**USER MANUAL: AGE-AND-SIZE-BASED MODEL**

The program requires two files: MODEL.DAT and MODEL.CTL, each of which is described in this document. The input to the model is fairly complex so the values inputed (and how those values are interpreted) are saved to a file called CHECK.OUT.

1. **MODEL.DAT**

This file provides some basic information about the population to be assessed and the data that will appear in the likelihood function. It does not provide specifications for the how the model will be parameterized and how the data are to be weighted (beyond the input weights). This latter information is provided in the file MODEL.CTL. You can include comments in the data file in the form “*# comment*”. Any text after the “#” symbol is ignored. Also, blank lines can be included in MODEL.DAT to improve clarity.

**A.1 Basic model specifications**

The first section of MODEL.DAT provides some basic model specifications.

1. Model. Available model types are: “1” for an age-structured model, “2” for a size-structured model, and “3” for an age- and size-structured model.
2. First year. This is the first year with catch data. The model may calculate numbers-at-age for earlier years depending on the range of years for which recruitment deviations are estimated.
3. Last year. This is the last year for which model outputs are to be provided.
4. Number of sexes. This is either “1” or “2”. For a 2-sex model, the convention is that sex=1 is females and sex=2 is males. However, sex =1 can be males.
5. Maximum age-class. This is one plus the number of age-classes that will be tracked. It should 1 or higher (even for a size-structured assessment model). The last age will be treated as a plus-group.
6. Number of size-classes (at least one).
7. Number of platoons (at least one).
8. Number of fishery fleets. Fishery fleets are fleets that are associated with catches, and possibly discards (or bycatch).
9. Number of survey fleets. Survey fleets are fleets that are not associated with catches (and possibly discards), usually because their catch is insignificant.
10. The timing during the year when each survey takes place. There should be one value for each survey.
11. The names of the fleets. The name for each fleet should be a single string (use “\_” for spaces), concatenated using “;”.

The following example shows the case in which a stock is assessed using a two-sex size-structured model, there are 17 size-classes, only one platoon, two fishery fleets and a survey (the survey takes place in the middle of the year).

*2 # Model Type*

*1981 # First Year*

*2013 # Last Year*

*2 # Number of sexes*

*1 # Maximum age-class*

*17 # Number of size-classes*

*1 # Number of platoons*

*2 # Number of fishery fleets*

1. *# Number of survey fleets*

*# Survey timing*

*0.5*

*# Fleet names*

*Fishery\_1:Fishery\_2;Survey\_1*

The next part of MODEL.DAT specifies the size-structure of the model. There are three inputs to set the growth interval specifications. The first input is either “1” or “2”. “1” sets the lower limit and a single size-class width. “2” sets a minimum and maximum size, and allows the model to have size classes of variable width. If “1” is entered, the user needs to specify the lower limit of the first size class and the width of each size-class, e.g.:

# Growth specifications

1 # Specify lower limit of first size-class and the size-class width

100.5 # Lower size of the first size-class

5.0 # Size-class width

If “2” is entered, the user needs to specify the vector of lower limits of each size-class (one lower limit for each of the number of size-classes specified above), and the upper limit of the last size-class. This option allows the model to have size-classes of variable width.

# Growth specifications

2 # All lower limits and the upper limit of the last size-class

10 15 20 … 90 99

**A.2 Catch data**

Catch data are only entered for fishery fleets (not survey fleets). Catches may be zero (no catch), a positive catch, or the catch may be missing / unknown. It is not necessary to specify zero catches as the software automatically deals with them. However, missing catches need to be indicated (see below). Catch data must be entered for all fishery fleets even if the whole catch by that fleet is discarded. In the case of a fishery fleet that does not land any catch, the catch by the fleet should be reported in this section and not under the discards.

The first input is how the missing catches are to be treated. There are three options:

1. “1”: estimate fishing mortalities (as parameters) for the years when the catch is missing.
2. “2”: set the fishing mortalities for the years when the catch is missing as the product of an estimated catchability coefficient and annual fishing effort.
3. “3”: set the fishing mortalities to the average fishing mortality over the years for which catches are available.

To select option 2, enter:

# Should missing Fs for missing catches by estimated

2

The next block of inputs provide some global specifications for each fishery fleet:

1. The fleet number.
2. The multiplier for the input catches. This is to convert of all of the inputs to the model into the same units. For example, weight for the model may be specified in kilograms, but the given catches may be in pounds. The multiplier value would in this case be the conversion rate between pounds and kilograms.
3. An indication whether some (or all) of the catch is retained (“1”) or whether the entire catch is discarded (“0”)

The following example shows input for two fleets where the catches by fleet 1 are multiplied by 0.001 (to convert from kg to tonnes for example). The catch by fleet 1 is retained while the catch by fleet 2 is discarded.

# Fleet Multiplier Retained?

1 0.001 1

2 1.000 0

The final input for this section are the catches. The first line of input is the number of lines of catch data, followed by the catch data themselves. The catch data for each year involves four inputs: 1) year, 2) fleet, 3) unit, and 4) the catch. The “unit” is either “1” (if the catches are in numbers) or “2” (if the catches are in weight). It is possible to have a mix of units for a given fishery fleet, as is the case for the example below. The catch should be set to “-1” if it is missing. In the example below, two of the catches for fleet 1 are in weight, one is numbers and one is missing.

1981 1 2 10

1982 1 1 3

1983 1 2 2

1984 1 2 -1

**A.3 The index data**

Indices may be in numbers or in weight (but unlike catches, a mix of units is not possible). There can only be one index for each fleet (fishery or survey). If there are two indices for one fleet, a “ghost” survey fleet should be created that “mirrors” the selectivity and retention specifications for the fleet (see Section B.5 below) that has two indices.

The first input in this section relates to the general specifications for each index (note that a line of input must be provided for all fleets even if some fleets do not have indices). The inputs for each fleet are: 1) the fleet number, and 2) the unit. Fishery indices (CPUE) will be related to mid-year numbers or biomass. The unit is either “1” (numbers) or “2” (weight). In the following example, there are two fleets, one is a fishery fleet where the index is mid-year CPUE (in numbers) and the other is a survey where the index is start-year biomass.

*# Fleet unit*

*1 1*

*2 2*

The next input is the number of rows of index values, which is followed by the index data. The information for each index value is: 1) year, 2) fleet, 3) index value, and 4) coefficient of variation, e.g.:

# Number of index values

3

# Year fleet index cv

1980 1 1.2 0.3

1981 1 2.2 0.3

1982 1 1.3 0.1

**A.4 The discard data**

Discard information can be provided for all fishery fleets (no survey fleets), and only when catch data are already provided in the catch data section (i.e., if a fleet discards all of its catch, that information needs to be provided in the catch data section and not in this section). The information for discards is firstly some general information for each fleet: 1) the fleet number, 2) the unit for the discard data, 3) the multiplier, and 4) the type. The fleet number, unit, and multiplier fields are the same as defined as for catches in Section A.2. The type determines how the discard data should be interpreted. Current options are “1” or “2”. “1” indicates the values are estimates of the amount of discard, and “2” indicates that the values are estimates of the total amount that is caught (some of which may be landed and some of which may be discarded). The discard mortality is defined as in Section A.2. In the following example, one fleet reports discards and the other fleet reports the total catch which appears on deck. There is no need to have discard data to use the model.

*# Fleet Unit Multiplier Type*

*1 2 1.0 1*

*2 2 1.0 2*

The discard data themselves are entered next. The first value entered is the number of data points (0 means no discard data), and this is followed by the data in the same format as for the index data.

# Number of discard values

3

# Year fleet sex discard cv

1980 1 0 1.2 0.3

1981 1 1 2.2 0.3

1982 1 2 1.3 0.1

The “sex” input is “1” or “2” (with “1” denoting females and “2” denoting males) if the discard are for a single sex (as is commonly the case in crab fisheries) or is “0” if the discards are aggregated across sex.

**A.5 The effort data**

Effort data can be provided for each fleet and year (fishery fleets only). The first input is the number of effort values (0 means no effort data) and this is followed by the effort data themselves. Some of the effort values can be missing. There is no need to have effort data to use the model.

# Number of effort values

3

# Year fleet effort cv

1980 1 100 0.2

1981 1 120 0.3

1982 1 200 0.1

**A.6 The size-frequency data**

The size-frequency data are also optional (but generally necessary for size-structured models). The size-frequency data are provided by first specifying the number of lines of data (0 means no size-frequency data) and whether the likelihood function for the size-composition data should be multinomial (1) or robust normal (2).

Each line of data contains: 1) year, 2) fleet, 2) sex, 3) type, 4) effective sample size, and 5) the size-frequency data. Sex options are “0”, “1”, or “2”, as follows:

0: Both sexes; a vector of female size-frequency data followed by a vector of male size-frequency data.

1: Only female data; a vector of female size-frequency data followed by a vector of 0’s.

2: Only male data; a vector of 0’s followed by a vector of male size-frequency data.

If the model is single-sex, the sex option should be “0” or “1” and data should be provided for only one sex. The type options are “0”, “1” and “2”. These options can be interpreted as follows:

0: The size data are for the entire catch (whether it is landed or not)

1: The size data are for the discards

2: The size data are for the landed catch

Note that if a fleet discards its whole catch (such as a bycatch fleet), that catch will be entered as catch data and the type should be set to “2” and not “1”. In the example below data are provided for two fleets. One of them only lands males and other discards males and females

*# Number of lines of size-frequency data*

*100*

*# Likelihood type (1=multinomial; 2=robust normal)*

*1*

*# Year fleet sex Type Effective\_size size data*

*1990 1 1 2 100 1 1 1 … 0 0 0 0 0*

*1991 2 0 1 1000 1 2 1 2 … 9 81 1*

The final input in this section is “plus minus”. This specification allows the program to merge the tails of size-frequencies to try to avoid fitting to small proportions. The data (by sex) are aggregated so that the size-frequency proportions for the first and last non-zero size-classes are at least the value entered at this input. The value for this input should be set to zero to ignore “plussing”.

**A.7 The age-size data**

The age-size data allow growth to be estimated within an age- or age-and-size-structured model (these data cannot be used in a size-structured model). These data are optional, but it is usually difficult to estimate growth and year-class strength reliably within an age-structured model without age-size data. The age-size data are provided by first specifying the number of lines of data (0 means no age-size data) and whether the likelihood function for the age data given size-class should be multinomial (1) or robust normal (2).

Each line of data contains: 1) year, 2) the fleet number, 2) sex, 3) type, 4) first size-class, 5) second size-class, 6) effective sample size, and 7) the age-composition data for the specified group of size-classes. The types are defined as for size-frequency data (section A.6) while the format for the age-composition data is the same as for the size-frequency data in section A.6. In the example below, the first line of age data is for size-classes 1 – 3 combined, whereas the second line of age data is for size-class 1 only (because the first and second size-classes are the same).

*# Number of lines of age-size data*

*100*

*# Likelihood type (1=multinomial; 2=robust normal)*

*1*

*# Year fleet sex Type Size-1 Size-2 Effective\_size age\_data*

*1990 1 1 2 1 3 100 1 0 1 1 … 0 0 0 0 0*

*1991 2 0 1 1 1 1000 1 2 1 2 … 9 81 1*

**A.8 The tagging data**

The tagging data allow growth to be estimated within a size-structured or age-size-structured model. These data cannot (currently) be used within an age-structured model. The tagging data are optional. These data are provided by entering the number of lines of tagging data (0 means no tagging data), followed by the tagging data in the form of: 1) sex, 2) release size-class, 3) recapture size-class, 4) time-at-liberty (in years – same-year recaptures are ignored), and 5) the number of tagged animals with these characteristics.

*# Number of lines of tagging data*

*222*

*#Sex Rel\_len Rec\_len Time\_at\_lib Number*

*1 1 3 1 2*

*1 1 4 1 2*

**A.9 Check number**

The last input in model.dat should be a check number that allows checking whether the input is formatted correctly (no further processing occurs if the check number is not equal to the correct value – because some other input has been specified incorrectly)

*# Check number*

*12345678*

**B. MODEL.CTL**

This file provides the specifications for how the model is to be parameterized and how the data are to be weighted.

**B.1 Blocks**

Blocks are used to allow parameters to change over time in discrete blocks. For example, natural mortality may have two values, one during standard years and one during warm years. This can be represented as a block with “1” for the years in which natural mortality takes its standard value and “2” for the years when natural mortality takes an alternative value. Blocks are specified by listing the number of blocks and then for each block an index (starting at “1”) which indicates the block structure. The example below involves two blocks. In the first block, the parameter concerned is constant over time and in the second block, the parameter changes in 1983. Block numbers must be entered from the first year to one year after the last year. In the example, the first year is 1981 and the last year in 1984.

*# Number of blocks*

*2*

*# 1981 1982 1983 1984 1985*

*1 1 1 1 1*

*1 1 2 2 2*

**B.2 Growth and natural mortality**

There are many inputs related to growth and natural mortality. The first four inputs provide generic specifications. The first input specifies whether maturity will be a logistic (1) or a spline (2) function of length (see Equation 3.5 of the technical specifications). The next input specifies the nature of the growth curve (or the size-transition matrix for size-structured and age-size-structured models). There are currently seven options for specifying the relationship that described growth in size) (see Section 3.3 of technical specifications):

1. The three-parameter von Bertlanffy growth curve (the only option for an age-structured model).
2. The size-increment is a linear function of size, molt probability is a declining logistic function of size, and the distribution for the size-increment is normal.
3. The size-increment is a log-linear function of size, molt probability is a declining logistic function of size, and the distribution for the size-increment is normal.
4. The size-increment is a linear function of size, molt probability is a declining logistic function of size, and the distribution for the size-increment is log-normal.
5. The size-increment is a log-linear function of size, molt probability is a declining logistic function of size, and the distribution for the size-increment is log-normal.
6. The size-increment is a linear function of size, molt probability is a declining logistic function of size, and the distribution for the size-increment is gamma.
7. The size-increment is a log-linear function of size, molt probability is a declining logistic function of size, and the distribution for the size-increment is gamma.

The third input specifies whether the normal distributions for growth curve options 2 and 3 are specified in terms of a coefficient of variation (1) or a standard deviation (2). The fourth input (“jump”) indicates the maximum number of size-classes an animal can grow in one year. The next input is the proportion of the recruitment in each platoon (“1” if there is only one platoon) by sex. The final input is the proportion of the variance in length-at-age or growth increment that is determined by the between-platoon variance in growth (0 if there is one platoon).

The following inputs pertain to the case where there are three platoons and half of the variability in growth increment is due to between-platoon effects

*1 # Type of maturity vector*

*2 # Type of growth curve*

*2 # CV (1) or Sigma (2)*

*15 # Jump*

*0.25 0.5 0.25 # Between-platoon variance (females)*

*0.25 0.5 0.25 # Between-platoon variance (males)*

*0.5 # variance due to between-platoon effects*

The next set of inputs are related to the parameters that are used to model growth and natural mortality. The format for each input involves 12 values:

1. Minimum value for the parameter
2. Maximum value for the parameter
3. Initial value for the parameter
4. Phase for the parameter (a negative phase means that the parameter should not be estimated, but set to its initial value)
5. Prior type (the current options are “0” – no prior and “1” – normal prior)
6. Prior mean (if input 5 is “1”). The value entered here is ignored if “0” is entered at input 5.
7. Prior standard deviation (if input 5 is “1”). The value entered here is ignored if “0” is entered at input 5.
8. Block. This input is set to 0 if the parameter is constant over time. The value for this input should be set to the number for one of the rows of blocks (see Section B.1) to allow a parameter to change over time in discrete blocks. If a block is selected, it is necessary to provide a minimum, a maximum, an initial value, the phase, and to specify the prior for the additional parameters needed to fully-specify the vector of parameter values. Apart from the first value, the parameters for a block are log-offsets (see below). If this input is set to 0, there is no need to provide additional input.
9. Should separate (but penalized) parameters be estimated for a range of years (“0” – no, “1” – yes).
10. First year for which a parameter is to be estimated (only used if input 9 is set to “1)”.
11. Last year for which a parameter is to be estimated (only used if input 9 is set to “1”).
12. Standard deviation used to penalize changes over time in the value of the parameter (only used if input 9 is set to “1”).

Note that blocks are currently only implemented for natural mortality and while the specifications related to time-varying parameters are read-in, they are currently not used. Note also that if “0” is entered as at input 9 above, the values for inputs 10-12 are ignored.

The following parameters need to be specified for each sex (females then males):

1. Natural mortality rate
2. Offset of natural mortality for immature animals
3. Growth data (depending on which growth model was selected above)
   1. There are three parameter for growth curve option 1 (,  and the standard deviation (or CV) of length-at-age / size-increment) (see Section 3.3.2 of the technical description)
   2. There are seven parameters for growth curve options 2-7 (two reference sizes, the size-increment for each size, the molt probability for each size, and the measure of growth variance (CV or standard deviation)) (see Section 3.3.1 of the technical description).
4. Length-weight regression intercept
5. Length-weight regression power
6. Length-at-50%-maturity
7. Slope of the maturity ogive
8. The asymptote of the relationship between maturity and size.

The following inputs are needed to specify the natural mortality for females if this quantity is to be modelled as a block with two values.

*# Low Hi Init Phase Ptype PMean PSD Block UseDev Dev1 Dev2 SigDev*

*0.0 0.4 0.29 3 1 0.29 0.05 6 0 1900 2100 0.5 # Base*

*0.0 0.4 0.0 4 1 0.00 0.05 # Dev*

*0.0 0.4 0.0 4 1 0.00 0.05 # Immature offset*

The next input specifies the fraction during the year when calculating the spawning biomass used to calculate *F*35% (i.e. 0.5 means that the numbers-at-age and -at-size in the middle of the year are used to compute spawning biomass and *F*35%). The final input specifies the parameters that determine the sex-ratio of recruitment (see Equation 3.2 of the technical description). The base value of this parameter is in logit space and the block parameters are added to change the base parameter.

**B.3 Stock and recruitment**

Five parameters are used to specify recruitment and how it is allocated to size-classes. The five parameters are:

1. Unfished recruitment (in log-space)
2. The steepness of the stock-recruitment relationship
3. The standard deviation of the deviations about the stock-recruitment relationship (this should parameter should not be estimated, i.e. the phase should be set to a negative number).
4. Mean size-at-recruitment (see Equation 3.7 of the technical description).
5. The parameter that determines the spread of recruitment by size about the mean size-at-recruitment.

The inputs for each of these parameters is the minimum, maximum, initial value and phase.

The next input specifies over how many size-classes does recruitment occur (recruitment always occurs to age-0).

# SR Parameters

1.50000 15.00000 9.03563 1 # R0

0.20000 1.00000 1.00000 -1 # Steepness

0.00000 10.00000 .57000 -4 # SigmaR

0.00000 100.00000 -1.55005 -1 # Alpha of rec fun

000000 100.00000 .09658 -1 # Beta of rec fn

10 # last recruitment size class

The next nine inputs specify for which years recruitment deviations are estimated, the phase during which recruitment is estimated, the details of the bias ramp for the recruitment deviation estimates, the first year that the standard recruitment deviation penalty applies for, and a standard deviation for the change in recruitment deviation for the years before the first years that the standard penalty applies for. The following input leads to recruitment deviations being estimated for 1961 to 2013 in phase 1, with full bias correction between 1980 and 2000.

*1961 # First Year*

*2013 # Last year*

*1 # Phase for recruiment*

*1960 # First Phase in*

*1980 # Flat top (part 1)*

*2000 # Flat top (part 2)*

*2025 # last Phase in*

*1955 # Last year of early devs*

*0.2 # Variation of early devs*

**B.4 Fishing mortality and selectivity**

The first set of inputs in this section pertains to the specifications related to the hybrid method used to calculate fully-selected fishing mortality for all of the non-zero catches entered in the catch table (Methot and Wetzel, 2013) (see Section A.2). Two inputs are provided: 1) the number of times the hybrid tuning algorithm is applied to calculate the fully-selected fishing mortality (larger values should lead to a better match to the observed catches, but at the expense of longer run-times), and 2) the maximum fully-selected fishing mortality rate.

The next set of inputs specify how the fishing mortality (by fishery fleet) is set for the first year of the modelled period. The following inputs are needed for each fishery fleet: 1) the minimum value (which must be zero or larger), 2) the maximum value, 3) the initial value and 4) the phase. The initial value should be set to zero and the phase set to a negative number to indicate that the stock was unfished at the start of the modelled period.

**B.5 Selectivity and retention**

The first input in this section is the “selectivity parameter style”. Setting this to “1” means that the male selectivity parameters are log-offsets from those for females while setting it to “2” means that the parameters for males are estimated independently from those for females. This input has no impact for a single-sex model.

The next set of inputs specify age-specific selectivity by fleet and sex (fishery fleets and then survey fleets). Note that selectivity can be age- and size-specific, although it may be difficult to estimate age- and size-selectivity simultaneously for most data sets.

Eight inputs need to be provided to specify the basic structure of age-specific selectivity for each fishery and survey fleet:

1. The selectivity pattern type. This can be “0” for constant selectivity, “1” for logistic selectivity, “2” for double-logistic selectivity, “3” for spline selectivity; and “4” for logistic selectivity with selectivity for the oldest age class fixed at 1 (see Section 3.2 of the technical documentation). The selectivity pattern type set to “5” is selectivity for this fleet / sex to be mirrored to that of another fleet / sex.
2. Spline option. This is input is only needed if “3” was specified at the first input. This is the number of knots that will be used to define the spline function
3. Mirror. This option allows the user to specify that the selectivity pattern for a fleet/sex is the same as that for another fleet/sex. The entered value is the number of the selectivity pattern whose selectivity is being used for the fleet under consideration (where for a two-sex model, the number of the selectivity for fleet 1, sex 1 is “1”, that for fleet 1, sex 2 is “2”, etc.) This option is ignored if “5” was not specified for the selectivity pattern.
4. Block. This option allows the parameters of the selectivity pattern to change over time in discrete blocks.
5. Special inputs. This is an option to specify case-specific options. At present there are only three possible values for this input: “0” – no special feature, “1” – this fleet is male only, and “2” – this fleet is female only. The latter two cases are used when survey results are available by sex.
6. Retention pattern. This option allows the user to specify that the fleet discards some (but not all) of their catch. There is no retention if the fleet is discard-only. The options are “0” no retention pattern (all retained), “-1” no retention (all discarded), or “1” a logistic function of size (i.e. the probability of being retained is an increasing function of age, although even some of the oldest animals may be discarded).
7. Retention block. This option allow retention to change over time in blocks. The value of this input should be the number for one of the blocks.
8. Survival rate. This value determines the survival rate for the discards.

The following example

*# Type Spline-opt Mirror Block Special Retain Retblock Surv\_disc*

*1 0 0 4 0 1 5 0.1 # Fishery fleet 1 fem*

*1 0 0 0 0 0 0 0.0 # Fishery fleet 1 mal*

*5 0 1 0 0 0 0 0.0 # Fishery fleet 2 fem*

*5 0 1 0 0 0 0 0.0 # Fishery fleet 2 mal*

*2 6 0 0 0 -1 0 0.0 # Fishery fleet 3 fem*

*2 6 0 0 0 -1 0 0.0 # Fishery fleet 3 mal*

*1 0 0 0 1 0 0 0.0 # Survey fleet 1 fem*

*1 0 0 0 2 0 0 0.0 # Survey fleet 1 mal*

There are three fisheries and one survey in this example. Selectivity for three of the fleets (fishery fleets 1 and 2 and survey fleet 1) are governed by logistic functions of age while selectivity for fishery fleet 3 is a spline function of age but the entire catch is discarded. Selectivity for fishery fleet 2 is assumed to be the same as that for fishery fleet 1. The spline function that defines selectivity for fishery fleet 2 is specified using six knots. Fishery fleet 1 has a retention function that changes in blocks. 10% of the discards from this fleet survive. Survey fleet 1 only catches males, and selectivity for this fleet is a logistic function of age.

Mirroring is done by fleet / sex. The following example, shows a case where there are three fleets. Selectivity is estimated for males and females by fleet 1. Selectivity for males by fleet 2 is mirrored to that for males for fleet 1 and selectivity for females of fleet 2 is mirrored to that for females for fleet 1. Selectivity for females by fleet 3 is estimated and mirrored so that selectivity for males is the same as that for females.

*# Type Spline-opt Mirror Block Special Retain Retblock Surv\_disc*

*1 0 0 0 0 0 0 0.0 # Fishery fleet 1 fem*

*1 0 0 0 0 0 0 0.0 # Fishery fleet 1 mal*

*0 0 1 0 0 0 0 0.0 # Fishery fleet 2 fem*

*0 0 2 0 0 0 0 0.0 # Fishery fleet 2 mal*

*1 0 0 0 0 0 0 0.0 # Fishery fleet 3 fem*

*0 0 5 0 0 0 0 0.0 # Fishery fleet 3 mal*

The next set of specifications relate to size-specific selectivity. The inputs for size-specific selectivity are the same as those for age-specific selectivity, except that the survival rate of discards is not provided because it is set based on the value specified for age-selectivity.

The next set of inputs are only needed if one or more of the selectivity patterns are defined using spline functions. In this case, it is necessary to provide a set of knots (ages or size-classes) at which selectivity is to be estimated for each fleet with a spline selectivity pattern. For example, if size-selectivity is defined using a spline function with six knots, the values provided at this input might be:

*# Knots for selex*

*1 5 10 20 32*

The next set of inputs provides the specifications for the selectivity parameters. The number of selectivity parameters depends on the type of selectivity pattern (logistic or spline) for each fleet as well as whether blocks are specified (see above for how which age- and size-specific selectivity patterns apply to each fishery and survey fleet). The parameters are divided into base parameters and offset parameters (used when a parameter is defined in terms of a block). For any parameters that are associated with a block, there is a base parameter and one or more offset parameters (with the number of offset parameters being the number of values in the block less one – which is the base value). The inputs for base parameters are the same as those for the base natural mortality and growth parameters, while the values for offset parameters are the minimum, maximum, initial value and phase. The first set of inputs for a selectivity parameter are those for the base parameter followed as many sets of inputs for the offset parameters.

*# Low Hi Init Phase Block UseDev Dev1 Dev2 SigDev*

*20.0 200.0 100.0 2 4 0 1900 2100 0.5 # Male Inflection point*

*-2.0 10.0 0.0 3 # Male Inflection point offset*

The final set of inputs in this section is used to define the parameters related to retention (see Section 3.3 of technical specifications document). Three parameters are needed to define a logistic selectivity pattern (inflection point, slope and asymptote, the latter being the maximum proportion of fish of given age or size that will be retained). The retention parameters need to be specified for each sex in the model. The base parameters are specified first followed by offset parameters. The values for each parameter are the minimum, maximum, initial value and phase. In this example, only males can be retained, so the phases for the female parameters are set to negative numbers and the value of the asymptote parameter for females is set to zero.

*#Retention fleet 1*

*10.0 100.0 10.0 -1 # Female Inflection point*

*0.0 5.0 0.1 -1 # Female Slope*

*0.0 1.0 0.0 -1 # Female Proportion*

*-500.0 200.0 150.0 2 # Male Inflection point*

*0.0 5.0 0.1 2 # Male Slope*

*0.0 1.0 1.0 2 # Male Proportion*

*-10.0 10.0 0.0 -2 # Female Inflection point offset*

*-10.0 10.0 0.0 -2 # Female Slope offset*

*-10.0 10.0 0.0 -2 # Female Proportion offset*

*-10.0 10.0 0.0 3 # Male Inflection point offset*

*-10.0 10.0 0.0 3 # Male Slope offset*

*-10.0 0.0 0.0 3 # Male Proportion offset*

**B.6 Catchability and additional variance.**

It is necessary to provide specifications for the catchability coefficient and the extent of additional variance for each fleet (fishery and survey), even if there is no index of abundance for some of the fleets. The inputs for each fleet for catchability are: 1) type: “0” – assume that catchability equals 1, “1” – estimate catchability accounting for the prior, “2” – estimate catchability but ignore the prior; 2) the mean of the prior for log-catchability; 3) the standard deviation of the prior for log-catchability; and 4) the block number if catchability is to be estimated in blocks. Catchability is always estimated in phase 1 so there is no need to specify a phase. In the example below, there are two surveys, catchability for one fleet (Survey 1) is estimated based on the specifications for block 2, but there are no priors for catchability while catchability for the other fleet (Survey 2) is constant over time (block = 0) and estimated accounting for a prior on log-catchability that is normal with mean 0 and standard deviation 0.1.

*# Type mean (of log) SD Block*

*2 .000 .0 2 # Survey 1*

*1 .000 .1 0 # Survey 2*

There are five specifications to define the additional variance for the indices of abundance for each fleet: 1) the type: “0” - assume there is no additional variance for this fleet, and “1” estimate additional variance; 2) the minimum value for the log of the additional variance; 2) the maximum value for the log of the additional variance; 3) the initial value for the log of the additional variance; and 4) the phase for the additional variance. In the following example, there are two fleets but additional variance is only estimated for the first fleet:

*# Type Low Hi Init Phase*

*1 -5 -2 -0.1 2*

*0 -5 -2 -0.1 2*

**B.7 Weights**

The results of the assessment can depend on how the data are weighted (see section 3.7 of the technical documentation). The first value in this section is the (assumed) standard deviation of the catch data (see Section A.1). This value should be small because the model should fit the catch data well.

# Sigma for catches

.050

The remaining inputs specify the weights assigned to catch, discard, effort, size and age-size data. Values should be provided for the weights for the catch, discard and effort data for each fishery fleet (but not survey fleet). Weights should be provided for all fleets (fishery and survey) for the index, size, and age-size data.

*# Columns are Fleet Numbers*

*# 1 2 3 4 5 6*

*1.000 1.000 1.000 1.000 # Catch Likelihood*

*0.100 1.000 1.000 1.000 # Discard Likelihood*

*1.000 1.000 1.000 1.000 5.000 5.000 # Index Likelihood*

*0.100 0.100 0.100 0.100 # Effort Likelihood*

*0.200 0.500 0.100 0.200 0.0500 0.0500 # Size Likelihood*

*1.000 1.000 1.000 1.000 1.000 1.000 # Age-size Likelihood*

**B.8 Final inputs**

The final three inputs are: 1) the diagnostic level (0 for no diagnostic output and higher values for more output); 2) the number of function calls before the estimation should stop; and 3) a check number. The second input is used to check the results after a certain number of function calls by dumping a full file of model results and fit diagnostics – normal estimation involves setting this input to -1 so that the estimation continues until the minimization is complete. The Checksum must be 12345678.

*# Diagnostic level*

*1*

*# Stop of xx function calls*

*-1*

*# Checksum*

*12345678*

1. **OUTPUTFILE.OUT**

This file summarizes the estimates of the parameters of the model, key model outputs and fit diagnostics. The values in this file can be plotted using user-specified R code to evaluate assessment configurations.

**C.1 Estimated parameters**

The first section of the output file lists the contributions to the objective function. The contribution by the penalties to the objective function is listed first, followed by the contributions by the catch data, the index data, the length-frequency data, the conditional age-at-length data, and the tagging data. The contributions are given by fleet (fishery then survey) within each data type, and the weight assigned to each data component is included in the summary output.

The second section of the output file lists the proxy value for *F*MSY and the Overfishing Level. The third section of the output file lists the values for the parameters (estimates for the estimated parameters and input values for those parameters that are not estimated). The order of the parameters matches the order of the file MODEL.CTL (i.e. natural mortality and growth, selectivity, retention, any fishing mortality rates for years for which catch is missing, catchability, and recruitment deviations). For parameters that are estimated, the point estimate is given, along with the contribution of the parameter to the prior and the asymptotic standard error. If a parameter is near its lower or upper bound, this is indicated by an asterisk.

The next set of outputs are the estimates of spawning stock biomass and recruitment followed by the estimate of the equilibrium catches by fleet used to initialize the model.

**C.2 Fit diagnostics**

The first set of fit diagnostics are the fits to catch data. The data are ordered by fleet and year, with the third column listing the reported catch, the fourth column the implied fishing mortality and the fifth column the model-predicted catches. The sixth and seventh columns report the model-predicted catches in number and by mass.

The fits to the index data are provided after the fits to the catch data. The columns for the index fit data are: 1) fleet, 2) year, 3) observed index, 3) input CV for the index data, 4) CV after accounting for additional variance, 5) predicted index, 6) biomass (or numbers) corresponding to the observed data, and 7) likelihood contribution. The fits to the index data are followed by time-series of catchability values.

The fits to the discards are provided next. The columns for the fits to the discard data are: 1) fleet, 2) year, 3) type, 4) observed discard, 5) input CV for the discard data, 6) model-estimate of the discard, and 7) likelihood contribution. The fits to the effort data are provided next. The columns for the fits to the effort data are: 1) fleet, 2) year, 3) observed effort, 4) input CV for the effort data, 5) model-estimate of the effort, and 6) likelihood contribution.

Two rows of output are provided for each year of length-frequency data. The first five values on both rows indicate the year, fleet, sex, type and input effective sample size for the length-frequency concerned. This is followed by the observed and model-predicted length-frequencies (expressed as fractions). The observed and model-predicted length-frequencies are followed by diagnostics to assist with weighting of the length-frequency data. The values for each combination of year, sex and fleet are: 1) year, 2) fleet, 3) sex, 4) type, 5) input effective sample size, 6) observed mean length, 7) model-predicted mean length, 8) standard error of the model-predicted mean length, and 9) observed mean length less model-predicted mean length divided by the standard error of the predicted mean length. The final output for each fleet is a weight based on Francis weighting.

The next set of outputs are related to conditional age-at-length data, and follow the same format as for length-frequency data.

The final set of model fit diagnostics relate to the tagging data. The outputs for the tagging data are first a table that lists: 1) sex, 2) size-class-at-release, 3) size-class-at-recapture, 4) time-at-liberty in years, 5) number of data points that match specifications 1-4, 6) probability of specifications 1-4 occurring given the available data, 7) observed length-at-recapture, and 8) model-estimate of the length-at-recapture. The next set of outputs for the tagging data are tables that show for each sex and time-at-liberty the observed and model-predicted frequencies of numbers recaptured by length-class. The final set of diagnostics for the tagging data are a table that lists: 1) sex, 2) length-class-at-release, 3) length-at-release (mid-point of the size-class), 4) observed mean length-at-recapture, 5) model-estimate of the mean length-at-recapture, 6) the standard error of the model-predicted mean length-at-recapture, 7) the McAllister-Ianelli effective sample size for the sex and length-class-at-release divided by the sample size for that combination of sex and length-class-at-release, and 8) observed mean length-at-recapture less model-predicted mean length-at-recapture divided by the standard error of the predicted mean length-at-recapture.

**C.3 Other model outputs**

The final sets of outputs are:

1. Natural mortality by sex, size-class and year
2. Partial recruitment by sex and size-class
3. Age-specific selectivity by fleet (and fleet x year)
4. Length-specific selectivity by fleet (and fleet x year)
5. Age-specific retention by fleet (and fleet x year)
6. Length-specific retention by fleet (and fleet x year)
7. The size-transition matrices
8. The weight-length and fecundity-length relationships
9. The numbers-at-size matrix (by year and sex)
10. The numbers-at-age matrix (by year and sex)
11. The catch-at-size matrix (by sex, fleet and year) (retained)
12. The catch-at-size matrix (by sex, fleet and year) (total)
13. The catch-at-age matrix (by sex, fleet and year) (retained)
14. The catch-at-age matrix (by sex, fleet and year) (total)
15. The model-estimates corresponding to the survey indices (in numbers and in weight)
16. Spawning stock biomass
17. Recruitment