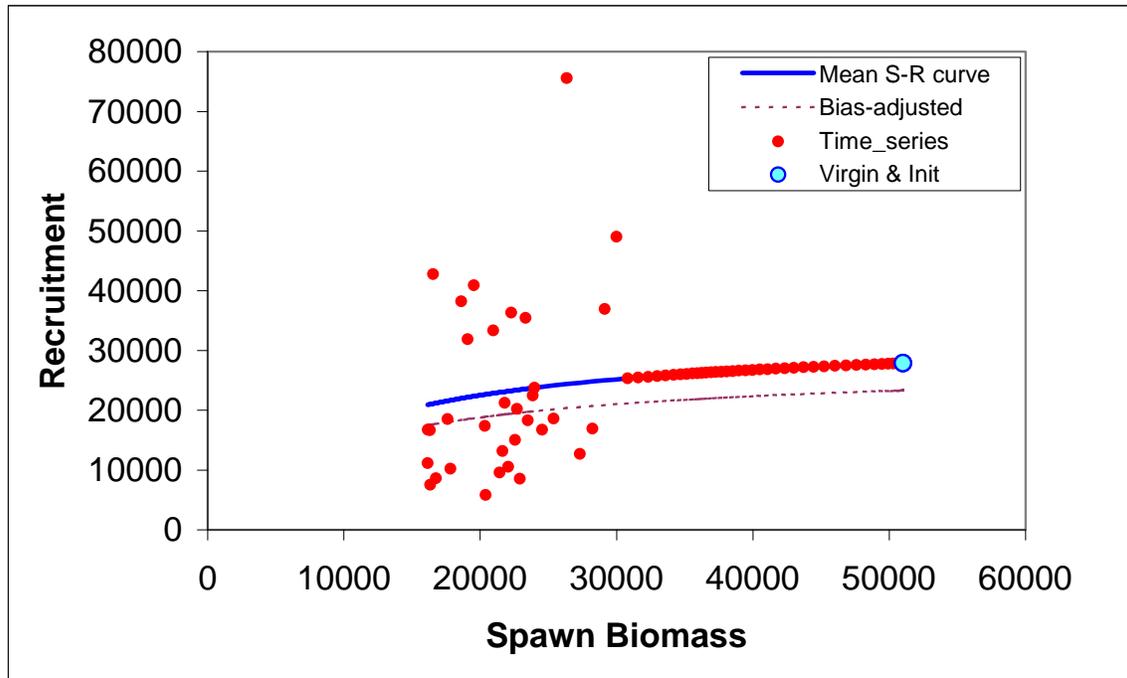


Figure. Spawner-recruitment results with a 72 year time series, no initial equilibrium catch,  $\sigma_R$  set to 0.6, estimated recruitments for last 32 years only, steepness and  $R_0$  parameters estimated.

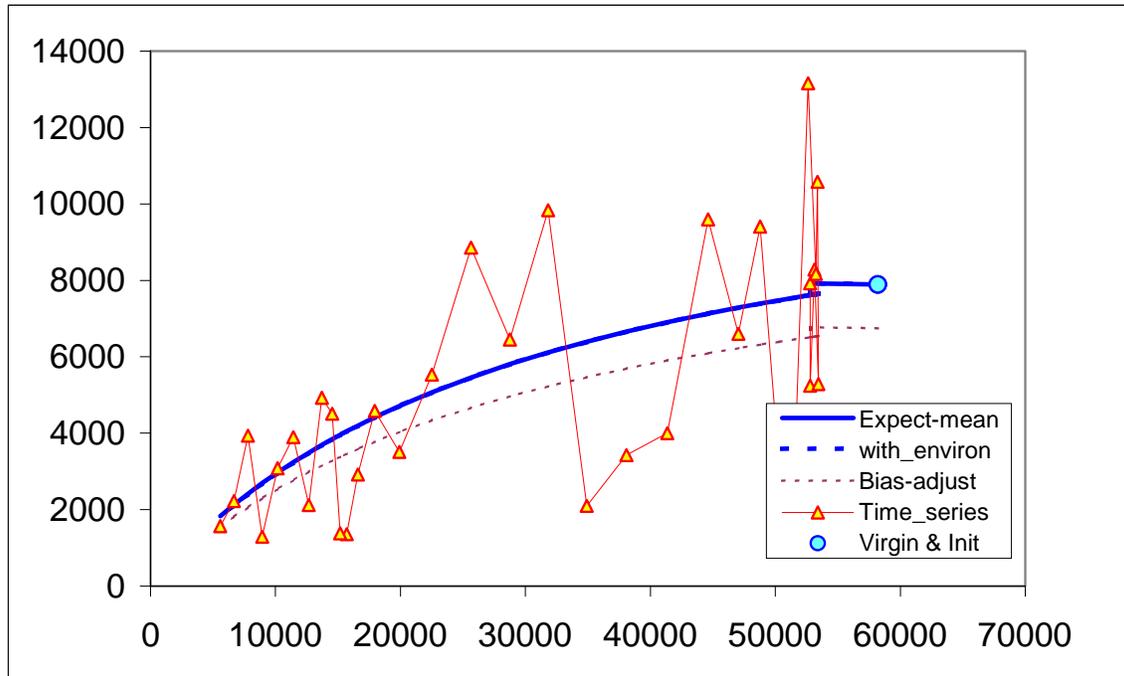


Figure. Spawner-recruitment results with a 30-year time series, initial equilibrium catch of 500 mtons,  $\sigma_R$  set to 0.56, estimated recruitments for all years, steepness and  $R_0$  parameters estimated.

1. Virgin – the  $R_0$  level of recruitment is a parameter of the spawner-recruitment curve. This recruitment and the corresponding spawning biomass,  $S_0$ , are expected to represent the long-term arithmetic mean.
2. Initial equilibrium – the level of recruitment is typically maintained at the  $R_0$  level even though the initial equilibrium catch will reduce the spawning biomass below the virgin level. If steepness is moderately low or the initial  $F$  is high, then the lack of response in recruitment level may appear paradoxical. The logic is that building in the spawner-recruitment response to initial  $F$  would significantly complicate the calculations and would imply that the initial equilibrium catch level had been going on for multiple generations. If the lack of response is considered to be problematic in a particular application, then start the model at an earlier year and with a lower initial equilibrium catch so that the dynamics of the spawner-recruitment response get captured in the early period, rather than getting lost in the initial equilibrium.
3. Early data-poor period – This is the early part of the time series where the only data typically are landed catch. There are no data to inform the model about the specific year-to-year fluctuations in recruitment, although the ending years of this period will begin to be influenced by the data. The “early time period” is not a formal concept. It is up to the user to decide whether to start estimating recruitment deviations beginning with the first year of the model, or to delay such estimation until the data become more informative.

Option A: do not estimate recruitment deviations during this early period. During years prior to the first year of recruitment deviations, the model will set the recruitment equal to the level of the spawner-recruitment curve. Thus, it is a

mean-based level of recruitment. Because these annual parameters are fixed to the level of the spawner-recruitment curve, they have no additional uncertainty and make no contribution to the variance of the model.

This approach may produce relatively large, or small, magnitude deviations at the very beginning of the subsequent period, as the model “catches up” to any slight signal that could not be captured through estimated deviations in the early data-poor period. There may be some effect on the estimate of  $R_0$  as a result of lack of model flexibility in balancing early period removals with signal in the early portion of the data-rich period.

Option B: estimate recruitment deviations for all the early years. Each of these recruitment deviations is now a dev parameter so will have a variance that contributes to the total model variance. The estimated standard deviation of each of these dev parameters should be equal to  $\sigma_R$  because  $\sigma_R$  is the only constraint on these parameters (however, the last few in the sequence will begin to feel the effect of the data so should have lower standard deviations).

MPD: The maximum posterior density will occur when these early recruitment deviations are at zero (except those influenced by the data). Because there are no year-to-year, lognormally distributed changes in these recruitments, their arithmetic mean declines to equal their geometric mean. Thus, the biomass at the end of the early period will decline below the initial equilibrium level just because recruitments are now at the lower geometric mean level. The magnitude of this decline depends on the magnitude of  $\sigma_R$  and the duration of the early period. Thus, reported depletion levels during this early period are an artifact of the MPD and should not be interpreted with respect to the status of the stock.

If the first year of recruitment devs is much before the onset of data that are informative about recruitment fluctuations, then it would be useful for the MPD estimation to have more control over the degree of log-bias adjustment to apply, similar to the control for the forecast recruitments. This could be done by creating another dev vector called “early recruitment deviations” so that the user can control use of the log-bias adjustment during the early period separately from the data-rich period.

MCMC: During the MCMC, the model will draw the recruitment deviation values from the lognormal distribution. Because these draws now have lognormal variability in year-to-year recruitment, the average biomass from the converged MCMC chain will behave as if arithmetic mean recruitment was occurring. Therefore, the early biomass levels in MCMC are in equivalent terms to the virgin biomass, so reported depletion levels are meaningful.

4. Data-rich period: Here the data inform the model on the year-to-year level of recruitment. These fluctuations in recruitment are assumed to have a lognormal distribution around the log-bias adjusted spawner-recruitment curve. The level of  $\sigma_R$  input to the model should match this level of fluctuation to a reasonable degree. Because

the recruitments are lognormal, they produce a mean biomass level that is comparable to the virgin biomass and thus the depletion level can be calculated without bias. However, if the early period has recruitment deviations estimated by MPD, then the depletion levels during the early part of the data-rich period may have some lingering effect of negative bias during the early time period.

The level of  $\sigma_R$  should be at least as large as the level of variability in these estimated recruitments. If too high a level of  $\sigma_R$  is used, then a bias can occur in the estimate of spawner-recruitment steepness, which determines the trend in recruitment. This occurs when the early recruitments are taken directly from the spawner-recruitment curve, so are mean unbiased, then the later recruitments are estimated as deviations from the log-bias adjusted curve. If  $\sigma_R$  is too large, then the bias-adjustment is too large, and the model may compensate by increasing steepness to keep the mean level of recent recruitments at the correct level.

5. Recent Years/Forecast: Here the situation is very similar to the early time period in that there are no data to inform the model about the year-to-year pattern in recruitment fluctuations so all devs will be pulled to a zero level in the MPD. A control has been introduced so that the user can select the fraction of the log-bias adjustment to use during the forecast. Setting this at 0.0 for the MPD will cause future recruitments to be at the mean level. Setting this to 1.0 for the MCMC will cause the future recruitments to have a lognormal distribution around the geometric mean, thus creating an expected arithmetic mean that should be the same as the arithmetic mean without log-bias adjustment. The structure of SS2 creates no sharp dividing line between the estimation period and the forecast period. In many cases one or more recruitments at the end of the time series will lack appreciable signal in the data and should therefore be treated as forecast recruit deviations. To the degree that some variability is observed in these recruitments, partial or full bias correction may be desirable for these devs separate from the purely forecast devs, there is therefore an additional control for the level of bias correction applied to forecast deviations occurring prior to endyear+1.

#### Issues with Including Environmental Effects:

The expected level of recruitment is a function of spawning biomass, an environmental time series, and a log-bias adjustment.

$$E(\text{Recruitment}) = f(\text{SpBio}) * \exp(\beta * \text{envdata}) * \exp(-0.5 * \sigma_R^2)$$

$\sigma_R$  is the variability of the deviations, so it is in addition to the variance “created” by the environmental effect. So, as more of the total recruitment variability is explained by the environmental effect, the residual  $\sigma_R$  should be decreased. The model does not do this automatically.

The environmental effect is inherently lognormal. So when an environmental effect is included in the model, the arithmetic mean recruitment level will be increased above the level predicted by  $f(\text{SpBio})$  alone. The consequences of this have not yet been thoroughly investigated, but there probably should be another bias correction based on the variability of the environmental data as scaled by the estimated linkage parameter,  $\beta$ .

It is also problematic that the environmental effect time series used as input is assumed to be measured without error.

The preferred approach to including environmental effects on recruitment is not to use the environmental effect in the direct calculation of the expected level of recruitment. Instead, the environmental data would be used as if it was a survey observation of the recruitment deviation. This approach is similar to using the environmental index as if it was a survey of age 0 recruitment abundance because by focusing on the fit to the deviations it removes the effect of SpBio on recruitment. In this alternative, the  $\sigma_R$  would not be changed by the environmental data; instead the environmental data would be used to explain some of the total variability represented by  $\sigma_R$ . This approach may also allow greater uncertainty in forecasts, as the variability in projected recruitments would reflect both the uncertainty in the environmental observations themselves and the model fit to these observations.

**Initial Age Composition** – If the first year with recruitment deviations is set less than the start year of the model, then these early deviations will modify the initial age composition. The amount of information on historical recruitment variability certainly will degrade as the model attempts to estimate deviations for older age groups in the initial equilibrium. So the degree of bias correction is reduced linearly in proportion to age so that the correction disappears when maximum age is reached. The initial age composition approach normally produces a result that is indistinguishable from a configuration that starts earlier in the time series and estimates a longer time series of recruitments. However, because the initial equilibrium is calculated from a recruitment level unaffected by spawner-recruitment steepness and initial age composition adjustments are applied after the initial equilibrium is calculated, it is possible that the initial age composition approach will produce a slightly different result than if the time series was started earlier and the deviations were being applied to the recruitment levels predicted from the spawner-recruitment curve.

## Version Log

This section records changes made to SS since the release of version 3.02D in Jan 2009.

### Required changes to input files

1. Two additional advanced spawner-recruitment input lines if advanced option are selected, one for the maximum bias adjustment and one to select recruitment cycles;
2. One additional biology input line to indicate whether or not gender change (hermaphroditism) is selected; more lines are then required if this option is selected;
3. Revised use of input parameters for selectivity pattern #6 (non-parametric length selectivity), but same number of parameters are used.

### Code fixes

1. Calculation of expected values for morph composition is revised to take into account size selectivity; (4/1/09)
2. Correct a problem with tag-recapture section when a morph does not occur in an area; (4/1/09)
3. Correct an output problem in the display of mean body size-at-age time series; (4/1/09)
4. Correction to calculation of F\_std in a multiple season setup with annual exploitation fraction used as the metric; (4/1/09)
5. Correct output of the F ratio. When F(Btarget) was requested as the ratio's denominator, F(msy) was being used. (4/6/09)
6. Correct propagation of time-varying growth into the forecast period. Also see new note on an unresolved issue with time-varying growth; (4/13/09)
7. First recruitment deviation was getting zero bias correction (4/14/09)
8. Correct a problem that disabled use of a specified range of selectivity years for the benchmarks and forecast (5/7/09)
9. fix array problem with length super years if N databins  $\neq$  N poplenbins (5/13/09);
10. Correct an error in the MCMC section. The biasadj was being set correctly to 1.0 for mceval, but not the MCMC calls. (7/1/09);
11. Correct an error in the logL for the distribution of tag returns among fleets. This was a major problem for models that used tag recaptures with multiple fleets, but it would not affect model setups where all recaptures were by a single fleet. (8/13/09);
12. Correct an output error in the benchmark section. The MSY section was using an incorrectly updated value of summary biomass so was reporting an incorrect summary biomass and exploitation rate. (8/25/09).
13. Restore the profile values capability (9/6/09).

### Code internal revisions

1. Move spawner-recruitment calculations into a function

2. Make spawner-recruitment calculation more robust to transient high F situations by adding 0.1 to spawning biomass in the recruitment function. This could cause a tiny change in results; (4/13/09)
3. Make Fmethod 3 more robust to transient high F situations by setting the initial calculation of  $H = C(V_{bio} + 0.1 * C)$ , rather than simply  $H = C/V_{bio}$ ; (4/13/09)
4. Re-arrange the selectivity calculations so that size and age selectivity can re-use the same code for calculation of time-varying parameters
5. The routine in the benchmark section to calculate a SPR and YPR profile on F intensity is expanded to provide more points for a smoother display
6. Re-arrange time-varying parameter effects so that all sections that use these effects now do blocks or trends first, then environmental effects, then annual devs.
7. Major re-work of internal calculations for non-parametric length selectivity pattern #6. It now will have a max of 1.0 at some size and is now in terms of length, not bin index number. This requires revision of the input parameters.
8. Rebuild.dat and rebuild.sso updated to work with Aug 2009 version of Andre Punt's rebuild program (8/26/09)
9. Revise CV\_growth. Currently if AFIX=999 and CV=F(A), the linear function extends to age 999, so not getting to CV2 by maxage. Revise so that if AFIX=999 this linear function will get to CV2 at maxage. (5/13/09);
10. Revise the indexing of COVAR.SSO so when forecast recruitment devs are not requested a placeholder will not be created in the COVAR list. (5/29/09)
11. Introduce phase-in of bias adjustment during early stages of MCMC (8/18/09 introduced; corrected on 9/9/09)
12. Restore functionality to the profilevalues feature. It was disabled in SS V2.x and is now restored. (9/9/09).

### Clarifications

1. The expected size/age composition of the fishery is calculated as a sample taken at a fixed interval through the season. This differs from the calculated catch-at-age, especially at higher F levels. An option is added to allow use of the calculated catch-at-age as the basis for the expected catch-at-age/size observations. See the Sample Timing description just above "catch" in the data file.
2. This manual adds a section describing the options for reporting fishing level.
3. Some of the time-varying parameter options are implemented as multiplicative effects. Application of such multiplicative effects to parameters that are themselves on a log scale is non-intuitive and probably produces sub-optimal model performance. New additive offset options are added and described in the Time-Varying Parameter Options section.
4. See notes on time-varying growth for clarification on propagation of growth changes into the forecast, growth as used in the equilibrium benchmark quantities, and an issue that can arise when using time-varying growth.
5. find that with hermaphroditism turned on there is a gradient error if  $fracfemale=1.0$  or  $0.0$  in  $equilcalcs$ . Cannot find specific source of problem so create trap to reset  $fracfemale$  to  $0.999999$  (5/13/09);

6.

## **New Features (see specific manual sections for full explanations)**

### Biology

1. Add capability for hermaphroditism. Females change to males according to an estimable logistic function and males contribute to reproductive potential.
2. Add capability to read empirical wt-at-age from separate input file: wtatage.ss. This is invoked using Maturity\_Option = 5. (9/2/2009)

### Time-Varying Parameters

3. Add a new capability for time-trend in MGparms and selectivity parameters. It takes 3 parameters per trend and can be invoked instead of blocks. This is described in the section on Time-Varying Parameter Options.
4. Add options to allow devs to have additive effects, rather than just the multiplicative effects previously implemented.

### Parameter Priors

1. Add a new capability for lognormal parameter prior (PR\_type=3).

### Effort Devs

1. Add a capability to read effort observations as an index of the fishing mortality rate. This becomes an option within the CPUE section.

### Survey/CPUE error structure

1. Add an option to allow a normal error structure to the deviations. See both the survey data section (where data standard errors are input) and the Catchability section (where the CPUE or survey error structure is defined).
2. Add options for more error structure for discard. The options are selected by the DF\_disc input near end of control file (9/2/2009)

### Spawner-Recruitment

1. Data are never perfectly informative about the true time series of recruitment deviations, so the maximum bias correction factor should not be going all the way to 1.0 even during the data-rich period. Advanced recruitment input 9 now specifies the value for the max bias correction. Use 1.0 to mimic results from previous model versions. User manual has a new section on recruitment bias adjustment.
2. Recruitment cycles. When SS is configured to work with continuous seasons (rather than seasons within years), then it may be desirable to have a cycle in the expected recruitment level that mimics the seasonal effect. The period of the cycles is invoked with advanced recruitment input 10.

### Selectivity

1. Introduce 3 parameter exponential-logistic selectivity functions. This is pattern #25 for size selectivity and pattern #26 for age-selectivity.

### Benchmark Calculations

2. The equilibrium N-at-age and Z-at-age are now output for each of the benchmark quantities. These vectors are included to provide comparison to the N-at-age and Z-at-age calculated in the dynamic Bzero section at the end of the report.sso.
3. The output of the benchmark calculations to the derived quantities that get standard deviations is re-ordered and expanded to match the set required for west coast groundfish assessment terms of reference. (see Derived Quantities section of report.sso).

### Output

1. Add column for season in output of the survey index (5/27/09);
2. Add column for survey Q as calculated from parameters and the effective Q which is survey expected value / “vulnerable biomass”;
3. Add more columns to biology output to identify the morphs more precisely
4. Create population NUMBERS\_AT\_LENGTH output in report.sso. Located right after NUMBERS\_AT\_AGE.

### Composition Output

5. The fit to the composition data is now separated into a specific file, CompReport.SSO. With this change, the excel output viewer has been completely rewritten to Excel 2007 so it can handle the large size of this section in some SS implementations. It is named SS3-output-X.xls.



## Example Input Files

All of the files below are \*.ss\_new files as output by SS.

### STARTER.SS

```
#C starter comment here
simple2.dat
simple2.ct1
0 # 0=use init values in control file; 1=use ss3.par
0 # run display detail (0,1,2)
1 # detailed age-structured reports in REPORT.SSO (0,1)
0 # write detailed checkup.sso file (0,1)
0 # write parm values to ParmTrace.sso (0=no,1=good,active; 2=good,all; 3=every_iter,all_parms;
4=every,active)
1 # write to cumreport.sso (0=no,1=like&timeseries; 2=add survey fits)
1 # Include prior_like for non-estimated parameters (0,1)
1 # Use Soft Boundaries to aid convergence (0,1) (recommended)
3 # Number of bootstrap datafiles to produce
6 # Turn off estimation for parameters entering after this phase
10 # MCMC burn interval
2 # MCMC thin interval
0 # jitter initial parm value by this fraction
1969 # min yr for sdreport outputs (-1 for styr)
2013 # max yr for sdreport outputs (-1 for endyr; -2 for endyr+Nforecastyrs)
0 # N individual STD years
#vector of year values

0.0001 # final convergence criteria (e.g. 1.0e-04)
0 # retrospective year relative to end year (e.g. -4)
1 # min age for calc of summary biomass
1 # Depletion basis: denom is: 0=skip; 1=rel X*B0; 2=rel X*Bmsy; 3=rel X*B_styr
0.25 # Fraction (X) for Depletion denominator (e.g. 0.4)
3 # SPR_report_basis: 0=skip; 1=(1-SPR)/(1-SPR_tgt); 2=(1-SPR)/(1-SPR_MSX); 3=(1-SPR)/(1-SPR_Btarget);
4=rawSPR
1 # F_report_units: 0=skip; 1=exploitation(Bio); 2=exploitation(Num); 3=sum(Frates)
3 # F_report_basis: 0=raw; 1=F/Fspr; 2=F/Fmsy ; 3=F/Fbtgt
999 # check value for end of file
```

### RUNNUMBER.SS

7

### PROFILEVALUES.SS

2 # number of parameters using profile feature  
0.4 # value for first selected parameter when runnumber equals 1  
11.0 # value for second selected parameter when runnumber equals 1  
0.5 # value for first selected parameter when runnumber equals 2  
11.0 # value for second selected parameter when runnumber equals 2  
0.4 # value for first selected parameter when runnumber equals 3  
13.0 # value for second selected parameter when runnumber equals 3  
etc.

### FORECAST.SS

1 # Forecast: 0=none; 1=F(SCR); 2=F(MSY) 3=F(Btgt); 4=F(endyr); 5=Ave F (enter yrs); 6=read Fmult  
2001 # first year to use for averaging selex to use in forecast (e.g. 2004; or use -x to be rel endyr)  
2001 # last year to use for averaging selex to use in forecast  
1 # Benchmarks: 0=skip; 1=calc F\_spr,F\_btgt,F\_msy  
2 # MSY: 1= set to F(SCR); 2=calc F(MSY); 3=set to F(Btgt); 4=set to F(endyr)  
0.4 # SPR target (e.g. 0.40)  
0.4 # Biomass target (e.g. 0.40)  
12 # N forecast years  
1 # read 10 advanced options  
0 # Do West Coast gfish rebuilder output (0/1)  
2000 # Rebuilder: first year catch could have been set to zero (Ydecl)(-1 to set to 1999)  
2002 # Rebuilder: year for current age structure (Yinit) (-1 to set to endyear+1)  
1 # Control rule method (1=west coast adjust catch; 2=adjust F)  
0.4 # Control rule Biomass level for constant F (as frac of Bzero, e.g. 0.40)  
0.1 # Control rule Biomass level for no F (as frac of Bzero, e.g. 0.10)  
1 # Control rule fraction of Flimit (e.g. 0.75)

1 # basis for max forecast catch by seas and area (0=none; 1=deadbio; 2=retainbio; 3=deadnum; 4=retainnum)  
0 # 0= no implementation error; 1=use implementation error in forecast (not coded yet)  
0.1 # stddev of log(realized F/target F) in forecast (not coded yet)  
# end of advanced options  
# max forecast catch  
# rows are seasons, columns are areas  
-1000  
1 # fleet allocation (in terms of F) (1=use endyr pattern, no read; 2=read below)  
# 0.252232  
0 # Number of forecast catch levels to input (rest calc catch from forecast F)  
# 1 # basis for input forecatch: 1=retained catch; 2=total dead catch  
#Year Seas Fleet Catch  
  
999 # verify end of input

## CONTROL FILE

```
#C growth parameters are estimated
1 #_N_Growth_Patterns
1 #_N_Morphs_Within_GrowthPattern
#_Cond 1 #_Morph_between/within_stdev_ratio (no read if N_morphs=1)
#_Cond 1 #vector_Morphdist_(-1_in_first_val_gives_normal_approx)

#_Cond 0 # N recruitment designs goes here if N_GP*nseas*area>1
#_Cond 0 # placeholder for recruitment interaction request
#_Cond 1 1 1 # example recruitment design element for GP=1, seas=1, area=1

#_Cond 0 # N_movement_definitions goes here if N_areas > 1
#_Cond 1.0 # first age that moves (real age at begin of season, not integer) also cond on do_migration>0
#_Cond 1 1 1 2 4 10 # example move definition for seas=1, morph=1, source=1 dest=2, age1=4, age2=10

2 #_Nblock_Patterns
3 2 #_blocks_per_pattern
# begin and end years of blocks
1975 1985 1986 1990 1995 2001
1987 1990 1995 2001

0.5 #_fracfemale
1 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
2 #_N_breakpoints
4 15 # age(real) at M breakpoints
1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=not implemented; 4=not implemented
1.6 #_Growth_Age_for_L1
25 #_Growth_Age_for_L2 (999 to use as Linf)
0 #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)
0 #_CV_Growth_Pattern: 0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A)
1 #_maturity_option: 1=length logistic; 2=age logistic; 3=read age-maturity matrix by growth_pattern;
4=read age-fecundity
#_placeholder for empirical age-maturity by growth pattern
1 #_First_Mature_Age
1 #_fecundity_option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b
0 #_Hermaphroditism
```

1 #\_parameter\_offset\_approach (1=none, 2= M, G, CV\_G as offset from female-GP1, 3=like SS2 V1.x)  
2 #\_env/block/dev\_adjust\_method (1=standard; 2=with logistic trans to keep within base parm bounds)

#\_growth\_parms

```
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
0.05 0.15 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # NatM_p_1_Fem_GP:1
0.05 0.15 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # NatM_p_2_Fem_GP:1
1 45 32.2862 36 0 10 2 0 0 0 0 0.5 0 0 # L_at_Amin_Fem_GP_1
40 90 71.3463 70 0 10 4 0 0 0 0 0.5 0 0 # L_at_Amax_Fem_GP_1
0.05 0.25 0.151915 0.15 0 0.8 4 0 0 0 0 0.5 0 0 # VonBert_K_Fem_GP_1
0.05 0.25 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # CV_young_Fem_GP_1
0.05 0.25 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # CV_old_Fem_GP_1
0.05 0.15 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # NatM_p_1_Mal_GP:1
0.05 0.15 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # NatM_p_2_Mal_GP:1
1 45 33.7789 36 0 10 2 0 0 0 0 0.5 0 0 # L_at_Amin_Mal_GP_1
40 90 69.7329 70 0 10 4 0 0 0 0 0.5 0 0 # L_at_Amax_Mal_GP_1
0.05 0.25 0.154349 0.15 0 0.8 4 0 0 0 0 0.5 0 0 # VonBert_K_Mal_GP_1
0.05 0.25 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # CV_young_Mal_GP_1
0.05 0.25 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # CV_old_Mal_GP_1
-3 3 2.44e-006 2.44e-006 0 0.8 -3 0 0 0 0 0.5 0 0 # Wtlen_1_Fem
-3 4 3.34694 3.34694 0 0.8 -3 0 0 0 0 0.5 0 0 # Wtlen_2_Fem
50 60 55 55 0 0.8 -3 0 0 0 0 0.5 0 0 # Mat50%_Fem
-3 3 -0.25 -0.25 0 0.8 -3 0 0 0 0 0.5 0 0 # Mat_slope_Fem
-3 3 1 1 0 0.8 -3 0 0 0 0 0.5 0 0 # Eg/gm_inter_Fem
-3 3 0 0 0 0.8 -3 0 0 0 0 0.5 0 0 # Eg/gm_slope_wt_Fem
-3 3 2.44e-006 2.44e-006 0 0.8 -3 0 0 0 0 0.5 0 0 # Wtlen_1_Mal
-3 4 3.34694 3.34694 0 0.8 -3 0 0 0 0 0.5 0 0 # Wtlen_2_Mal
0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_GP_1
0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_Area_1
0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_Seas_1
0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # CohortGrowDev
```

#\_Cond 0 #custom\_MG-env\_setup (0/1)

#\_Cond -2 2 0 0 -1 99 -2 #\_placeholder when no MG-environ parameters

#\_Cond 0 #custom\_MG-block\_setup (0/1)

#\_Cond -2 2 0 0 -1 99 -2 #\_placeholder when no MG-block parameters

```

#_seasonal_effects_on_biology_parms
0 0 0 0 0 0 0 0 0 0 #_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no seasonal MG parameters

#_Cond -4 #_MGparm_Dev_Phase

#_Spawner-Recruitment
3 #_SR_function
#_LO HI INIT PRIOR PR_type SD PHASE
3 31 8.81726 10.3 0 10 1 # SR_R0
0.2 1 0.605063 0.7 2 0.2 4 # SR_steep
0 2 0.6 0.8 0 0.8 -4 # SR_sigmaR
-5 5 0.1 0 0 1 -3 # SR_envlink
-5 5 0 0 0 1 -4 # SR_R1_offset
0 0 0 0 -1 0 -99 # SR_autocorr
1 #_SR_env_link
1 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness

1 #do_recdev: 0=none; 1=devvector; 2=simple deviations
1971 # first year of main recr_devs; early devs can precede this era
2001 # last year of main recr_devs; forecast devs start in following year
3 #_recdev phase
1 # (0/1) to read 11 advanced options
0 #_recdev_early_start (0=none; neg value makes relative to recdev_start)
-4 #_recdev_early_phase
0 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
1 #_lambda for prior_fore_recrr occurring before endyr+1
1970 #_last_early_yr_nobias_adj_in_MPD
1971 #_first_yr_fullbias_adj_in_MPD
2001 #_last_yr_fullbias_adj_in_MPD
2002 #_first_recent_yr_nobias_adj_in_MPD
-5 #min rec_dev
5 #max rec_dev
1.0 # max bias adjustment (1.0 matches previous usage)
0 # N recruitment cycles
0 #_read_recdevs
#_end of advanced SR options

```

```

# read specified recr devs
#_Yr Input_value

#Fishing Mortality info
0.3 # F ballpark for tuning early phases
2001 # F ballpark year (neg value to disable)
3 # F_Method: 1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
2.9 # max F or harvest rate, depends on F_Method
# no additional F input needed for Fmethod 1
# read overall start F value; overall phase; N detailed inputs to read for Fmethod 2
# read N iterations for tuning for Fmethod 3 (recommend 3 to 7)
4 # N iterations for tuning F in hybrid method (recommend 3 to 7)
#Fleet Year Seas F_value se phase (for detailed setup of F_Method=2)

#_initial_F_parms
#_LO HI INIT PRIOR PR_type SD PHASE
0 1 0 0.01 0 99 2 # InitF_1FISHERY1

#_Q_setup
# A=do power, B=env-var, C=extra SD, D=devtype(<0=mirror, 0/1=none, 2=cons, 3=rand, 4=randwalk);
E=0=num/1=bio, F=err_type
#_A B C D E F
0 0 0 0 1 0 # 1 FISHERY1
0 0 0 2 1 0 # 2 SURVEY1
0 0 0 2 0 0 # 3 SURVEY2

#_Cond 0 #_If q has random component, then 0=read one parm for each fleet with random q; 1=read a parm for
each year of index
#_Q_parms(if_any)
# LO HI INIT PRIOR PR_type SD PHASE
-7 5 0.503084 0 -1 1 1 # Q_base_2_SURVEY1
-7 5 -6.64542 0 -1 1 1 # Q_base_3_SURVEY2

#_size_selex_types
#_Pattern Discard Male Special
1 0 0 0 # 1 FISHERY1
1 0 0 0 # 2 SURVEY1

```

```

0 0 0 0 # 3 SURVEY2

#_age_selex_types
#_Pattern ___ Male Special
11 0 0 0 # 1 FISHERY1
11 0 0 0 # 2 SURVEY1
11 0 0 0 # 3 SURVEY2
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
19 80 54.1446 50 1 0.01 2 0 0 0 0 0.5 0 0 # SizeSel_1P_1_FISHERY1
0.01 60 19.8156 15 1 0.01 3 0 0 0 0 0.5 0 0 # SizeSel_1P_2_FISHERY1
19 70 36.2086 30 1 0.01 2 0 0 0 0 0.5 0 0 # SizeSel_2P_1_SURVEY1
0.01 60 6.20618 10 1 0.01 3 0 0 0 0 0.5 0 0 # SizeSel_2P_2_SURVEY1
0 40 0 5 0 99 -1 0 0 0 0 0.5 0 0 # AgeSel_1P_1_FISHERY1
0 40 40 6 0 99 -1 0 0 0 0 0.5 0 0 # AgeSel_1P_2_FISHERY1
0 40 0 5 0 99 -1 0 0 0 0 0.5 0 0 # AgeSel_2P_1_SURVEY1
0 40 40 6 0 99 -1 0 0 0 0 0.5 0 0 # AgeSel_2P_2_SURVEY1
0 40 0 5 0 99 -1 0 0 0 0 0.5 0 0 # AgeSel_3P_1_SURVEY2
0 40 0 6 0 99 -1 0 0 0 0 0.5 0 0 # AgeSel_3P_2_SURVEY2
#_Cond 0 #_custom_sel-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no enviro fxns
#_Cond 0 #_custom_sel-blk_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no block usage
#_Cond -4 # placeholder for selparm_Dev_Phase
#_Cond 0 #_env/block/dev_adjust_method (1=standard; 2=logistic trans to keep in base parm bounds)

# Tag loss and Tag reporting parameters go next
0 # TG_custom: 0=no read; 1=read if tags exist
#_Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0 #_placeholder if no parameters

1 #_Variance_adjustments_to_input_values
#_1 2 3
0 0 0 #_add_to_survey_CV
0 0 0 #_add_to_discard_stddev
0 0 0 #_add_to_bodywt_CV
1 1 1 #_mult_by_lencomp_N
1 1 1 #_mult_by_agecomp_N
1 1 1 #_mult_by_size-at-age_N

```

```

0 #_DF_for_discard_like (>0 for T-distribution; 0 for normal with CV; -1 for normal with se; -2 for
lognormal)
30 #_DF_for_meanbodywt_like

4 #_maxlambdaphase
1 #_sd_offset

3 # number of changes to make to default Lambdas (default value is 1.0)
# Like_comp codes: 1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch;
# 9=init_equ_catch; 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-comp; 16=Tag-
negbin
#like_comp fleet/survey phase value sizefreq_method
  1 2 2 1 1
  4 2 2 1 1
  4 2 3 1 1

1 # (0/1) read specs for more stddev reporting
  0 1 -1 5 1 5 1 -1 5 # placeholder for selex type, len/age, year, N selex bins, Growth pattern, N growth
ages, NatAge_area(-1 for all), NatAge_yr, N Natages
-1 1 1 1 1 # for vector of selex bins to be reported
-1 1 1 1 1 # for vector of growth ages to be reported
-1 1 1 1 1 # for vector of NatAges ages to be reported999

```

### DATA FILE

```
#C comment regarding data file
1971 #_styr
2001 #_endyr
1 #_nseas
  12 #_months/season
1 #_spawn_seas
1 #_Nfleet
2 #_Nsurveys
1 #_N_areas
FISHERY1%SURVEY1%SURVEY2
  0.5 0.5 0.5 #_surveytiming_in_season
  1 1 1 #_area_assignments_for_each_fishery_and_survey
  1 #_units of catch: 1=bio; 2=num
  0.01 #_se of log(catch) only used for init_eq_catch and for Fmethod 2 and 3
2 #_Ngenders
40 #_Nages
  0 #_init_equil_catch_for_each_fishery
31 #_N_lines_of_catch_to_read
#_catch_biomass(mtons):_columns_are_fisheries,year,season
0 1971 1
200 1972 1
1000 1973 1
1000 1974 1
2000 1975 1
3000 1976 1
4000 1977 1
5000 1978 1
6000 1979 1
8000 1980 1
10000 1981 1
10000 1982 1
10000 1983 1
10000 1984 1
10000 1985 1
10000 1986 1
```

```
10000 1987 1
9000 1988 1
8000 1989 1
7000 1990 1
6000 1991 1
4000 1992 1
4000 1993 1
4000 1994 1
4000 1995 1
4000 1996 1
3000 1997 1
3000 1998 1
3000 1999 1
3000 2000 1
3000 2001 1
```

```
21 #_N_cpue_and_surveyabundance_observations
```

```
#_year seas index obs se(log)
1977 1 2 339689 0.3 # SURVEY1
1980 1 2 193353 0.3 # SURVEY1
1983 1 2 151984 0.3 # SURVEY1
1986 1 2 55221.8 0.3 # SURVEY1
1989 1 2 59232.3 0.3 # SURVEY1
1992 1 2 31137.5 0.3 # SURVEY1
1995 1 2 35845.4 0.3 # SURVEY1
1998 1 2 27492.6 0.3 # SURVEY1
2001 1 2 37338.3 0.3 # SURVEY1
1990 1 3 5.19333 0.7 # SURVEY2
1991 1 3 1.1784 0.7 # SURVEY2
1992 1 3 5.94383 0.7 # SURVEY2
1993 1 3 0.770106 0.7 # SURVEY2
1994 1 3 16.318 0.7 # SURVEY2
1995 1 3 1.36339 0.7 # SURVEY2
1996 1 3 4.76482 0.7 # SURVEY2
1997 1 3 51.0707 0.7 # SURVEY2
1998 1 3 1.36095 0.7 # SURVEY2
1999 1 3 0.862531 0.7 # SURVEY2
2000 1 3 5.97125 0.7 # SURVEY2
```

```

2001 1 3 1.69379 0.7 # SURVEY2

2 #_discard_type (1=bio or num; 2=fraction)
0 #_N_discard_obs

0 #_N_meanbodywt_obs

2 # length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector
2 # binwidth for population size comp
10 # minimum size in the population (lower edge of first bin and size at age 0.00)
94 # maximum size in the population (lower edge of last bin)

0 #_comp_tail_compression
1e-007 #_add_to_comp
0 #_combine males into females at or below this bin number
25 #_N_LengthBins
 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 68 72 76 80 90
40 #_N_Length_obs
#Yr Seas Flt/Svy Gender Part Nsamp datavector(female-male)
1971 1 1 3 0 125 0 0 0 0 0 0 0 0 0 0 4 1 1 2 4 1 5 6 2 3 11 8 4 5 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 3 0 3 4 2 4 5 9
17 8 3 8 0 0
1972 1 1 3 0 125 0 0 0 0 0 0 0 0 0 0 3 0 1 2 1 1 6 2 7 4 10 10 4 5 3 0 0 0 0 0 0 0 0 0 0 0 0 1 3 2 4 1 3 1 4 4 7 3
8 11 4 10 0 0
1973 1 1 3 0 125 0 0 0 0 0 0 0 0 0 0 0 0 0 7 3 4 5 6 3 10 12 6 10 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 0 1 3 0 7 2
6 7 8 5 5 3 0
1974 1 1 3 0 125 0 0 0 0 0 0 0 0 0 0 2 2 0 1 1 1 4 5 3 8 8 10 4 7 0 0 0 0 0 0 0 0 0 0 0 0 1 2 0 4 0 0 1 5 6 6 4 6
15 11 5 0 3 0
1975 1 1 3 0 125 0 0 0 0 0 0 0 0 2 1 2 1 1 3 0 2 5 6 2 3 5 9 10 10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 2 2 1 2 3 5 1 4 5
13 11 6 4 0 0
1976 1 1 3 0 125 0 0 0 0 0 0 0 0 2 1 0 2 2 0 3 2 3 3 3 7 18 14 4 2 2 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 2 4 6 6 5 7
12 6 4 3 0 0
1977 1 1 3 0 125 0 0 0 0 0 0 0 0 1 0 2 0 2 2 4 0 2 6 7 5 11 7 8 5 4 0 0 0 0 0 0 0 2 1 3 0 1 3 3 2 0 1 4 5 3 7
7 9 5 3 0 0
1978 1 1 3 0 125 0 0 0 0 0 0 0 5 1 1 1 0 1 3 1 8 4 4 6 5 9 8 3 6 5 0 0 0 0 0 0 0 0 2 1 1 2 1 1 2 2 4 1 4 1
13 9 6 4 0 0
1979 1 1 3 0 125 0 0 0 0 0 0 0 0 0 0 0 3 5 2 1 5 0 5 5 2 7 4 7 5 5 0 0 0 0 0 0 0 0 0 2 2 1 3 2 7 2 4 4 5 8
10 8 6 4 1 0

```

1980 1 1 3 0 125 0 0 0 0 0 0 0 4 0 0 1 0 2 4 3 2 3 2 3 16 11 12 4 2 0 0 0 0 0 0 0 0 0 1 4 1 1 2 3 5 2 6 3  
 1 10 11 4 2 0 0  
 1981 1 1 3 0 125 0 0 0 0 0 0 1 0 0 0 3 1 2 2 4 5 2 7 3 13 9 8 4 0 0 0 0 0 0 0 2 1 1 1 2 2 3 3 1 6 1 2 1 7  
 5 10 6 7 0 0  
 1982 1 1 3 0 125 0 0 0 0 0 0 0 5 2 1 3 2 3 8 2 5 4 4 6 10 11 0 0 0 0 0 0 0 0 0 0 1 0 3 0 2 1 5 6 1 8 5 5  
 10 5 2 5 0 0  
 1983 1 1 3 0 125 0 0 0 0 0 0 0 0 0 0 7 1 1 5 4 2 2 6 2 8 13 8 6 0 0 0 0 0 0 0 0 0 0 4 1 0 3 3 0 4 9 5 4  
 7 8 6 6 0 0  
 1984 1 1 3 0 125 0 0 0 0 0 0 1 0 0 4 3 0 3 1 2 5 2 4 7 11 9 6 8 0 0 0 0 0 0 0 0 3 3 1 1 3 3 3 2 2 4 4 8  
 11 4 5 2 0 0  
 1985 1 1 3 0 125 0 0 0 0 0 0 0 1 1 2 2 5 0 3 3 5 11 4 8 9 3 2 4 0 0 0 0 0 0 0 0 1 0 1 2 0 3 8 3 4 3 8 4  
 13 7 4 1 0 0  
 1986 1 1 3 0 125 0 0 0 3 1 0 1 2 0 4 2 0 0 4 2 8 3 5 11 5 6 6 1 0 0 0 0 0 0 2 2 0 1 2 1 3 4 2 3 4 6 5 5  
 6 4 6 5 0 0  
 1987 1 1 3 0 125 0 0 0 0 1 1 1 1 1 0 2 1 6 4 2 7 6 3 5 11 9 5 4 0 0 0 0 0 0 0 2 1 0 5 2 4 3 4 4 4 2 4  
 7 6 5 2 0 0  
 1988 1 1 3 0 125 0 0 0 0 0 2 0 1 4 2 1 1 2 2 1 7 4 5 6 9 9 2 1 0 0 0 0 0 0 2 1 1 3 1 3 6 3 3 0 4 5 3 5 9  
 9 8 0 0 0  
 1989 1 1 3 0 125 0 0 0 0 0 1 0 2 1 3 3 2 1 4 4 3 4 2 3 9 5 11 2 0 0 0 0 0 0 0 3 6 2 1 3 0 4 3 3 2 5 7 7  
 9 3 3 4 0 0  
 1990 1 1 3 0 125 0 0 0 0 0 0 2 2 2 2 2 2 2 9 4 4 6 6 8 4 4 1 0 0 0 0 0 0 1 1 2 2 3 8 2 8 6 6 3 2 3 4 6  
 5 1 2 0 0  
 1991 1 1 3 0 125 0 0 0 0 0 0 3 0 3 3 5 5 4 3 3 0 1 6 10 4 4 0 0 0 0 0 0 1 1 1 1 3 4 6 5 3 5 6 6 6 6 4  
 7 3 3 0 0 0  
 1992 1 1 3 0 125 0 0 0 0 2 2 0 1 1 1 3 3 2 7 6 4 4 2 5 6 3 6 0 0 0 0 0 0 0 0 5 3 1 3 5 3 5 8 3 4 6 3  
 13 4 1 0 0 0  
 1993 1 1 3 0 125 0 0 0 0 0 1 2 2 2 2 2 4 5 10 5 7 3 2 12 7 6 0 0 0 0 0 0 0 0 0 3 1 1 3 2 6 4 8 4 6 4 2  
 4 3 1 1 0 0  
 1994 1 1 3 0 125 0 0 0 0 0 0 0 4 1 4 3 4 4 9 4 6 7 8 5 3 2 0 0 0 0 0 0 0 2 0 2 1 1 4 4 10 5 8 6 3  
 5 6 1 3 0 0  
 1995 1 1 3 0 125 0 0 0 1 0 0 1 1 1 1 2 2 5 8 4 11 5 5 4 8 7 0 0 0 0 0 0 0 1 0 0 1 1 3 3 1 2 6 3 4 4 8 3  
 12 4 3 0 0 0  
 1996 1 1 3 0 125 0 0 0 1 0 2 1 0 2 4 3 3 2 3 6 6 3 3 4 11 6 6 0 0 0 0 0 0 0 1 2 0 3 3 1 0 5 4 6 7 4 5  
 10 3 4 1 0 0  
 1997 1 1 3 0 125 0 0 0 2 0 0 2 2 0 0 3 1 6 4 6 2 9 4 5 9 12 0 0 0 0 0 0 0 3 1 0 5 3 2 4 1 1 6 4 1 6 6  
 5 6 4 0 0 0  
 1998 1 1 3 0 125 0 0 0 0 3 1 2 2 2 2 3 1 3 6 2 0 7 4 5 12 3 1 2 0 0 0 0 0 4 1 1 0 2 2 0 1 1 4 6 2 5 4 6  
 13 7 4 1 0 0



```

1 #_Lbin_method: 1=poplenbins; 2=datalenbins; 3=lengths
1 #_combine males into females at or below this bin number
#Yr Seas Flt/Svy Gender Part Ageerr Lbin_lo Lbin_hi Nsamp datavector(female-male)
1971 1 1 3 0 2 1 -1 75 0 0 0 0 3 1 1 4 2 1 0 1 2 2 13 2 3 0 0 4 2 1 1 2 1 2 2 1 2 1 2 6 5 8
1972 1 1 3 0 2 1 -1 75 2 1 1 1 0 3 1 2 2 5 3 1 2 2 9 8 3 0 0 1 2 3 1 3 0 5 1 3 0 2 1 2 3 2
1973 1 1 3 0 2 1 -1 75 0 0 1 0 1 1 2 3 3 1 1 5 2 2 7 4 3 0 0 0 4 1 3 5 1 2 3 1 3 2 0 5 3 6
1974 1 1 3 0 2 1 -1 75 0 0 2 0 1 4 2 2 2 4 1 1 1 2 6 6 6 0 0 4 1 2 2 1 2 0 0 1 2 1 1 6 5 7
1975 1 1 3 0 2 1 -1 75 0 0 1 2 3 1 1 1 2 1 2 2 2 3 10 3 4 0 0 0 0 10 1 2 3 2 1 0 0 0 0 9 3 6
1976 1 1 3 0 2 1 -1 75 0 0 1 0 2 2 2 1 3 1 2 3 1 1 7 1 3 0 0 0 0 7 4 3 2 1 2 4 4 0 0 8 10 0
1977 1 1 3 0 2 1 -1 75 0 0 0 0 7 1 0 0 2 4 2 2 3 1 7 2 3 0 0 2 1 4 2 3 3 4 2 2 2 0 1 8 3 4
1978 1 1 3 0 2 1 -1 75 0 0 3 2 1 1 0 2 0 2 4 3 1 0 9 4 6 0 0 2 2 5 1 0 2 3 2 4 2 0 4 4 3 3
1979 1 1 3 0 2 1 -1 75 2 0 1 5 2 1 2 3 3 3 2 2 1 0 3 7 0 0 0 2 0 1 0 2 3 2 5 1 3 1 2 6 9 1
1980 1 1 3 0 2 1 -1 75 0 1 0 2 0 1 1 2 2 3 2 1 1 0 7 8 0 0 0 0 3 2 1 1 1 2 2 4 2 2 2 11 3 8
1981 1 1 3 0 2 1 -1 75 0 4 0 3 7 2 2 2 2 1 1 2 2 1 4 4 6 0 0 3 2 2 1 1 3 2 2 0 1 2 2 5 3 3
1982 1 1 3 0 2 1 -1 75 0 2 1 1 3 3 2 1 1 2 2 1 0 2 6 3 9 0 0 0 0 3 5 0 1 4 1 1 1 2 1 8 9 0
1983 1 1 3 0 2 1 -1 75 0 0 0 6 1 2 2 2 1 1 4 5 0 0 6 2 7 0 0 3 1 3 5 1 0 1 1 3 0 3 3 5 3 4
1984 1 1 3 0 2 1 -1 75 0 0 0 3 4 0 3 6 3 1 4 0 2 0 7 2 3 0 0 3 1 5 4 2 3 5 1 2 1 2 0 1 2 5
1985 1 1 3 0 2 1 -1 75 0 0 0 5 1 2 4 5 0 2 4 3 2 3 3 4 5 0 0 0 1 2 3 2 4 2 0 2 3 1 1 7 2 2
1986 1 1 3 0 2 1 -1 75 0 2 2 1 3 7 4 3 2 2 2 2 0 4 2 2 0 0 0 0 4 4 4 1 2 3 4 0 0 1 5 7 0
1987 1 1 3 0 2 1 -1 75 0 3 1 3 1 2 3 4 2 3 3 2 2 1 3 2 0 0 0 7 1 5 1 4 2 4 3 2 3 1 0 2 1 4
1988 1 1 3 0 2 1 -1 75 1 0 5 0 2 3 3 4 3 3 1 0 3 3 5 0 0 1 3 3 2 2 1 4 3 2 1 2 4 0 5 3 0
1989 1 1 3 0 2 1 -1 75 0 3 1 1 4 3 7 1 5 1 1 4 1 0 1 7 0 0 0 5 3 4 1 1 5 3 1 5 2 1 0 2 2 0
1990 1 1 3 0 2 1 -1 75 0 0 7 3 7 3 0 1 3 0 1 1 1 1 3 4 0 0 1 0 8 4 3 3 2 4 5 1 5 1 0 1 2 0
1991 1 1 3 0 2 1 -1 75 0 0 4 1 7 4 2 3 2 1 0 1 1 3 3 3 0 0 3 4 2 5 4 4 1 3 3 0 4 2 0 4 1 0
1992 1 1 3 0 2 1 -1 75 0 0 7 4 5 10 4 3 0 3 1 0 2 0 2 1 1 0 0 5 1 3 8 3 3 1 2 0 1 3 0 1 1 0
1993 1 1 3 0 2 1 -1 75 0 0 7 4 3 7 5 7 2 1 0 1 0 4 0 0 0 0 0 3 3 4 3 7 0 0 4 2 1 1 1 5 0 0
1994 1 1 3 0 2 1 -1 75 0 0 3 6 4 4 4 9 4 5 1 0 0 0 0 0 3 0 0 0 9 0 7 2 2 3 4 0 3 2 0 0 0 0
1995 1 1 3 0 2 1 -1 75 3 1 2 0 8 5 2 6 2 5 0 2 1 4 0 0 0 0 0 2 5 3 2 3 5 6 1 0 1 1 3 1 1
1996 1 1 3 0 2 1 -1 75 0 0 1 1 5 4 3 7 2 3 2 3 3 1 5 1 0 0 2 5 0 5 4 1 2 3 4 2 3 0 1 2 0 0
1997 1 1 3 0 2 1 -1 75 0 5 3 5 0 2 4 3 4 5 1 1 3 2 2 0 0 0 0 3 1 6 5 5 2 3 4 1 2 3 0 0 0
1998 1 1 3 0 2 1 -1 75 5 3 1 4 1 2 3 4 3 2 0 2 0 1 5 0 0 0 0 4 6 4 2 7 2 1 1 6 3 0 0 2 1 0
1999 1 1 3 0 2 1 -1 75 2 2 3 3 6 3 3 3 8 3 3 3 0 1 1 0 0 0 1 3 3 3 5 4 0 4 2 4 0 1 0 1 0 0
2000 1 1 3 0 2 1 -1 75 0 2 1 9 4 4 2 2 4 3 1 0 1 0 5 0 0 0 0 8 11 3 1 2 2 1 1 2 1 0 2 3 0 0
2001 1 1 3 0 2 1 -1 75 0 1 1 6 8 1 1 0 5 2 2 2 0 3 4 0 0 0 0 5 3 4 6 3 3 1 4 3 1 1 2 3 0 0
1977 1 2 3 0 2 1 -1 75 2 1 2 1 0 4 3 3 2 1 1 0 1 1 4 7 0 0 2 2 7 1 0 1 0 1 2 4 1 2 2 7 10 0
1980 1 2 3 0 2 1 -1 75 3 3 4 6 5 2 0 2 3 0 3 2 2 2 1 4 0 2 3 5 3 1 2 1 1 2 1 1 1 0 3 1 4
1983 1 2 3 0 2 1 -1 75 3 4 3 2 3 0 0 7 0 0 3 1 1 0 5 6 0 0 2 2 4 1 2 3 4 3 2 0 1 1 2 7 1 2
1986 1 2 3 0 2 1 -1 75 3 0 2 5 3 5 5 3 1 3 2 1 1 1 3 0 2 0 0 2 3 6 6 1 3 3 1 1 1 1 2 2 3 0

```

```

1989 1 2 3 0 2 1 -1 75 7 3 7 3 2 1 0 3 2 1 2 1 1 5 0 0 0 0 4 8 6 1 2 3 5 1 1 2 0 4 0 0 0 0
1992 1 2 3 0 2 1 -1 75 2 5 3 4 0 5 0 5 2 0 0 0 1 0 3 0 0 0 4 5 5 10 8 6 2 1 2 0 0 1 0 1 0 0
1995 1 2 3 0 2 1 -1 75 0 5 2 3 2 3 5 4 2 1 1 2 0 0 3 0 0 0 2 3 5 11 2 6 5 1 2 1 2 0 0 2 0 0
1998 1 2 3 0 2 1 -1 75 9 4 4 3 1 1 1 1 3 3 1 2 1 7 0 0 0 0 6 5 3 5 1 3 3 2 3 2 0 1 0 0 0 0
2001 1 2 3 0 2 1 -1 75 4 0 4 11 5 3 4 2 2 0 0 0 0 2 0 0 0 2 4 7 11 5 2 0 2 2 2 0 0 0 1 0 0

```

```
4 #_N_MeanSize-at-Age_obs
```

```
#Yr Seas Flt/Svy Gender Part Ageerr Ignore datavector(female-male)
```

```
# sample size(female-male)
```

```

1971 1 1 3 0 1 2 29.8931 40.6872 44.7411 50.027 52.5794 56.1489 57.1033 61.1728 61.7417 63.368 64.4088
65.6889 67.616 68.5972 69.9177 71.0443 72.3609 32.8188 39.5964 43.988 50.1693 53.1729 54.9822 55.3463
60.3509 60.7439 62.3432 64.3224 65.1032 64.1965 66.7452 67.5154 70.8749 71.2768 20 20 20 20 20 20 20 20
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
1995 1 1 3 0 1 2 32.8974 38.2709 43.8878 49.2745 53.5343 55.1978 57.4389 62.0368 62.1445 62.9579 65.0857
65.6433 66.082 65.6117 67.0784 69.3493 72.2966 32.6552 40.5546 44.6292 50.4063 52.0796 56.1529 56.9004
60.218 61.5894 63.6613 64.0222 63.4926 65.8115 69.5357 68.2448 66.881 71.5122 20 20 20 20 20 20 20 20 20 20
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
1971 1 2 3 0 1 2 34.1574 38.8017 43.122 47.2042 49.0502 51.6446 56.3201 56.3038 60.5509 60.2537 59.8042
62.9309 66.842 67.8089 71.1612 70.7693 74.5593 35.3811 40.7375 44.5192 47.6261 52.5298 53.5552 54.9851
58.9231 58.9932 61.8625 64.0366 62.7507 63.9754 64.5102 66.9779 67.7361 69.1298 20 20 20 20 20 20 20 20 20 20
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
1995 1 2 3 0 1 2 34.6022 38.3176 42.9052 48.2752 50.6189 53.476 56.7806 59.4127 60.5964 60.5537 65.3608
64.7263 67.4315 67.1405 68.9908 71.9886 74.1594 35.169 40.2404 43.8878 47.3519 49.9906 52.2207 54.9035
58.6058 60.0957 62.4046 62.2298 62.1437 66.2116 65.7657 69.9544 70.6518 71.4371 20 20 20 20 20 20 20 20 20 20
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20

```

```
1 #_N_environ_variables
```

```
0 #_N_environ_obs
```

```
1 # N sizefreq methods to read
```

```
25 #Sizefreq N bins per method
```

```
2 #Sizetfreq units(bio/num) per method
```

```
3 #Sizefreq scale(kg/lbs/cm/inches) per method
```

```
1e-005 #Sizefreq mincomp per method
```

```
1 #Sizefreq N obs per method
```

```
#_Sizefreq bins
```

```
26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 68 72 76 80 90
```

```
#_Year season Fleet Partition Gender SampleSize <data>
```

1 1971 1 1 3 0 125 0 0 0 0 0 0 0 0 0 0 4 1 1 2 4 1 5 6 2 3 11 8 4 5 0 0 0 0 0 0 0 0 0 0 1 0 1 3 0 3 4 2 4 5  
9 17 8 3 8 0 0

0 # no tag data

0 # no morphcomp data

999