AGEPRO Reference Manual

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Abstract

This reference manual describes version 4.25 of the AGEPRO model and software to perform stochastic projections for age-structured stock assessments. The AGEPRO model can be used to quantify the probable effects of alternative harvest scenarios by multiple fleets on an age-structured population over a given time horizon. Primary outputs include the projected distribution of spawning biomass, fishing mortality, recruitment, and landings by time period. This updated version allows for multiple recruitment models to account for alternative hypotheses about recruitment dynamics and applies model-averaging to predict the distribution of realized recruitment given estimates of recruitment model probabilities. The reference manual also describes the logical structure of the projection model, including program inputs, outputs, structure and usage. This includes three examples which illustrate: a standard two-fleet projection analysis projection, a stock rebuilding projection analysis, and projections to calculate the annual catch limits that produce probabilities of exceeding an overfishing level. Although all reasonable efforts have been taken to ensure the accuracy and reliability of the AGEPRO software and data, the National Oceanic and Atmospheric Administration and the U.S. Government do not and cannot warrant the performance or results that may be obtained by using this software or data.

Introduction
The AGEPRO (Age-Structured Projection) model is a stochastic simulation framework developed to support fishery management by evaluating the uncertainty of future stock trajectories under alternative harvest strategies. Initially created in 1994 to determine optimal rebuilding strategies for depleted fish stocks, AGEPRO has been applied in multiple New England groundfish assessments (e.g., NEFSC 1994; NEFMC 1994, 1996) and has undergone several updates since its original documentation (Brodziak and Rago 1994; Brodziak et al. 1998). Written in the C programming language, AGEPRO efficiently performs stochastic projections of age-structured populations, generating outputs such as landings, spawning stock biomass, and fishing mortality across user-specified time horizons. The model is available in the NOAA Fisheries Integrated Toolbox.

AGEPRO is designed to generate stochastic projections that inform fishery management decisions by quantifying the uncertainty in population and fishery outcomes over time. It simulates the dynamics of an exploited age-structured population, projecting variables such as landings, spawning stock biomass, fishing mortality, and population age composition (Figure 1). The acronym "AGEPRO" highlights its focus on age-structured projections, distinguishing it from biomass-based approaches. Users can evaluate alternative harvest strategies by specifying annual quotas or fishing mortality targets.

AGEPRO incorporates three main sources of uncertainty in population projections: **(1) recruitment**, **(2) initial population size**, and **(3) process error in biological and fishery parameters**.

Recruitment: Recruitment is the primary stochastic component of AGEPRO projections, typically representing the number of age-1 fish entering the population each year. The model includes fifteen recruitment options, ranging from empirical bootstrap sampling to parametric stochastic models. A deterministic recruitment trajectory can also be specified (see Recruitment Model 3).

Initial population size: The second source of uncertainty concerns the initial population size at the start of the projection period (Figure 1). This can be represented as a probability distribution estimated using methods such as bootstrapping or Markov chain Monte Carlo sampling, or as a fixed point estimate if uncertainty is not considered.

Process error: The third uncertainty source reflects random variation (process error) in population and fishery processes over time. AGEPRO models these as multiplicative lognormal deviations with a mean of one and a specified coefficient of variation. The user can choose to apply process errors to parameters such as:

1. Natural mortality at age
2. Maturation fraction at age
3. Stock and spawning stock weight at age

4. Mean population weight at age
5. Fishery selectivity, discard fractions, and weights at age.

These simulated time series can be saved in auxiliary files to document the stochastic realizations underlying each projection.

Age-Structured Population Model

The AGEPRO framework is based on a pooled-sex, age-structured population model that tracks changes in abundance through time due to recruitment, natural mortality, and fishing mortality from one or more fleets. The model represents an iteroparous fish population in which abundance at each age evolves continuously under the combined effects of natural and fishing mortality. Recruitment occurs at the start of each year (January 1) and represents the number of new age-1 fish entering the population (Table 1). The following sections describe the model's treatment of population abundance, survival, spawning biomass, catch, harvest control, initial population abundance, and retrospective adjustment.

Population Abundance

AGEPRO computes the number of fish alive in each age class for every year of the projection. Let Y denote the total number of projection years, with $t = 1,2, ... Y$ indexing time. The youngest age class (age 1) comprises recruits, and the oldest age (age-A) is a plus-group which aggregates all individuals age A or older. The total number of age classes is set by the user. For each age *a* and year *t*, the number of fish alive at the start of the year (January 1) is $N_a(t)$. The number of fish in the plus-group is $N_A(t)$, which accounts for all fish of age A or older.

Hence, population abundance at the start of year *t* is represented by

(1) $$\underline{N}(t) = \begin{bmatrix} N_1(t) \\ N_2(t) \\ N_3(t) \\ \vdots \\ N_A(t) \end{bmatrix}$$

where $N_A(t)$ is determined by a recruitment submodel (see *Stock–Recruitment Relationship* section).

Survival

Population survival from year *t* to *t* + 1 is governed by instantaneous natural and fishing mortality at age. Let $M_a(t)$ denote the instantaneous natural mortality rate for age *a* and and $F_a(t)$ the instantaneous fishing mortality rate for age *a* in year *t*, where $F_a(t)$ is the sum of fishing mortalities at age *a* over fleets, $F_a(t) = \sum_v F_{a,v}(t)$. The expected number of survivors of age *a* fish from year *t* to year *t* + 1 is

(2) $$N_{a+1}(t+1) = N_a(t) \cdot e^{-M_a(t)-F_a(t)}$$

For the plus-group, survival accounts for both age *A* and age *A*-1 cohorts:

(3) $$N_A(t+1) = N_A(t) \cdot e^{-M_A(t)-F_A(t)} + N_{A-1}(t) \cdot e^{-M_{A-1}(t)-F_{A-1}(t)}$$

Recruitment $N_a(t)$ is determined by a stochastic process that may depend on spawning biomass in year *t* or be independent of it.

Spawning Biomass
Spawning biomass represents the total weight of mature fish surviving to the midpoint of the spawning season. It is calculated from the abundance vector $\underline{N}(t)$, mortality rates, maturity and weight at age.

Let $p_a(t)$ be the fraction of age-*a* fish that are mature in year *t*, $w_{s,a}(t)$ be the average spawning weight of age-*a* fish in year *t*, and $\varphi(t)$ be the fraction of total mortality that occurs the spawning season midpoint in year *t*. Population size at the midpoint of the spawning season $\underline{N_S}(t)$ is

(4) $$\underline{N_S}(t) = \begin{bmatrix} N_1(t) \cdot e^{-\varphi(t)[M_1(t)+F_1(t)]} \\ N_2(t) \cdot e^{-\varphi(t)[M_2(t)+F_2(t)]} \\ N_3(t) \cdot e^{-\varphi(t)[M_3(t)+F_3(t)]} \\ \vdots \\ N_A(t) \cdot e^{-\varphi(t)[M_A(t)+F_A(t)]} \end{bmatrix}$$

Spawning biomass in year *t* is then

(5) $$B_S(t) = \sum_{a=1}^{A} w_{S,a}(t) \cdot p_a(t) \cdot N_{S,a}(t)$$

Catch, Landings, and Discards
AGEPRO calculates catch at age for each fleet using the Baranov catch equation (Quinn and Deriso 1999). Catch represents the portion of the population vulnerable to harvest as determined by selectivity and mortality at age. The catch of age-*a* fish by fleet *v* in year *t* is

(6) $$C_{a,v}(t) = \frac{F_{a,v}(t)}{M_a(t)+F_{a,v}(t)}\left[1 - e^{-M_a(t)-F_{a,v}(t)}\right] \cdot N_a(t)$$

To account for discards, let $d_{a,v}(t)$ be the proportion of age-*a* fish discarded by fleet *v* in year *t*; $w_{L,a,v}(t)$ and $w_{D,a,v}(t)$ are the mean landed and discarded weights at age. Then the total landed and discarded weights by fleet *v* in year *t* are

(7) $$L_v(t) = \sum_{a=1}^{A}\left[1 - d_{a,v}(t)\right] C_{a,v}(t) w_{L,a,v}(t)$$

(8) $$D_v(t) = \sum_{a=1}^{A} d_{a,v}(t) C_{a,v}(t)\, w_{D,a,v}(t)$$

Population Harvest Options

The annual harvest level is determined by a user-specified harvest index $H(t)$, which selects between two control types:

1. **Fishing Mortality Control (Effort-Based)** – The user specifies fishing mortality $F_{a,v}(t)$ by fleet and age in year *t*.
2. **Quota Control (Catch-Based)** – The user specifies a total annual landings quota $Q_v(t)$ by fleet (metric tons) in year *t*.

A mixed harvest strategy may combine both controls within the same projection, allowing quota control in early years and effort-based control in later years.
The binary index $H(t)$ indicates which rule applies in year *t*:
$H(t) = 1 \rightarrow$ quota-based; $H(t) = 0 \rightarrow$ fishing-mortality-based.

Effort-Based Harvest

When effort-based management is used, the fishing mortality rate on age-a fish by fleet *v* in year *t* is

(9) $$F_{a,v}(t) = F_v(t) \cdot S_{a,v}(t)$$

Here $F_v(t)$ is the fully selected fishing mortality rate for fleet *v* and $S_{a,v}(t)$ is the age-specific selectivity. Landings and discards are then calculated using equations (7) and (8).

Quota-Based Harvest

Under quota control, the fully selected fishing mortality rate that yields the user-specified landings quota $Q_v(t)$ by fleet must be determined numerically. Ignoring fleet and time subscripts for simplicity, the catch and landings functions are

(10) $$C_a(F) = \frac{F \cdot S_a}{M_a + F \cdot S_a}[1 - e^{-M_a - F \cdot S_a}]N_a$$

As a result, landings can also be expressed as a function of F

(11) $$L(F) = \sum_{a=1}^{A}[1 - d_a(t)\,]C_a(F)w_{L,a}$$

The value of F that satisfies $Q = L(F)$ is found using a robust root-finding algorithm. AGEPRO applies the bisection method, replacing Newton's method used in earlier versions. Total annual quotas exceeding the exploitable biomass are flagged as infeasible.

Initial Population Abundance

The initial population abundance vector $\underline{N}(1)$ represents the number of fish alive on January 1 of the first projection year. This vector defines the starting condition for all forward simulations in AGEPRO.

AGEPRO provides two methods for initializing the population:
1. **Stochastic Initialization** – A set of B initial population vectors $\underline{N}(1)^{(b)}$ are sampled from the estimated distribution of $\underline{N}(1)$. This approach explicitly incorporates uncertainty in the initial population estimate and propagates that uncertainty through the projection. The sampling distribution of $\underline{N}(1)$, denoted by $\underline{N}^{(*)}(1) = \{\underline{N}^{(1)}(1), \underline{N}^{(2)}(1), \dots, \underline{N}^{(B)}(1)\}$, can be derived using frequentist (bootstrapping), Bayesian (Markov Chain Monte Carlo), or other methods.

2. **Deterministic Initialization** – A single point estimate of $\underline{N}(1)$ is used, ignoring uncertainty. The deterministic option uses a single best estimate for $\underline{N}(1)$. This approach assumes the initial population size is known exactly and only other stochastic elements (e.g., recruitment or process error) contribute to variability.

If the initial population vectors are expressed in relative units (e.g., thousands of fish), they must be converted to absolute numbers using a scaling coefficient k_N. For each replicate *b*,

$$\underline{N}^{(b)}(1) = k_N \cdot \underline{n}^{(b)}(1) = \left(k_N \cdot n_1^{(b)}(1), \dots, k_N \cdot n_A^{(b)}(1)\right)$$

where $\underline{n}^{(b)}(1)$ is the relative abundance vector and $\underline{N}^{(b)}(1)$ is the corresponding absolute abundance vector.

AGEPRO uses dynamic memory allocation, allowing users to specify large numbers of initial population replicates (e.g., $B = 10^5$) to explore uncertainty comprehensively.

Retrospective Adjustment

To correct for retrospective bias in estimated initial abundance, AGEPRO applies multiplicative bias-correction coefficients. Let $\underline{C}$ denote the vector of age-specific correction factors applied to $\underline{N}(1)$. The bias-corrected initial population vector $\underline{N^C}(1)$ is calculated from the element-wise product of $\underline{N}(1)$and $\underline{C}$ as

(12) $$\underline{N^C}(1) = (C_1 N_1(1), \dots, C_a N_a(1), \dots, C_A N_A(1))$$

The bias-correction coefficients are applied to each initial population vector.

If bias is constant across ages, the vector simplifies to

(13) $$\underline{N}^*(1) = C \cdot \underline{N}(1)$$

Bias correction is applied only in the first projection year to account for systematic estimation bias in the starting population. Further discussion of retrospective adjustment is provided by (Mohn 1999).

Stock-Recruitment Relationship

In general, the relationship between spawning stock B_S and recruitment R is highly variable owing to intrinsic variability in factors governing early life history survival and to measurement error in the estimates of recruitment and the spawning biomass that generated it. The stock-recruitment relationship ultimately defines the sustainable yield curve and its expected variability, assuming that the stochastic processes of growth, maturation, and natural mortality are density-independent and stationary throughout the time horizon. Quinn and Deriso (1999) provide a useful discussion of stock-recruitment models, renewal processes, and sustainable yield. Note that the assumed stock-recruitment relationship does not affect the initial population abundance at the beginning of the time horizon (see **Initial Population Abundance**).

A total of twenty-one stochastic recruitment models are available for population projection in the AGEPRO software. Thirteen of the recruitment models are functionally dependent on B_S while eight do not depend on spawning biomass. Five of the recruitment models have time-dependent parameters, twelve are time-invariant, and four may include time as a predictor, or not. The user is responsible for the choice and parameterization of the recruitment models. A description of each of the recruitment models follows. <u>Important: note that the absolute units for recruitment *R* are numbers of age-1 fish, while for spawning biomass B_S, the absolute units are kilograms of spawning biomass in each of the recruitment models below.</u>

Model 1. Markov Matrix

A Markov matrix approach to modeling recruitment may be useful when there is uncertainty about the functional form of the stock-recruitment relationship. A Markov matrix contains transition probabilities that define the probability of obtaining a given level of recruitment given that B_S was within a defined interval range. In particular, the distribution of recruitment is assumed to follow a multinomial distribution conditioned on the spawning biomass interval or spawning state of the stock. The Markov matrix model depends on spawning biomass and is time-invariant.

An empirical approach to estimate a Markov matrix uses stock-recruitment data to determine the parameters of a multinomial distribution for each spawning biomass state. In this case, matrix elements can be empirically determined by counting the number of times that a recruitment observation interval lies within a given spawning biomass state, defined by an interval of spawning biomass, and normalizing over all spawning states. To do this, assume that there are *K* recruitment values and *J* spawning biomass states. The spawning biomass states are defined by disjoint intervals on the spawning biomass axis

(14) $$I_1 = \left[0, B_{S,1}\right) \; and \;\; for \;\; j = 1,...,J-2 \;\; I_j = \left[B_{S,j-1}, B_{S,j}\right) \; and \;\; I_J = \left[B_{S,J-1}, \infty\right)$$

where the spawning biomass values $B_{S,j}$ are the input endpoints of the disjoint intervals of categories of spawning biomass (e.g., high, medium, low). Note that the spawning biomass intervals are defined by the cut points $B_{S,j}$. The conditional probability of realizing the k^{th} recruitment value given that observed spawning biomass $B_{S,Observed}$ is in the j^{th} interval is $P_{j,k}$. Here $P_{j,k}$ is the element in the j^{th} row and k^{th} column of the Markov matrix $\underline{\underline{P}} = \left[P_{j,k} \right]$ of conditional recruitment probabilities with elements

(15) $$P_{j,k} = \Pr\left(R_k \,|\, B_{S,Observed} \in I_j\right)$$

These individual conditional probabilities can be estimated by the computing the number of points in the stock recruitment data set that fall within a selected recruitment $\left[O_{k-1}, O_k\right]$ range conditioned on the spawning biomass interval I_j. If $x_{j,k}$ represents the number of stock-recruitment observations in cell $I_j \times O_k$ and there is at least one observation in spawning state j, then the empirical maximum likelihood estimate of $P_{j,k}$ is

(16) $$\Pr\left(R = O_k \mid B_S \in I_j\right) = \frac{x_{j,k}}{\sum_k x_{j,k}}$$

Here $P_{j,k} \geq 0$ and $\sum_{k=1} P_{j,k} = 1$.

The number of recruitment values and spawning biomass states are set by the user. For each spawning biomass interval, the user needs to specify the conditional probabilities of realizing the expected recruitment level, e.g., the $P_{j,k}$. Given the conditional probabilities $P_{j,k}$, simulated values of $\hat{R}$ are generated by randomly sampling the conditional distribution $\hat{R}(t) = \Pr\left(R = O_k \mid B_S(t) \in I_j\right)$ through time.

Model 2. Empirical Recruits Per Spawning Biomass Distribution

For some stocks, the distribution of recruits per spawner may be independent of the number of spawners over the range of observed data. The recruitment per spawning biomass $\left(R / B_S\right)$ model randomly generates recruitment under the assumption that the distribution of the R / B_S ratio is stationary and independent of stock size. <u>The empirical recruits per spawning biomass distribution model depends on spawning biomass and is time-invariant.</u>

To describe this nonparametric approach, let S_t be the R / B_S ratio for the t^{th} stock recruitment data point assuming age-1 recruitment

(17) $$S_t = \frac{R(t)}{B_S(t-1)}$$

and let R_S be the S^{th} element in the ordered set of S_t. The empirical probability density function for R_S, denoted as $g\left(R_S\right)$, assigns a probability of 1/T to each value of R / B_S

where T is the number of stock-recruitment data points. Let $G(R_S)$ denote the cumulative distribution function (cdf) for R_S. Set the values of G at the minimum and maximum observed R_S to be $G(R_{\min})=0$ and $G(R_{\max})=0$ so that the cdf of R_S can be written as

(18) $$G(R_S) = \frac{s-1}{T-1}$$

Random values of R_S can be generated by applying the probability integral transform to the empirical cdf. To do this, let U be a uniformly distributed random variable on the interval [0,1]. The value of $\widehat{R_S}$ corresponding to a randomly chosen value of U is determined by applying the inverse function of the cdf $G(R_S)$. In particular, if U is an integer multiple of $1/(T-1)$ so that $U=s/(T-1)$ then $\widehat{R_S}=G^{-1}(U)$. Otherwise $\widehat{R_S}$ can be obtained by linear interpolation when U is not a multiple of $1/(T-1)$.

In particular, if $(s-1)/(T-1)<U<s/(T-1)$, then $\widehat{R_S}$ is interpolated between R_S and R_{S+1} as

(19) $$U = \left(\frac{\dfrac{s}{T-1} - \dfrac{s-1}{T-1}}{R_{S+1}-R_S} \right)\left(\widehat{R_S} - R_S \right) + \frac{s-1}{T-1}$$

Solving for $\widehat{R_S}$ as a function of U yields

(20) $$\widehat{R_S} = (T-1)(R_{S+1}-R_S)\left(U - \frac{s-1}{T-1} \right) + R_S$$

where the interpolation index s is determined as the greatest integer in $1+U(T-1)$. Given the value of $\widehat{R_S}$, recruitment is generated as

(21) $$R(t) = N_1(t) = B_S(t-1)\cdot \widehat{R_S}$$

The AGEPRO program can generate stochastic recruitments under model 2 based on thousands of input stock-recruitment data points (i.e., the stock-recruitment data array size is defined as a long int variable in the C language and is user specified with the input variable MaxRecObs, (see Table 3, keyword RECRUIT) conditioned on available computer memory.

Model 3. Empirical Recruitment Distribution
Another simple model for generating recruitment is to draw randomly from the observed set of recruitments $\underline{R} = \{R(1), R(2), ..., R(T)\}$ .This may be a useful approach when the recruitment has randomly fluctuated about its mean and appears to be independent of spawning biomass over the observed range of data. In this case, the recruitment distribution may be modeled as a multinomial random variable where the probability of randomly choosing a particular recruitment is $1/T$ given T observed recruitments. The empirical recruitment distribution model does not depend on spawning biomass and is time-invariant.

In this model, realized recruitment $\hat{R}$ is simulated from the empirical recruitment distribution as

(22) $$\Pr\left(\hat{R} = R(t)\right) = \frac{1}{T}, \quad for\ t \in \{1, 2, ..., T\}$$

The empirical recruitment distribution approach is nonparametric and assumes that future recruitment is totally independent of spawning stock biomass. When current levels of B_S are near the midrange of historical values this assumption seems reasonable. However, if contemporary B_S values are near the bottom of the range, then this approach could be overly optimistic, for it assumes that all historically observed recruitment levels are possible, regardless of B_S. The AGEPRO program can generate stochastic recruitments under model 3 based on thousands of input recruitment data points. Note that the empirical recruitment distribution model can be used to make deterministic projections by specifying a single observed recruitment.

Model 4. Two-Stage Empirical Recruits Per Spawning Biomass Distribution
The two-stage recruits per spawning biomass model is a direct generalization of the R/B_S model where the spawning stock of the population is categorized into "low" and "high" states. The two-stage empirical recruits per spawning biomass distribution model depends on spawning biomass and is time-invariant.

In this model, there is an R/B_S distribution for the low spawning biomass state and an R/B_S distribution for the high spawning biomass state. Let G_{Low} be the cdf and let T_{Low} be the number of R/B_S values for the low B_S state. Similarly, let G_{High} be the cdf and let T_{High} be the number of R/B_S values for the high B_S state. Further, let B_S^* denote the cutoff level of B_S such that, if $B_S > B_S^*$, then B_S falls in the high state. Conversely if $B_S < B_S^*$ then B_S falls in the low state. Recruitment is stochastically generated from G_{Low} or G_{High} using equations (20) and (21) dependent on the B_S state. The AGEPRO program can generate stochastic recruitments under model 4 based on thousands of input stock-recruitment data points per B_S state.

Model 5. Beverton-Holt Curve with Lognormal Error

The Beverton-Holt curve (Beverton and Holt 1957) with lognormal errors is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to stochastic variation. <u>The Beverton-Holt curve with lognormal error model depends on spawning biomass and is time-invariant</u>.

The Beverton-Holt curve with lognormal error generates recruitment as

$$\hat{r}(t) = \frac{\alpha \cdot b_S(t-1)}{\beta + b_S(t-1)} \cdot e^{w}$$

(23)

$$\textit{where } w \sim N\left(0, \sigma_w^2\right),\ \hat{R}(t) = c_R \cdot \hat{r}(t),\ \textit{and } B_S(t) = c_B \cdot b_S(t)$$

The stock-recruitment parameters α, β, and σ_w^2 and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. Here it is assumed that the parameter estimates for the Beverton-Holt curve have been estimated in relative units of recruitment $r(t)$ and spawning biomass $b_S(t)$, which are converted to absolute values using the conversion coefficients. Note that the absolute value of recruitment is expressed as numbers of fish, while for spawning biomass, the absolute value is expressed as kilograms of B_S. For example, if the stock-recruitment curve was estimated with stock-recruitment data that were measured in millions of fish and thousands of metric tons of B_S, then $c_R = 10^6$ and $c_B = 10^6$. It may be important to estimate the parameters of the stock-recruitment curve in relative units to reduce the potential effects of roundoff error on parameter estimates. It is important to note that the expected value of the lognormal error term is not unity but is $\exp\left(\frac{1}{2}\sigma_w^2\right)$. Therefore, in order to generate a recruitment model that has a lognormal error term that is equal to 1, one needs to multiply the parameter α by $\exp\left(-\frac{1}{2}\sigma_w^2\right)$. This bias correction applies when the lognormal error used to fit the Beverton-Holt curve has a log-scale error term w with zero mean.

The Beverton-Holt curve is often reparameterized in a modified form with parameters for steepness h, unfished recruitment R_0 , and unfished spawning biomass B_0. The modified Beverton-Holt curve produces $h \cdot R_0$ recruits when $B_S = 0.2B_0$ and has the form

$$\hat{R} = \frac{4hR_0B_S}{B_0\left(1-h\right)+B_S\left(5h-1\right)} \tag{24}$$

The parameters α and β can be expressed as functions of the parameters of the modified Beverton-Holt curve as

$$\alpha = \frac{4hR_0}{5h-1} = 4B_0\frac{h}{\left(\frac{B_0}{R_0}\right)\left(5h-1\right)} \tag{25}$$

and

$$\beta = \frac{B_0\left(1-h\right)}{\left(5h-1\right)} = \frac{\alpha\left(\frac{B_0}{R_0}\right)\left(h^{-1}-1\right)}{4} \tag{26}$$

Thus, parameter estimates for the modified curve can be used to determine the Beverton-Holt parameters for the AGEPRO program.

Model 6. Ricker Curve with Lognormal Error

The Ricker curve (Ricker 1954) with lognormal error is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to stochastic variation. <u>The Ricker curve with lognormal error model depends on spawning biomass and is time invariant</u>.

The Ricker curve with lognormal error generates recruitment as

$$\begin{aligned} &\hat{r}\left(t\right) = \alpha \cdot b_S\left(t-1\right)\cdot e^{-\beta \cdot b_S\left(t-1\right)}\cdot e^{w} \\ &where\ \ w \sim N\left(0,\sigma_w^2\right),\ \hat{R}\left(t\right) = c_R\cdot \hat{r}\left(t\right),\ and\ \ B_S\left(t\right) = c_B\cdot b_S\left(t\right)\end{aligned} \tag{27}$$

The stock-recruitment parameters α, β, and σ_w^2 and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. Here it is assumed that the parameter estimates for the Beverton-Holt curve have been estimated in relative units of recruitment $r\left(t\right)$ and spawning biomass $b_S\left(t\right)$ which are converted to absolute values using the conversion coefficients. It is important to note that the expected value of the lognormal error term is not unity but is $\exp\left(\frac{1}{2}\sigma_w^2\right)$. To generate a recruitment model that has a lognormal error term that is equal to 1, premultiply the parameter α by $\exp\left(-\frac{1}{2}\sigma_w^2\right)$; this mean correction applies when the lognormal error used to fit the Ricker curve has a log-scale error term w with zero mean.

Model 7. Shepherd Curve with Lognormal Error
The Shepherd curve (Shepherd 1982) with lognormal error is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to stochastic variation. <u>The Shepherd curve with lognormal error model depends on spawning biomass and is time-invariant.</u>

The Shepherd curve with lognormal error generates recruitment as

$$\hat{r}(t) = \frac{\alpha \cdot b_S(t-1)}{1 + \left(\frac{b_S(t-1)}{k}\right)^{\beta}} \cdot e^{w}$$

(28)

$$where \;\; w \sim N\left(0, \sigma_w^2\right),\; \hat{R}(t) = c_R \cdot \hat{r}(t),\; and \;\; B_S(t) = c_B \cdot b_S(t)$$

The stock-recruitment parameters α, β, k, and σ_w^2 and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. Here it is assumed that the parameter estimates for the Beverton-Holt curve have been estimated in relative units of recruitment $r(t)$ and spawning biomass $b_S(t)$ which are converted to absolute values using the conversion coefficients. It is important to note that the expected value of the lognormal error term is not unity but is $\exp\left(\frac{1}{2}\sigma_w^2\right)$. To generate a recruitment model that has a lognormal error term that is equal to 1, premultiply the parameter α by $\exp\left(-\frac{1}{2}\sigma_w^2\right)$; this mean correction applies when the lognormal error used to fit the Ricker curve has a log-scale error term w with zero mean.

Model 8. Lognormal Distribution
The lognormal distribution provides a parametric model for stochastic recruitment generation. <u>The lognormal distribution model does not depend on spawning biomass and is time-invariant.</u>

The lognormal distribution generates recruitment as

$$\hat{r}(t) = e^{w}$$

(29)

$$where \;\; w \sim N\left(\mu_{\log(r)}, \sigma_{\log(r)}^2\right) \;\; and \;\; \hat{R}(t) = c_R \cdot \hat{r}(t)$$

The lognormal distribution parameters $\mu_{\log(r)}$ and $\sigma^2_{\log(r)}$ as well as the conversion coefficient for recruitment c_R are specified by the user. It is assumed that the parameters of the lognormal distribution have been estimated in relative units $r(t)$ and then converted to absolute values with the conversion coefficients.

Model 9. Time-Varying Empirical Recruitment Distribution
This recruitment model has been deprecated. The model for a time-varying empirical recruitment distribution can be fully implemented using model 3.

Model 10. Beverton-Holt Curve with Autocorrelated Lognormal Error
The Beverton-Holt curve with autocorrelated lognormal errors is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to serially correlated stochastic variation. The Beverton-Holt curve with autocorrelated lognormal error model depends on spawning biomass and is time-dependent.

The Beverton-Holt curve with autocorrelated lognormal error generates recruitment as

(30)

$$\hat{r}(t) = \frac{\alpha \cdot b_S(t-1)}{\beta + b_S(t-1)} \cdot e^{\varepsilon_t}$$

$$where\ \ \varepsilon_t = \phi\varepsilon_{t-1} + w_t\ \ with\ \ w_t \sim N\left(0, \sigma_w^2\right),$$

$$\hat{R}(t) = c_R \cdot \hat{r}(t),\ and\ \ B_S(t) = c_B \cdot b_S(t)$$

The stock-recruitment parameters α, β, ϕ, ε_0, and σ_w^2 and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. The parameter ε_0 is the log-scale residual for the stock-recruitment fit in the time prior to the projection. If this value is not known, the default is to set ε_0 =0.

Model 11. Ricker Curve with Autocorrelated Lognormal Error
The Ricker curve with autocorrelated lognormal error is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to serially correlated stochastic variation. The Ricker curve with autocorrelated lognormal error model depends on spawning biomass and is time-dependent.

The Ricker curve with autocorrelated lognormal error generates recruitment as

$$\hat{r}(t) = \alpha \cdot b_S(t-1) \cdot e^{-\beta \cdot b_S(t-1)} \cdot e^{\varepsilon_t}$$

(31)

$$\text{where } \varepsilon_t = \phi\varepsilon_{t-1} + w_t \text{ with } w_t \sim N\left(0, \sigma_w^2\right),$$
$$\hat{R}(t) = c_R \cdot \hat{r}(t), \text{ and } B_S(t) = c_B \cdot b_S(t)$$

The stock-recruitment parameters α, β, ϕ, ε_0, and σ_w^2 and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. The parameter ε_0 is the log-scale residual for the stock-recruitment fit in the time prior to the projection. If this value is not known, the default is to set ε_0 =0.

Model 12. Shepherd Curve with Autocorrelated Lognormal Error
The Shepherd curve with autocorrelated lognormal error is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to serially correlated stochastic variation. The Shepherd curve with autocorrelated lognormal error model depends on spawning biomass and is time-dependent.

The Shepherd curve with autocorrelated lognormal error generates recruitment as

$$\hat{r}(t) = \frac{\alpha \cdot b_S(t-1)}{1 + \left(\dfrac{b_S(t-1)}{k}\right)^{\beta}} \cdot e^{\varepsilon_t}$$

(32)

$$\text{where } \varepsilon_t = \phi\varepsilon_{t-1} + w_t \text{ with } w_t \sim N\left(0, \sigma_w^2\right),$$
$$\hat{R}(t) = c_R \cdot \hat{r}(t), \text{ and } B_S(t) = c_B \cdot b_S(t)$$

The stock-recruitment parameters α, β, k, ϕ, ε_0, and σ_w^2 and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. The parameter ε_0 is the log-scale residual for the stock-recruitment fit in the time prior to the projection. If this value is not known, the default is to set ε_0 =0.

Model 13. Autocorrelated Lognormal Distribution
The autocorrelated lognormal distribution provides a parametric model for stochastic recruitment generation with serial correlation. The autocorrelated lognormal distribution model does not depend on spawning biomass and is time-dependent.

The autocorrelated lognormal distribution is

$$n_r(t) = e^{\varepsilon_t}$$

(33)

$$\begin{aligned} & \textit{where}\ \ \varepsilon_t = \phi\varepsilon_{t-1} + w_t \ \ \textit{with}\ \ w_t \sim N\left(\mu_{\log(r)}, \sigma^2_{\log(r)}\right), \\ & \textit{and}\ \ R(t) = c_R \cdot n_r(t) \end{aligned}$$

The lognormal distribution parameters $\mu_{\log(r)}$, $\sigma^2_{\log(r)}$, ϕ, and ε_0 as well as the conversion coefficient for recruitment c_R are specified by the user. It is assumed that the parameters of the lognormal distribution have been estimated in relative units $r(t)$ and then converted to absolute values with the conversion coefficient.

Model 14. Empirical Cumulative Distribution Function of Recruitment

The empirical cumulative distribution function of recruitment can be used to randomly generates recruitment under the assumption that the distribution of *R* is stationary and independent of stock size. The empirical cumulative distribution function of recruitment model does not depend on spawning biomass and is time-invariant.

To describe this nonparametric approach, let R_S denote the S^{th} element in the ordered set of observed recruitment values. The empirical probability density function for R_S, denoted as $g(R_S)$, assigns a probability of 1/T to each value of $R(t)$ where *T* is the number of stock-recruitment data points. Let $G(R_S)$ denote the cumulative distribution function (cdf) for R_S. Set the values of G at the minimum and maximum observed R_S to be $G(R_{\min}) = 0$ and $G(R_{\max}) = 0$ so that the cdf of R_S can be written as

(34)

$$G(R_S) = \frac{s-1}{T-1}$$

Random values of R_S can be generated by applying the probability integral transform to the empirical cdf. To do this, let U be a uniformly distributed random variable on the interval [0,1]. The value of $\widehat{R_S}$ corresponding to a randomly chosen value of U is determined by applying the inverse function of the cdf $G(R_S)$. In particular, if U is an integer multiple of $1/(T-1)$ so that $U = s/(T-1)$ then $\widehat{R_S} = G^{-1}(U)$. Otherwise $\widehat{R_S}$ can be obtained by linear interpolation when U is not a multiple of $1/(T-1)$.

In particular, if $(s-1)/(T-1) < U < s/(T-1)$, then $\widehat{R_S}$ is interpolated between R_S and R_{S+1} as

(35) $$U = \left(\frac{\frac{s}{T-1} - \frac{s-1}{T-1}}{R_{S+1} - R_S} \right) \left(\widehat{R_S} - R_S \right) + \frac{s-1}{T-1}$$

Solving for $\widehat{R_S}$ as a function of U yields

(36) $$\widehat{R_S} = (T-1)\left(R_{S+1} - R_S\right)\left(U - \frac{s-1}{T-1}\right) + R_S$$

where the interpolation index *s* is determined as the greatest integer in $1+U(T-1)$. Given the value of $\widehat{R_S}$, recruitment is set to be

(37) $$\hat{R}(t) = \widehat{R_S}$$

The AGEPRO program can generate stochastic recruitments under model 14 based on thousands of input recruitment data points.

Model 15. Two-Stage Empirical Cumulative Distribution Function of Recruitment
The two-stage empirical cumulative distribution function of recruitment model is an extension of Model 14 where the spawning stock of the population is categorized into low and high states. <u>The two-stage empirical cumulative distribution function of recruitment model depends on spawning biomass and is time-invariant.</u>

In this model, there is an empirical recruitment distribution $\underline{R}_{Low}$ for the low spawning biomass state and an empirical recruitment distribution $\underline{R}_{High}$ for the high spawning biomass state. Let G_{Low} be the cdf and let T_{Low} be the number of R values for the low B_S state. Similarly, let G_{High} be the cdf and let T_{High} be the number of R values for the high B_S state. Further, let B_S^* denote the cutoff level of B_S such that, if $B_S > B_S^*$, then B_S falls in the high state. Conversely if $B_S < B_S^*$ then B_S falls in the low state. Recruitment is stochastically generated from G_{Low} or G_{High} using equations (36) and (37) dependent on the B_S state. The AGEPRO program can generate stochastic recruitments under model 15 based on thousands of input stock-recruitment data points per B_S state.

Model 16. Linear Recruits Per Spawning Biomass Predictor with Normal Error
The linear recruits per spawning biomass predictor with normal error is a parametric model to simulate random values of recruits per spawning biomass $\frac{R}{B_S}$ and realized recruitment values. The predictors in the linear model $X_p\left(t\right)$ can be any continuous variable and may typically be survey indices of cohort abundance or environmental covariates that are correlated with recruitment strength. Input values of each predictor are required for each time period. If a value of a predictor is missing or not known for one or more periods, the missing values can be imputed using appropriate measures of central tendency, e.g., mean or median values. Similarly, if this model has zero probability in a given time period (e.g., is not a member of the set of probable models), then dummy values can be input for each predictor. For each time period and simulation, a random value of $\frac{R}{B_S}$ is generated using the linear model

(38) $$\frac{R}{B_S} = \beta_0 + \sum_{p=1}^{N_p} \beta_p \cdot X_p\left(t\right) + \varepsilon$$

where N_p is the number of predictors, β_0 is the intercept, β_p is the linear coefficient of the p^{th} predictor and ε is a normal distribution with zero mean and constant variance σ^2. It is possible negative values of $\frac{R}{B_S}$ to be generated using this formulation; such values are excluded from the set of simulated values of $\frac{R}{B_S}$ from equation (35) by testing if $\frac{R}{B_S} \le 0$ repeating the random sampling until an feasible positive value of $\frac{R}{B_S}$ is obtained. This model randomly generates $\frac{R}{B_S}$ values under the assumption that the linear predictor of the $\frac{R}{B_S}$ ratio is stationary and independent of stock size. Random values of $\frac{R}{B_S}$ are multiplied by realized spawning biomass to generate recruitment in each time period. The linear recruits per spawning biomass predictor with normal error depends on spawning biomass and is time-invariant unless time is used as a predictor.

Model 17. Loglinear Recruits Per Spawning Biomass Predictor with Lognormal Error
The loglinear recruits per spawning biomass predictor with lognormal error is a parametric model to simulate random values of recruits per spawning biomass $\frac{R}{B_S}$ and associated random recruitments. Predictors for the loglinear model $X_p\left(t\right)$ can be any

continuous variable and could include survey indices of cohort abundance or environmental covariates that are correlated with recruitment strength. Input values of each predictor are required for each time period. If a value of a predictor is missing or not known for one or more periods, the missing values can be imputed using appropriate measures of central tendency, e.g., mean or median values. If this model has zero probability in a given time period (e.g., is not a member of the set of probable models), then dummy values can be input for each predictor. For each time period and simulation, a random value of the natural logarithm of $\frac{R}{B_S}$ is generated using the loglinear model

(39)
$$\log\left(\frac{R}{B_S}\right) = \beta_0 + \sum_{p=1}^{N_p} \beta_p \cdot X_p(t) + \varepsilon$$

where N_p is the number of predictors, β_0 is the intercept, β_p is the linear coefficient of the p^{th} predictor and ε is a normal distribution with constant variance σ^2 and mean equal to $-0.5\sigma^2$. In this case, the mean of ε implies that the expected value of the lognormal error term is unity. This model generates positive random values of $\frac{R}{B_S}$ under the assumption that the linear predictor of the $\frac{R}{B_S}$ ratio is stationary and independent of stock size. Simulated values of $\frac{R}{B_S}$ are multiplied by realized spawning biomass to generate recruitment in each time period. <u>The loglinear recruits per spawning biomass predictor with lognormal error depends on spawning biomass and is time-invariant unless time is used as a predictor.</u>

Model 18. Linear Recruitment Predictor with Normal Error

The linear recruitment predictor with normal error is a parametric model to simulate representative random values of recruitment. The predictors in the linear model $X_p(t)$ can be any continuous variable and could represent survey indices of cohort abundance or environmental covariates correlated with recruitment strength. Input values of each predictor are required for each time period. If a value of a predictor is missing or not known for one or more periods, the missing values can be imputed using appropriate measures of central tendency, e.g., mean or median values. Similarly, if this model has zero probability in a given time period (e.g., is not a member of the set of probable models), then dummy values can be input for each predictor. For each time period and simulation, a random value of *R* is generated using the linear model

(40)
$$n_r(t) = \beta_0 + \sum_{p=1}^{N_p} \beta_p \cdot X_p(t) + \varepsilon$$
$$\text{with } R(t) = c_R \cdot n_r(t)$$

here N_p is the number of predictors, β_0 is the intercept, β_p is the linear coefficient of the p^{th} predictor and ε is a normal distribution with zero mean and constant variance σ^2 and the conversion coefficients for recruitment is c_R. It is possible that negative values of *R* can be generated using this formulation; such values are excluded from the set of simulated values of R from equation (37) by testing if *R* repeating the random sampling until an feasible positive value of *R* is obtained. This model randomly generates *R* values under the assumption that the linear predictor of *R* is stationary and independent of stock size. The linear recruitment predictor with normal error does not depend on spawning biomass and is time-invariant unless time is used as a predictor.

Model 19. Loglinear Recruitment Predictor with Lognormal Error

The loglinear recruitment predictor with lognormal error is a parametric model to simulate random values of recruitment R. Predictors for the loglinear model $X_p(t)$ can be any continuous variable such as survey indices of cohort abundance or environmental covariates that are correlated with recruitment strength. Input values of each predictor are required for each time period. If a value of a predictor is missing or not known for one or more periods, the missing values can be imputed using appropriate measures of central tendency, e.g., mean or median values. If this model has zero probability in each time period (e.g., is not a member of the set of probable models), then dummy values can be input for each predictor. For each time period and simulation, a random value of the natural logarithm of *R* is generated using the loglinear model

$$\log\left(n_r(t)\right) = \beta_0 + \sum_{p=1}^{N_p} \beta_p \cdot X_p(t) + \varepsilon \qquad (41)$$
$$with \;\; R(t) = c_R \cdot n_r(t)$$

where N_p is the number of predictors, β_0 is the intercept, β_p is the linear coefficient of the p^{th} predictor and ε is a normal distribution with constant variance σ^2 and mean equal to $-0.5\sigma^2$, and the conversion coefficients for recruitment is c_R. In this case, the mean of ε implies that the expected value of the lognormal error term is unity. This model generates positive random values of R under the assumption that the linear predictor of the *R* is stationary and independent of stock size. The loglinear recruitment predictor with lognormal error does not depend on spawning biomass and is time-invariant unless time is used as a predictor.

Model 20. Fixed Recruitment

The fixed recruitment predictor applies a specified value of recruitment for each year of the time horizon. The vector of input recruitment values in relative units is $\underline{n}_r = \left[n_r(1), n_r(2), ..., n_r(Y)\right]$ for projections years 1 through Y. The fixed recruitment model predicts recruitment as

(42) $$R(t) = c_R \cdot n_r(t)$$

where the conversion coefficient for input recruitment to absolute numbers is c_R.
The fixed recruitment model does not depend on spawning biomass and is time-invariant.

Model 21. Empirical Cumulative Distribution Function of Recruitment with Linear Decline to Zero

The empirical cumulative distribution function of recruitment with linear decline to zero model is an extension of the empirical cumulative distribution function of recruitment (Model 14) in which recruitment strength declines when the spawning stock biomass falls below a threshold B_S^*. The decline in recruitment randomly generated from the empirical cdf of the observed recruitment is proportional to the ratio of current spawning stock biomass to the threshold $\frac{B_S}{B_S^*}$ when $B_S < B_S^*$. In particular, predicted recruitment values are randomly generated using equation (37) given the input time series of observed recruitment. That is, if the current spawning biomass is at or above the threshold with $B_S \geq B_S^*$ then the predicted recruitment is

(43) $$R = c_R \cdot \left[(T-1)(R_{S+1} - R_S)\left(U - \frac{s-1}{T-1}\right) + R_S \right]$$

where the conversion coefficient for input recruitment to absolute numbers is c_R.

Otherwise, if the current spawning biomass falls below the threshold with $B_S < B_S^*$ then the predicted recruitment is reduced to be

(44) $$R = c_R \cdot \frac{B_S}{B_S^*}\left[(T-1)(R_{S+1} - R_S)\left(U - \frac{s-1}{T-1}\right) + R_S \right]$$

where the conversion coefficient for input recruitment to absolute numbers is c_R.
The empirical cumulative distribution function of recruitment with linear decline to zero model depends on spawning biomass and is time-invariant.

Recruitment Model Probabilities

Model uncertainty about the appropriate stock-recruitment model can be directly incorporated into AGEPRO projections. Using a set of recruitment models may be appropriate when each model provides a similar statistical fit to a set of stock-recruitment data, where similarity can be measured using Akaike information criterion, deviance information criterion, widely applicable information criterion, or other goodness-of-fit measures. Given a measure of a stock-recruitment model's relative likelihood compared to a set of alternative models, one can use information criteria to calculate an individual model's probability of best representing the true state of nature. Alternatively, one can assign model probabilities based on judgment of other measures of goodness of fit or use the principle of indifference to assign equal probabilities in the absence of compelling information.

Regardless of the approach used to estimate them, the recruitment model probabilities are used to generate stochastic recruitment dynamics in a straightforward manner. Suppose there are a total of N_M probable recruitment models, as determined by the user. The probability that recruitment model m is realized in year *t* is denoted by $P_{R,m}(t) > 0$. Conservation of total probability implies that the sum of model probabilities over the set of probable models in each year is unity

(45) $$\sum_{m=1}^{N_M} P_{R,m}(t) = 1$$

This gives a conditional probability distribution for randomly sampling recruitment submodels in each year of the projection time horizon. As in previous versions of AGEPRO, a single recruitment model can be used for the entire projection time horizon by setting $N_M = 1$.

One advantage of including multiple recruitment models with time-varying probabilities is that one can use auxiliary information on recruitment strength, such as environmental covariates, to make short-term recruitment predictions (1-2 years) and then change to a less informative set of medium-term recruitment models for medium-term recruitment predictions (3-5 years). Another advantage of including multiple recruitment models is to account for model selection uncertainty, which can be a substantial source of uncertainty for some fishery systems.

Process Errors for Population and Fishery Processes

Process errors to generate time-varying dynamics of population and fishery processes can be included in stock projections using AGEPRO. These process errors are defined as independent multiplicative lognormal error distributions for each life history and fishery process.

The general form for a lognormal multiplicative process error term in year *t*, denoted by ε_t, is

$$\text{(46)} \quad \begin{aligned} &\varepsilon_t \sim \exp(w) \\ &where\ w \sim N\left(-0.5\sigma^2,\ \sigma^2\right) \end{aligned}$$

And where the user specifies the coefficient of variation of the lognormal process error as $CV = \sqrt{\exp\left(\sigma^2\right)-1}$ which sets the value of σ as $\sigma = \sqrt{\log\left(CV^2+1\right)}$.

The five population processes and four fishery processes that can include process error along with the input file keyword to specify the process are (keyword):

- Natural mortality at age (NATMORT) $M_a(t)$
- Maturation fraction at age (MATURITY) $p_a(t)$
- Stock weight on January 1^{st} at age (STOCK_WEIGHT) $w_{P,a}(t)$
- Spawning stock weight at age (SSB_WEIGHT) $w_{S,a}(t)$
- Midyear mean population weight at age (MEAN_WEIGHT) $w_{MY,a}(t)$
- Fishery selectivity at age by fleet (FISHERY) $S_{a,v}(t)$
- Discard fraction at age by fleet (DISCARD) $p_{D,a,v}(t)$
- Landed catch weight at age by fleet (CATCH_WEIGHT) $w_{L,a,v}(t)$
- Discard weight at age by fleet (DISC_WEIGHT) $w_{D,a,v}(t)$

For detailed documentation of projection results, the user can choose to store individual simulated values of these processes through time in auxiliary data files by setting the value of the DataFlag=1 under the keyword OPTIONS (Table 3). The auxiliary data file names are constructed from the AGEPRO input filename with file extensions ranging from .xxx1 to .xxx9 for the nine processes in the bullet list above, noting that not all processes may be used in a given projection, e.g., discarding. For processes that are used, the auxiliary file names are assigned in the order in which the process parameters are set in the AGEPRO input file. For example, if the spawning stock weight at age process parameters appeared fifth in the ordering of keywords to specify these nine processes in the AGEPRO input file, then the time series of simulated spawning stock weights at age would be store in the auxiliary output file name "input_filename.xxx5". Each row in this file would be the spawning weights at age for one year, in sequence, for each bootstrap replicate and simulation.

Total Stock Biomass

Total stock biomass B_T is the sum of stock biomass at age on January 1^{st}

$$\text{(47)} \qquad B_T(t) = \sum_{a=1}^{A} w_{P,a}(t) \cdot N_a(t)$$

where $W_{P,a}(t)$ is the population mean weight of age-a fish on January 1^{st} in year *t*.

Mean Biomass

Mean stock biomass $\overline{B}$ is the average biomass of the stock over a given year. In particular, mean stock biomass depends on the total mortality rate experienced by the stock in each year. In the AGEPRO model, the user selects the range of ages to be used for calculating mean biomass. One can choose the full range of ages in the model (age-*r* through age-*A*) or alternatively select a smaller age range if desired. In this case, the upper age A_U for mean biomass calculations must be less than or equal to the plus group age *A*. Let $w_{MY,a}(t)$ be the mean weight of age-*a* fish at the mid-point of year *t* then $\overline{B}$ in year *t* is

$$\overline{B}(t) = \sum_{a=A_L}^{A_U} w_{MY,a}(t) \cdot N_a(t) \cdot \frac{\left(1-\exp\left(-M_a(t)-F_a(t)\right)\right)}{\left(M_a(t)+F_a(t)\right)} \tag{48}$$

where $F_a(t)$ is the total fishing mortality on age-*a* fish calculated across all fleets.

Fishing Mortality Weighted by Mean Biomass

Fishing mortality weighted by mean biomass $F_{\overline{B}}(t)$ in year t is the mean-biomass weighted sum of fishing mortality at age over the age range of A_L to A_U (see Mean Biomass above). This quantity may be useful for equilibrium comparisons with fishing mortality reference points developed from surplus production models. The computational formula for fishing mortality weighted by mean biomass is

$$\begin{gathered} F_{\overline{B}}(t) = \frac{\sum_{a=A_L}^{A_U} \overline{B}_a(t) \cdot F_a(t)}{\overline{B}(t)} \\ where\ \overline{B}_a(t) = w_{MY,a}(t) N_a(t) \frac{\left(1-\exp\left(-M_a(t)-F_a(t)\right)\right)}{\left(M_a(t)+F_a(t)\right)} \end{gathered} \tag{49}$$

where $F_a(t)$ is the total fishing mortality on age-*a* fish calculated across all fleets.

Feasible Simulations

A feasible simulation is defined as one where the all landings quotas by fleet can be harvested in each year of the projection time horizon. An infeasible simulation is one where the exploitable biomass is insufficient to harvest at least one landings quota in one or more years of the time horizon. All simulations are feasible for projections where population harvest is based solely on fishing mortality values. For projections that specify landings quotas by fleet in one or more years, the feasibility of harvesting the landings quota is evaluated using an upper bound on *F* that defines infeasible quotas relative to the exploitable biomass. For purposes of summarizing projection results, the total number of simulations is denoted as K_{TOTAL} and the total number of feasible simulations is denoted as $K_{FEASIBLE}$.

Biomass Thresholds

The user can specify biomass thresholds for spawning biomass $\left(B_{S,THRESHOLD}\right)$, mean biomass $\left(\overline{B}_{THRESHOLD}\right)$, and total stock biomass $\left(B_{T,THRESHOLD}\right)$ for Sustainable Fisheries Act (SFA) policy evaluation. These biomass thresholds can be specified using the input keyword REFPOINT (Tables 2 and 3). If the REFPOINT keyword is used in an AGEPRO model, then projected biomass values are compared to the input thresholds through time. Probabilities that biomasses meet or exceed threshold values are computed for each year. In addition, the probability that biomass thresholds were exceeded in at least one year within a single simulated population trajectory is computed. If the user specifies fishing mortality-based harvesting with no landings quotas, then the SFA-threshold probabilities are computed over the entire set of simulations. Let $K_B\left(t\right)$ be the number of times that projected biomass $B\left(t\right)$ meets or exceeds a threshold biomass $B_{THRESHOLD}$ in year *t*. The counter $K_B\left(t\right)$ is evaluated for each year and biomass series (spawning, mean, or total stock). Given that K_{TOTAL} is the total number of feasible simulation runs, the estimate of the annual probability that $B_{THRESHOLD}$ would be met or exceeded in year *t* is

(50) $$\Pr\left(B\left(t\right) \geq B_{THRESHOLD}\right) = \frac{K_B\left(t\right)}{K_{TOTAL}}$$

Note that this also provides an estimate of the probability of the complementary event that biomass does not exceed the threshold via

(51) $$\Pr\left(B(t) < B_{THRESHOLD}\right) = 1 - \Pr\left(B(t) \geq B_{THRESHOLD}\right) = 1 - \frac{K_B(t)}{K_{TOTAL}}$$

Next, if $K_{THRESHOLD}$ denotes the number of simulations where biomass exceeded its threshold at least once, then the probability that $B_{THRESHOLD}$ would be met or exceeded at least

(52) $$\Pr\left(\exists t \in \left[1,2,...,Y\right] \; such \; that \; B\left(t\right) \geq B_{THRESHOLD}\right) = \frac{K_{THRESHOLD}}{K_{TOTAL}}$$

If the user specifies landings quota-based harvesting in one or more years, then the

SFA-threshold probabilities can be computed over the set of feasible simulations. In this case, the year-specific conditional probability that $B_{THRESHOLD}$ would be met or exceeded for feasible simulations is

(53) $$\Pr\left(B(t) \geq B_{THRESHOLD}\right) = \frac{K_B(t)}{K_{FEASIBLE}}$$

Note that the counter $K_B(t)$ can only be incremented in a feasible simulation. In contrast, the joint probability that $B_{THRESHOLD}$ would be met or exceeded for the entire set of simulations is given by (52) and the probability that $B_{THRESHOLD}$ would be met or exceeded at least once during the projection time horizon is given by (53).

Fishing Mortality Thresholds

The user can specify the fishing mortality rate threshold for annual total fishing mortality $(F_{THRESHOLD})$ calculated across all fleets using the keyword REFPOINT. In this case, projected total F values are compared to the $F_{THRESHOLD}$ through time. Probabilities that fishing mortalities exceed threshold values are computed for each year in the same manner as for biomass thresholds (see Biomass Thresholds above). In particular, if $K_F(t)$ is the number of times that fishing mortality $F(t)$ exceeds the threshold fishing mortality $F_{THRESHOLD}$ in year t, then the annual probability that the fishing mortality threshold is exceeded is

(54) $$\Pr\left(F(t) > F_{THRESHOLD}\right) = \frac{K_F(t)}{K_{TOTAL}}$$

and the complementary probability that the fishing mortality threshold is not exceeded is

(55) $$\Pr\left(F(t) \leq F_{THRESHOLD}\right) = 1 - \frac{K_F(t)}{K_{TOTAL}}$$

Types of Projection Analyses

The AGEPRO module can perform three types of projection analyses. These are: standard, rebuilding and PStar projection analyses.

Standard Projection

The standard projection analysis is the most flexible and can be used to apply mixtures of quota and fishing mortality based harvest by multiple fleets to the age-structured population. For a standard projection, alternative models can be setup and evaluated using any of the keyword options (Tables 2 and 3) except the REBUILD keyword.

Rebuilding Projection

The rebuilding type of projection analysis is focused on the calculation of the constant total fishing mortality calculated across all fleets that will rebuild the population, denoted as $F_{REBUILD}$. In this case, the user needs to specify the target year (TargetYear, see keyword REBUILD in Table 3) in which the population is to be rebuilt, the target biomass value (TargetType), the type of biomass being rebuilt (TargetType, e.g., spawning stock biomass), and the target percentage for achieving the rebuilding target expressed in terms of the fraction of simulations that achieve the rebuilding target (TargetPercent). Note that in cases where the rebuilding target is not achievable, the summary output of the rebuilding analysis will report that the combined catch, total fishing mortality and landings distributions are zero throughout the projection time horizon. For a rebuilding projection, the user needs to specify an initial harvest scenario of total fishing mortality values by year using the keyword HARVEST. The value of $F_{REBUILD}$ will then be iteratively calculated and the model results will be reported for the projection using the calculated value of $F_{REBUILD}$. For a rebuilding projection, the model can be setup and evaluated using any of the keyword options (Tables 2 and 3) except the PSTAR keyword.

PStar Projection

The acronym PStar stands for the probability of exceeding the overfishing threshold in a target year. The PStar type of projection analysis is focused on the calculation of the total allowable catch TAC_{PStar} that will achieve the specified probability of overfishing in the target year. In this case, the user needs to specify the target year (TargetYear, see keyword PSTAR in Table 3) in which the total annual catch to achieve PStar is calculated, the number of PStar values to be evaluated (KPStar), the vector of probabilities of overfishing or PStar values to be used (PStar), and the fishing mortality rate that defines the overfishing level (PStarF). For a PSTAR projection, the model can be setup and evaluated using any of the keyword options (Tables 2 and 3) except the REBUILD keyword.

Age-Structured Projection Software

This section covers operational details for using the AGEPRO software and is organized into four sections. First, input data requirements and projection options are covered and the structure of an input file is described. Second, projection model outputs are described in relation to keywords in the input file and the structure of the standard output file is described. Third, a set of examples are provided to illustrate projection options and features of the software.

Input Data

There are four categories of input data for an AGEPRO projection run: system, simulation, biological, and fishery (Figure 2). The system data consists of the input filename and this information is read from standard input (e.g., from the command line or via the AGEPRO GUI). The simulation, biological and fishery data are read from the text input file and the associated text bootstrap file containing the initial population numbers at age data.

The AGEPRO input file is structured by keywords. Each keyword identifies a set of related inputs for the projection run in a single section of the input file (Table 2). The table of AGEPRO input keywords below lists the 23 possible keywords in the sequential order that the information is read into the program.

Each keyword specifies a projection model attribute and the associated set of inputs that are required to implement it (Table 3). This includes a detailed listing of the AGEPRO input file structure showing the sequence of inputs by keyword. Here the input data type is shown in parentheses, where the types are: I=integer, S=string, F=floating point (Table 3). For data that are input as an array, the array dimensions are listed in order as [0: Dimension1] [0: Dimension2] and so on (Table 3).

The system data consists of the input file name for the projection run (Figure 2). The input file name can be any text string with the recommended file extension "inp". For example, a valid input file name is "GB_cod_2017_FMSY_projection.inp".

Within the input file, the simulation data are specified (Tables 2 and 3) within the keyword sections named: GENERAL, CASEID, BOOTSTRAP, RETROADJUST, BOUNDS, OPTIONS, SCALE, PERC, REFPOINT, REBUILD, and PSTAR.

The biological data are specified (Tables 2 and 3) within the keyword sections of the input file named: NATMORT, BIOLOGICAL, MATURITY, STOCK_WEIGHT, SSB_WEIGHT, MEAN_WEIGHT, and RECRUIT. The recruitment models are specified in the RECRUIT keyword section and the specific inputs needed for each recruitment model are listed in Table 4.

The fishery data are specified (Tables 2 and 3) within the keyword sections of the input file named: HARVEST, FISHERY, DISCARD, CATCH_WEIGHT, and DISC_WEIGHT.

To run the AGEPRO program using the AGEPRO GUI, do the following:

- Start the AGEPRO program (double left click on the program icon)
- Under the File menu tab, select either "Create a New Case" or "Select Existing AGEPRO Input Data File" to set the input data file

- For the selected input file, click on the Run menu tab and select "Launch AGEPRO model …".
- When the projection run is completed, the AGEPRO output files are written to a new folder. The new folder is created in the folder ~/Username/Documents/AGEPRO/New_Folder_Name where the New_Folder_Name is the input data file name with the time stamp of the run appended to it.

To run the AGEPRO program from the DOS command line, enter "agepro.exe inputfilename.inp". The software first checks whether the input file exists and will stop if the input file does not exist. If the input file exists and is successfully read, you will see the following output in the command line screen:

```
>agepro.exe inputfilename.inp
> Bootstrap Iteration: 1
> Bootstrap Iteration: 2
...
> Bootstrap Iteration: NBootstrap
> Summary Reports …
```

Model Outputs
An AGEPRO model run creates a standard output file that summarizes the projection analysis results (Figure 2). The model will also create a set of files containing the raw output results for key quantities of interest. The user also has the option of creating output files for the simulated process error data for documentation and the option of creating an R export file that stores the projections results in an R language dataframe.

There are nine categories of output in the standard output file. The first output describes the setup of the AGEPRO model and lists the input and bootstrap file names and the recruitment models and associated model probabilities. The second output shows the input harvest scenario in terms of quotas or fishing mortality rates by year and fleet. The third output shows the realized distribution of recruitment through time. The fourth output shows the realized distribution of spawning stock biomass through time. The fifth output shows the realized distribution of total stock biomass on January 1st through time. The sixth output shows the realized distribution of mean biomass through time. The seventh output shows the realized distribution of combined catch biomass across fleets through time. The eighth output shows the realized distribution of landings through time. The ninth output shows the realized distribution of total fishing mortality through time. In addition, if the user has setup REBUILD or PSTAR projection analyses, then the results of those analyses will also be listed in the standard output file.

In AGEPRO version 4.25 the former StockSummaryFlag option has been replaced by a more general AuxiliaryOutputFlag that gives finer control over (1) whether the stock size-at-age ("stock at age") distribution tables are computed and written to the AGEPRO output file, and (2) which auxiliary output files (.xx1–.xx10) are created. This flag is specified under the keyword OPTIONS in the AGEPRO input file (Table 3).

When the stock size-at-age distribution is enabled, AGEPRO calculates, for each projection year (and time period, if used), a table with age classes in rows and selected percentiles of the distribution of numbers of fish at age in columns. These tables are appended to the main AGEPRO calculation-engine output file (inputfilename.out) and may be large, especially for long projections and wide age ranges. The corresponding auxiliary file inputfilename.xx1 ("Stock Numbers at Age") can readily exceed 100 MB and should be enabled only when the detailed numbers-at-age simulations are needed for post-processing or diagnostic analyses.

In version 4.25 the behavior of AuxiliaryOutputFlag is summarized conceptually in the decision diagram shown for AGEPRO 4.25 on page 2 (AuxiliaryOutputFlag Implementation). The five allowable values are:

- **AuxiliaryOutputFlag = 0 – No stock-at-age distributions; auxiliary files 2–10 only**
  - Stock size-at-age distributions are **not calculated** and therefore are **not appended** to the AGEPRO output file.
  - Auxiliary file #1 (inputfilename.xx1, stock numbers at age) is cleared/null and not populated.
  - Auxiliary files #2–#10 (recruitment, spawning biomass, total biomass, mean biomass, combined catch biomass, landings, discards, fishing mortality, and catch by fleet) are created and populated with simulation results.
  - This option reproduces the behavior of StockSummaryFlag = 0 in AGEPRO version 4.2 and earlier.
- **AuxiliaryOutputFlag = 1 – Stock-at-age distributions; all auxiliary files 1–10**
  - Stock size-at-age distributions are **calculated** and **appended** to the AGEPRO output file.
  - Auxiliary file #1 (stock numbers at age) and auxiliary files #2–#10 are all created and populated.
  - This option reproduces the behavior of StockSummaryFlag = 1 in AGEPRO version 4.2 and earlier and corresponds to a "verbose" output setting in which the full set of auxiliary files is retained.
- **AuxiliaryOutputFlag = 2 – Output file only, no stock-at-age distributions, no auxiliary files**
  - Stock size-at-age distributions are **not calculated** and therefore are **not appended** to the AGEPRO output file.
  - No auxiliary output files (inputfilename.xx1–inputfilename.xx10) are created.
  - This option is useful when only scalar summary quantities reported in the main AGEPRO output file are needed and auxiliary files are not required for downstream analyses, minimizing disk usage and run-directory clutter.
- **AuxiliaryOutputFlag = 3 – Stock-at-age distributions only; no auxiliary files**
  - Stock size-at-age distributions are **calculated** and **appended** to the AGEPRO output file.

    - No auxiliary output files are created; in particular, inputfilename.xx1–inputfilename.xx10 are not written.
    - This option is intended for users who need the detailed stock-at-age distribution tables in the main output file, but do not require the separate auxiliary time series files.
- **AuxiliaryOutputFlag = 4 – Stock-at-age distributions; auxiliary files 2–10 only**
    - Stock size-at-age distributions are **calculated** and **appended** to the AGEPRO output file.
    - Auxiliary file #1 (stock numbers at age) is cleared/null and not retained, but auxiliary files #2–#10 are created and populated.
    - This option is useful when the stock-at-age distribution tables in the main output file are sufficient for numbers-at-age summaries, while the remaining auxiliary quantities (recruitment, biomass, catch, fishing mortality, etc.) are still needed as separate files.

In summary, AuxiliaryOutputFlag in AGEPRO 4.25 generalizes the earlier StockSummaryFlag behavior by separating control of stock-at-age distribution calculations from control of auxiliary file creation. Values 0 and 1 maintain backward-compatible behavior with AGEPRO 4.2, while values 2–4 add new options that allow users to suppress all auxiliary files, keep only the main output file, or omit the large numbers-at-age auxiliary file while retaining other auxiliary summaries.

The user may also select to produce a percentile summary of the key results in the output file. This is done by using the keyword PERC in the input file (Tables 2 and 3).

The user may also select to store age-specific population and fisheries process error simulation results in auxiliary output files. This is done by setting the DataFlag=1 under the keyword OPTIONS in the input file (Table 3). Setting the DataFlag makes it possible to replicate a a projection run with the same random draws for setting population and fishery processes. The simulated process error data can include the following age-specific information, depending on the projection model setup:
natural mortality at age, maturity fraction at age, stock weight on January 1*st* at age, spawning stock weight at age, mean population weight at age, fishery selectivity at age, discard fraction at age, catch weight at age and discard weight at age

The AGEPRO model will create auxiliary output data files to store simulated trajectories of recruitment, spawning biomass, total stock biomass on January 1*st*, mean biomass, combined catch biomass, landings, discards, and fishing mortality as well as catch by fleet if there is more than one fleet in the projection. This auxiliary output data can be used to characterize the distribution of these key outputs through time. One auxiliary file is created for each the outputs used in the projection model. The auxiliary output data files with names set to the projection inputfilename with an extension "xx#" are:

1. <u>Stock numbers at age summary on January 1st</u>: inputfilename.xx1[1]
2. <u>Recruitment</u>: inputfilename.xx2

[1] Note that the stock numbers at age auxiliary file is created only if AuxiliaryOutputFlag=1.

3. Spawning Stock Biomass: inputfilename.xx3
4. Total Stock Biomass on January 1^{st}: inputfilename.xx4
5. Mean Biomass: inputfilename.xx5
6. Combined Catch Biomass: inputfilename.xx6
7. Landings: inputfilename.xx7
8. Discards: inputfilename.xx8
9. Fishing Mortality: inputfilename.xx9
10. Catch by Fleet: inputfilename.xx10

The auxiliary output data files have similar file structures. In the stock numbers at age summary file each row represent the numbers at age (from age-1 to age-A) by year for each bootstrap-simulation block of Y rows. The auxiliary stock numbers at age output file will have a total number of rows equal to the number of bootstraps times the number of simulations per bootstrap.

For auxiliary output files 2 through 9, each row represents a single bootstrap-simulation combination and stores the simulated time trajectory of the output quantity with Y entries ordered from time t=1 to time t=Y. Within each file, the projection trajectories are blocked by the bootstrap population vector and then the set of simulations for that bootstrap vector. For example, if $B_S^{[b,k]}(t)$ denotes the spawning biomass in year t simulated from the b^{th} initial population vector and the k^{th} simulation for that vector, then the output file for spawning biomass with B initial bootstrap vectors and K simulations would have $B \cdot K$ rows that were ordered as

(56)
$$\begin{bmatrix} B_S^{[1,1]}(1) & B_S^{[1,1]}(2) & \dots & B_S^{[1,1]}(Y) \\ B_S^{[1,2]}(1) & B_S^{[1,2]}(2) & \dots & B_S^{[1,2]}(Y) \\ \vdots & \vdots & \vdots & \vdots \\ B_S^{[B,K]}(1) & B_S^{[B,K]}(2) & \dots & B_S^{[B,K]}(Y) \end{bmatrix}$$

For the catch by fleet summary file, each block of four consecutive tows represents the time series of fishing mortality, catch biomass, landed biomass and discard biomass by fleet. If there are N fleets, then there are $4N$ rows per bootstrap-simulation combination. These N blocks of four rows have the same ordering as the input fleet data, fleet 1, followed by fleet 2 and so on. Overall, the catch by fleet summary fleet has $4N \cdot B \cdot K$ rows.

The units of the entries of the auxiliary output files are similar. The output units of the stock numbers at age and the recruitment files are numbers of fish. The output units of the spawning biomass, total stock biomass, mean biomass, combined catch biomass, landings, and discards files are metric tons. The units of the F summary file are the total annual instantaneous fishing mortality rate calculated across all fleets. The output units of the catch by fleet file are the annual instantaneous fishing mortality rates by fleet, and the catch, landings and discard biomasses by fleet in metric tons.

AGEPRO Projection Examples

The following set of examples is provided to illustrate projection options and features of the software. These projections use actual fishery data but are for the purposes of illustration only.

Example 1. The first example is a fishing mortality and landings quota projection for Acadian redfish. The time horizon is 2004-2009. The fishery is comprised of two fleets that have identical fishing mortality rates in 2004, identical quotas in 2005, and fishing mortality rates that differ by 2-fold during 2006-2009. This is standard projection analysis with 1000 bootstraps and 100 simulations per bootstrap based on an ADAPT-VPA stock assessment analysis. The model also outputs an R dataframe named example1.rdat.

Running example1.inp (see Appendix for input file) produces the following output file example1.out:

```
AGEPRO VERSION 4.25

REDFISH - RECRUITMENT MODEL 14

Date & Time of Run: 03 Dec 2025  12:45

Input File Name:    example1.inp

First Age Class:                  1
Number of Age Classes:            26
Number of Years in Projection:    6
Number of Fleets:                 2
Number of Recruitment Models:     1
Number of Bootstraps:             1000
Number of Simulations:            100

Bootstrap File Name:        Example1.BSN

Number of Feasible Solutions:    100000  of    100000 Realizations

Input Harvest Scenario

Year  Type       Fleet-1   Fleet-2

2004  F-Mult     0.0024    0.0024
2005  Landings     350       350
2006  F-Mult     0.0100    0.0200
2007  F-Mult     0.0100    0.0200
2008  F-Mult     0.0100    0.0200
2009  F-Mult     0.0100    0.0200

Recruits    1000000  Fish

Year Class   Average      StdDev
2004       40.1044     48.2427
2005       39.9399     48.4981
2006       40.2597     48.6950
2007       39.9988     48.2832
2008       39.7856     47.8594
2009       39.9688     48.3182

Recruits Distribution

Year Class 1%       5%       10%      25%      50%       75%       90%       95%       99%
2004    1.6349   2.0914   2.5542   6.4615   29.3437   62.2498   77.8929   90.2558   286.7976
2005    1.6336   2.0901   2.5512   6.4411   29.2167   60.7815   77.8458   90.3986   287.6837
```

2006	1.6339	2.0818	2.5503	6.4087	29.2849	62.5382	78.0184	90.7273	288.0993
2007	1.6350	2.0884	2.5535	6.4762	29.2302	61.9145	77.9858	90.5247	286.4707
2008	1.6291	2.0739	2.5581	6.5566	29.2446	60.6213	77.7622	89.1439	285.0904
2009	1.6344	2.0814	2.5486	6.3915	29.2240	61.4137	77.9242	90.3276	286.2365

Spawning Stock Biomass x 1000 MT

Year	Average	StdDev
2004	175.6964	4.2235
2005	192.3968	5.2539
2006	201.4634	6.0700
2007	207.9324	6.4531
2008	213.1456	6.8011
2009	215.0860	7.3413

Spawning Stock Biomass Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2004	165.8702	168.7647	170.1585	172.7627	175.8220	178.5685	180.8516	182.8590	185.5053
2005	179.8749	183.7187	185.6316	188.7579	192.5022	195.8404	198.9150	201.2241	204.6585
2006	187.0111	191.5018	193.8064	197.3170	201.4803	205.3870	209.1778	211.8169	215.7979
2007	192.7825	197.3533	199.8075	203.5520	207.8802	212.1475	216.2537	218.9965	223.3172
2008	197.3391	201.9932	204.6073	208.5440	213.0623	217.5740	221.9409	224.7985	229.3704
2009	198.4676	203.2255	205.9027	210.1326	214.9256	219.7950	224.6927	227.6786	232.7286

JAN-1 Stock Biomass x 1000 MT

Year	Average	StdDev
2004	200.4105	5.4728
2005	211.6190	6.0268
2006	219.0101	6.6628
2007	224.8244	7.3809
2008	230.5532	8.6656
2009	233.1329	10.5266

JAN-1 Stock Biomass Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2004	187.3184	191.4228	193.6020	196.6427	200.3895	203.9879	207.4028	209.8767	213.3962
2005	197.4898	201.7826	204.0533	207.4975	211.5900	215.5430	219.3343	222.0184	226.0499
2006	203.4715	208.0624	210.6298	214.5142	218.9408	223.3504	227.6199	230.4028	234.8195
2007	208.3775	213.0983	215.6009	219.8556	224.5965	229.4970	234.4657	237.6273	242.8899
2008	212.2679	217.3234	220.0581	224.7349	230.0168	235.6999	241.6313	245.6361	254.4078
2009	212.1551	217.8595	220.8946	226.1200	232.1720	238.8669	246.3148	251.9618	265.1028

Mean Biomass x 1000 MT

Year	Average	StdDev
2004	195.1458	5.3333
2005	206.0695	5.8806
2006	211.4023	6.4287
2007	216.9493	7.1218
2008	222.4861	8.3792
2009	225.0470	10.1991

Mean Biomass Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2004	182.4417	186.3658	188.4707	191.4729	195.1342	198.6408	201.9257	204.3625	207.8441
2005	192.2944	196.4665	198.6674	202.0518	206.0438	209.8962	213.5909	216.1960	220.1623
2006	196.4359	200.8599	203.3086	207.0732	211.3393	215.5927	219.6996	222.4014	226.6476
2007	201.0893	205.6563	208.0480	212.1527	216.7332	221.4409	226.2433	229.2841	234.3950
2008	204.8088	209.7175	212.3363	216.8661	221.9610	227.4491	233.1935	237.1022	245.6560
2009	204.7735	210.2648	213.1964	218.2617	224.1069	230.5921	237.8002	243.2953	256.1339

Combined Catch Biomass x 1000 MT

Year	Average	StdDev
2004	0.6798	0.0165
2005	0.7000	0.0000

2006	4.4690	0.1527
2007	4.7193	0.1773
2008	4.8199	0.1837
2009	4.7281	0.1781

Combined Catch Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2004	0.6412	0.6528	0.6582	0.6686	0.6804	0.6910	0.6998	0.7076	0.7181
2005	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000
2006	4.1055	4.2163	4.2773	4.3641	4.4707	4.5678	4.6673	4.7225	4.8303
2007	4.2936	4.4271	4.4985	4.5986	4.7187	4.8331	4.9488	5.0200	5.1366
2008	4.3998	4.5203	4.5918	4.6971	4.8175	4.9389	5.0572	5.1349	5.2583
2009	4.3327	4.4381	4.5064	4.6087	4.7229	4.8433	4.9631	5.0356	5.1587

Landings x 1000 MT

Year	Average	StdDev
2004	0.6798	0.0165
2005	0.7000	0.0000
2006	4.4690	0.1527
2007	4.7193	0.1773
2008	4.8199	0.1837
2009	4.7281	0.1781

Landings Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2004	0.6412	0.6528	0.6582	0.6686	0.6804	0.6910	0.6998	0.7076	0.7181
2005	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000
2006	4.1055	4.2163	4.2773	4.3641	4.4707	4.5678	4.6673	4.7225	4.8303
2007	4.2936	4.4271	4.4985	4.5986	4.7187	4.8331	4.9488	5.0200	5.1366
2008	4.3998	4.5203	4.5918	4.6971	4.8175	4.9389	5.0572	5.1349	5.2583
2009	4.3327	4.4381	4.5064	4.6087	4.7229	4.8433	4.9631	5.0356	5.1587

Total Fishing Mortality

Year	Average	StdDev
2004	0.0048	0.0000
2005	0.0048	0.0001
2006	0.0300	0.0000
2007	0.0300	0.0000
2008	0.0300	0.0000
2009	0.0300	0.0000

Total Fishing Mortality Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2004	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
2005	0.0045	0.0046	0.0047	0.0047	0.0048	0.0049	0.0050	0.0051	0.0052
2006	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300
2007	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300
2008	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300
2009	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300

JAN-1 Stock Numbers at Age - 1000 Fish

2004

Age	1%	5%	10%	25%	50%	75%	90%	95%	99%
1	12980.4000	18663.2000	21701.1000	25681.5000	29898.3500	34597.0000	38643.0000	40879.9000	46319.7000
2	11012.5000	14992.7000	17067.0000	20861.2000	24688.7000	28313.2000	31703.5000	33915.6000	37991.9000
3	11843.8000	14379.0000	16732.3000	19660.0000	22777.9000	26374.3000	29338.5000	30861.6000	34220.9000
4	14631.7000	18363.3000	20158.2000	23132.3000	26539.6000	29624.0000	32703.8000	34627.2000	37915.7000
5	39321.1000	47758.8000	51266.7000	58450.0000	66254.6500	75027.3000	82757.9000	86914.7000	94299.9000
6	76711.2000	88108.7000	93763.8000	107388.6000	120555.9000	132828.1000	144316.0000	149223.0000	160158.6000
7	41239.8000	50885.2000	54643.8000	61621.7000	70058.8000	77584.0000	84239.8000	89573.4000	97410.1000
8	17696.1000	20383.9000	21852.0000	24527.6000	27082.3500	29770.3000	32105.4000	33636.0000	36595.0000
9	12784.7000	14244.0000	15217.9000	16648.0000	18047.2000	19370.0000	20766.1000	21689.7000	22928.3000
10	22797.0000	24359.6000	25183.7000	27037.8000	29181.5000	31094.3000	33082.5000	34043.0000	35878.2000

11	29175.6000	31160.8000	32789.2000	34906.2000	37188.6500	39709.7000	41823.5000	43349.7000	46085.3000
12	148937.5000	151393.6000	152967.8000	155734.2000	159307.7000	162082.0000	164823.3000	166757.3000	170414.4000
13	19296.4000	20361.9000	20843.6000	21972.2000	22993.7500	24176.5000	25053.9000	25562.1000	26542.5000
14	3630.2000	3939.5000	4095.9000	4415.9000	4741.3000	5059.9000	5336.6000	5489.9000	5780.6000
15	23274.4000	24173.1000	24849.4000	25794.3000	26982.5500	28125.9000	29204.3000	29907.3000	31110.6000
16	7200.0000	7925.4000	8276.4000	8969.3000	9753.8500	10518.0000	11137.9000	11616.7000	12312.1000
17	1428.2000	1537.6000	1589.1000	1683.7000	1793.3500	1908.8000	2011.1000	2067.0000	2171.2000
18	1688.2000	1821.4000	1883.0000	1980.9000	2083.3500	2173.8000	2267.2000	2330.4000	2442.0000
19	4025.2000	4218.2000	4335.6000	4562.6000	4810.0000	5036.4000	5239.8000	5352.6000	5539.9000
20	5503.5000	5798.0000	6012.8000	6298.4000	6600.7000	6913.5000	7173.3000	7299.5000	7622.9000
21	2002.3000	2159.2000	2247.8000	2418.3000	2588.3500	2760.3000	2921.5000	3024.9000	3156.9000
22	5127.7000	5290.6000	5384.3000	5554.6000	5759.7500	5966.0000	6142.3000	6278.8000	6478.8000
23	2091.4000	2237.8000	2305.4000	2403.9000	2533.0500	2629.3000	2724.5000	2773.4000	2899.3000
24	473.2000	516.3000	536.4000	574.9000	613.0500	654.3000	683.8000	705.2000	741.2000
25	333.0000	363.6000	378.9000	405.4000	435.4500	464.7000	488.8000	502.8000	522.0000
26+	15582.3000	15855.1000	15972.9000	16175.2000	16386.1000	16574.2000	16753.4000	16854.0000	17053.3000

2005

Age	1%	5%	10%	25%	50%	75%	90%	95%	99%
1	1634.9050	2091.3580	2554.2110	6461.5020	29343.6950	62249.8000	77892.9300	90255.7900	286797.6000
2	12404.4000	17770.0600	20673.3000	24432.9400	28455.4750	32883.7800	36787.1100	38974.5100	44154.7800
3	10587.7600	14259.3400	16263.1600	19836.4400	23500.4900	26891.4800	30177.0200	32205.2100	36260.5800
4	11285.9300	13716.4700	15918.4400	18674.3000	21675.5200	25105.4100	27922.6300	29415.5000	32642.6700
5	13959.2400	17488.8600	19194.2900	22008.7000	25286.4500	28203.0100	31163.1200	33015.3600	36117.5400
6	37546.3300	45497.1500	48694.0100	55562.6500	62998.9900	71255.7600	78599.8300	82499.8800	89686.8700
7	72914.7800	83607.5500	89072.2500	102083.4000	114294.1000	126059.0000	136937.1000	141589.0000	152832.4000
8	39577.1000	48218.9300	51834.2500	58446.8600	66450.1850	73534.0500	79911.0000	84929.7700	92504.9300
9	16809.0100	19345.8500	20699.9800	23218.2500	25672.9000	28255.1900	30432.0600	31875.7000	34865.1500
10	12104.0900	13507.5300	14405.3600	15766.5300	17078.5300	18328.8100	19706.9100	20567.8600	21753.7800
11	21584.6000	23048.5200	23866.8500	25625.4500	27603.9600	29441.6800	31359.7900	32260.6600	34073.7600
12	27633.9100	29613.6500	31101.5200	33058.8600	35225.8850	37644.2400	39631.0100	41074.8300	43755.4800
13	140835.7000	143255.2000	144870.5000	147550.9000	150858.2000	153645.8000	156265.9000	158049.6000	161543.3000
14	18318.3800	19301.4300	19747.0900	20795.0100	21812.4600	22935.3100	23756.2000	24257.5400	25214.6100
15	3448.6550	3730.1610	3881.9280	4183.9860	4490.4720	4800.3410	5061.6830	5206.3510	5502.2860
16	22068.8100	22904.1600	23542.1600	24467.1800	25572.2650	26666.1100	27672.1000	28331.5500	29634.8300
17	6845.8070	7515.4660	7841.4510	8507.7950	9241.4985	9959.9020	10567.9700	11016.5800	11690.5700
18	1352.1820	1456.8560	1506.4220	1595.9600	1701.8040	1808.7340	1906.8530	1962.1780	2063.4870
19	1608.5510	1725.9130	1782.7160	1875.1780	1972.6305	2059.7620	2149.6690	2207.1060	2320.6210
20	3823.7300	3997.1220	4106.9940	4322.0520	4556.8515	4774.9750	4966.8000	5077.7530	5272.2170
21	5222.2840	5502.6230	5699.3250	5973.3890	6256.0230	6554.0860	6802.4180	6938.2550	7234.9510
22	1903.1400	2046.5150	2131.8830	2292.5410	2451.2070	2617.9470	2769.2590	2862.9020	2999.8580
23	4863.8980	5012.6490	5101.2380	5266.3660	5456.8795	5652.0330	5827.9980	5952.3480	6144.0370
24	1988.2130	2122.8030	2186.7260	2278.4290	2399.4130	2493.3450	2584.5640	2627.9410	2752.0140
25	448.4781	489.6495	508.3790	545.1621	581.0267	620.1249	649.0766	668.9445	702.9467
26+	15188.0700	15421.4400	15540.4800	15731.6000	15941.7750	16134.6400	16302.8400	16400.8400	16595.9300

2006

Age	1%	5%	10%	25%	50%	75%	90%	95%	99%
1	1633.5550	2090.0730	2551.2010	6441.0810	29216.7200	60781.5300	77845.8400	90398.5900	287683.7000
2	1554.5840	1988.3930	2429.3180	6148.0710	27947.3500	59162.8700	74152.5000	85893.7700	272379.1000
3	11808.5300	16897.2500	19662.3000	23237.1800	27068.3600	31274.7500	34991.7100	37089.5400	42020.8500
4	10072.0900	13561.3000	15474.4800	18863.3500	22356.8800	25574.6300	28713.4200	30615.8700	34482.0900
5	10725.2200	13059.8600	15122.7900	17750.2100	20618.3400	23882.6900	26557.5800	27969.1600	31016.0500
6	13264.8000	16621.4900	18243.0400	20921.6800	24027.7700	26812.1100	29629.8500	31388.0500	34349.7200
7	35642.2000	43200.3700	46202.9300	52710.7600	59784.4150	67604.9600	74563.5300	78265.2300	85104.9900
8	69163.6400	79217.1100	84472.2800	96778.8600	108334.2000	119526.2000	129852.3000	134357.9000	145012.4000
9	37651.6200	45643.6800	49127.3700	55377.2300	62979.1550	69696.9900	75764.8700	80447.7900	87768.6100
10	15907.7100	18322.9600	19599.5800	21969.4600	24304.6350	26760.3900	28823.3200	30186.0600	32994.5500
11	11450.5000	12789.8700	13635.9800	14928.1300	16161.4950	17349.8800	18667.6700	19480.3400	20597.5000
12	20409.7200	21820.5300	22611.4300	24278.1200	26131.1950	27889.3200	29703.5300	30574.3700	32315.9800
13	26160.4200	28063.3500	29463.9000	31315.7900	33387.8600	35692.7500	37566.8000	38933.5200	41483.0800
14	133319.2000	135741.3000	137259.8000	139861.5000	142994.8000	145708.5000	148230.7000	149937.4000	153275.3000
15	17387.4600	18292.1600	18717.7500	19705.0800	20681.9200	21747.9400	22535.5100	23005.3000	23922.2800
16	3268.3730	3535.4920	3679.2940	3965.6490	4255.8290	4551.9880	4800.0730	4938.4300	5219.0200
17	20912.9900	21711.7200	22301.3500	23194.6800	24242.7200	25286.6200	26239.4600	26867.4400	28091.3100
18	6487.4040	7119.3860	7431.9400	8063.3250	8763.5810	9439.9440	10024.8200	10446.5000	11090.3900
19	1280.0760	1380.8470	1427.8160	1513.1600	1613.8665	1715.1190	1808.5360	1860.6590	1956.8070
20	1525.8160	1635.4730	1689.7810	1776.6430	1869.8330	1952.8200	2038.2680	2092.9440	2200.4670

21	3625.4690	3787.8570	3892.2190	4095.5200	4319.6270	4527.4450	4709.0310	4815.0730	5006.7560
22	4953.9110	5218.2170	5400.9480	5662.0610	5931.9825	6213.3380	6450.3580	6582.9370	6860.6230
23	1804.9150	1940.6280	2021.1980	2173.3170	2323.7725	2481.5780	2625.4240	2713.7320	2846.0640
24	4608.8600	4750.6550	4835.5090	4992.3780	5172.5240	5358.7520	5527.3500	5640.9010	5828.6620
25	1885.6220	2012.7910	2073.1110	2159.9330	2274.0410	2364.8120	2450.2040	2491.5730	2608.4110
26+	14943.0800	15148.4600	15262.1100	15458.7600	15661.0100	15853.8800	16024.0000	16123.8400	16312.5700

2007

Age	1%	5%	10%	25%	50%	75%	90%	95%	99%
1	1633.8770	2081.7880	2550.2700	6408.6690	29284.9300	62538.1600	78018.4100	90727.2800	288099.3000
2	1553.9560	1987.5510	2426.3150	6126.7130	27840.3150	57809.0500	74065.0600	85936.4400	273819.8000
3	1478.2740	1892.3280	2311.5590	5846.9230	26608.8100	56220.3400	70562.7900	81738.1800	259063.7000
4	11221.1200	16062.9700	18684.6000	22089.5000	25748.3600	29736.4400	33266.4000	35263.6600	39954.8000
5	9591.8010	12870.5200	14690.0000	17906.7100	21233.4500	24281.6900	27261.3100	29078.5600	32732.5100
6	10123.9200	12347.7800	14280.3200	16766.5300	19489.0300	22569.2300	25102.5100	26437.2200	29284.8300
7	12412.5400	15569.1700	17094.1700	19592.3900	22493.5500	25115.8200	27759.3100	29388.8800	32193.5800
8	33268.2900	40305.4800	43081.2700	49166.9800	55760.7550	63067.0700	69540.9200	73012.7000	79386.9900
9	64273.1100	73579.6300	78517.0600	89910.6300	100639.2000	111050.4000	120645.3000	124934.9000	134877.2000
10	34789.4400	42091.9500	45333.9000	51112.8300	58143.6800	64349.4800	69949.2400	74239.0000	81027.9100
11	14681.6200	16914.1200	18096.2800	20274.7400	22438.0650	24710.1400	26614.8900	27867.0900	30455.6500
12	10614.3300	11857.2800	12634.3600	13838.6500	14980.2000	16086.5400	17316.4800	18069.2100	19094.4400
13	18958.2400	20277.6700	21017.6500	22566.2400	24284.6400	25924.0000	27616.7300	28433.5700	30042.6600
14	24341.3600	26159.4000	27448.5000	29189.3100	31116.3450	33273.8400	35018.5300	36285.8300	38663.3300
15	124119.8000	126497.1000	127897.1000	130372.3000	133311.9500	135924.1000	138304.8000	139880.4000	142997.2000
16	16192.7600	17050.0600	17454.4500	18368.0100	19283.1650	20278.7000	21021.0400	21460.6300	22313.1000
17	3044.9410	3294.9670	3430.8980	3697.2650	3968.0605	4243.9300	4477.7210	4607.3190	4868.8690
18	19488.3800	20247.3900	20785.5000	21629.0200	22609.0550	23582.1300	24479.4600	25052.9800	26195.2200
19	6047.9080	6636.9130	6927.4790	7517.5440	8171.6335	8799.5860	9349.8760	9742.5300	10350.3600
20	1192.5400	1287.0810	1331.4860	1410.7070	1505.0030	1599.5570	1686.7890	1734.9440	1825.0320
21	1423.1090	1523.8990	1575.2460	1655.9950	1743.1115	1821.1540	1901.0320	1951.4100	2053.1220
22	3376.3490	3530.4540	3628.5860	3817.7870	4027.0575	4221.7900	4391.3920	4491.2230	4675.0600
23	4616.6280	4865.6160	5035.3570	5278.6950	5531.5805	5794.1770	6016.4370	6139.6360	6402.6650
24	1682.2490	1809.1320	1883.9760	2026.2560	2166.8960	2314.1510	2448.7740	2529.5140	2656.0550
25	4295.9040	4427.8880	4508.6410	4654.3580	4822.9430	4997.4580	5155.8980	5259.9980	5435.9720
26+	15939.8100	16170.1700	16295.3700	16497.3000	16710.3100	16919.8400	17105.7400	17218.0100	17427.8800

2008

Age	1%	5%	10%	25%	50%	75%	90%	95%	99%
1	1635.0320	2088.3650	2553.4760	6476.1610	29230.2100	61914.5500	77985.7600	90524.6800	286470.7000
2	1554.6100	1979.6510	2426.6440	6098.1270	27916.7850	59484.4600	74294.7400	86307.5500	274000.8000
3	1477.5630	1890.0370	2307.9560	5831.3390	26497.3200	54958.4900	70472.6300	81779.6900	260586.5000
4	1406.4420	1800.1310	2199.3400	5561.4770	25313.3500	53445.7200	67123.7800	77712.6200	246408.5000
5	10654.7200	15247.2300	17734.8100	20978.6800	24447.3100	28231.9500	31589.9400	33493.0800	37954.4300
6	9061.2470	12151.6400	13877.2200	16918.5400	20066.7700	22944.0400	25763.1700	27484.3200	30975.0000
7	9475.2330	11572.4000	13365.2100	15698.5000	18252.8800	21134.8400	23509.2900	24753.4400	27412.9700
8	11573.2000	14518.7100	15946.3500	18276.8000	20972.1000	23435.1300	25905.9500	27428.3300	30035.8100
9	30884.4500	37473.4700	40042.1700	45680.5700	51810.2600	58609.7600	64601.7800	67841.1800	73785.7500
10	59338.9700	67895.4500	72503.9700	82971.6700	92882.4900	102497.8000	111365.0000	115390.2000	124626.9000
11	32140.3400	38831.0000	41832.1300	47181.1300	53671.9850	59411.6000	64611.2600	68509.2700	74845.3300
12	13597.6800	15683.6400	16777.0800	18794.6700	20808.5350	22914.7900	24682.6200	25845.6800	28217.5800
13	9858.6200	11022.5300	11743.0500	12858.8800	13921.6200	14954.6400	16097.6300	16798.7200	17766.4100
14	17663.2800	18894.3800	19593.6700	21034.0100	22624.3650	24166.1600	25735.3600	26509.9400	28005.4200
15	22650.8400	24392.8400	25590.6700	27211.2200	29016.1400	31025.0700	32662.3200	33839.6200	36039.5500
16	115572.0000	117877.7000	119200.9000	121541.9000	124271.4000	126776.9000	129027.1000	130519.5000	133465.9000
17	15097.1400	15888.5300	16276.2800	17121.1100	17982.1350	18908.7600	19604.2200	20014.5800	20818.1900
18	2839.7310	3072.3100	3199.3780	3447.5750	3699.2655	3956.3810	4175.1820	4297.7180	4541.5740
19	18155.8600	18871.9200	19375.1400	20169.5800	21082.8650	21993.3100	22828.5900	23363.8200	24418.7100
20	5639.4070	6185.9540	6458.7520	7009.5110	7619.5430	8203.4690	8720.7260	9086.2030	9664.8090
21	1111.6510	1199.8570	1241.4600	1315.3150	1403.6360	1491.6420	1573.0090	1618.0260	1702.7350
22	1327.4670	1420.3660	1468.1660	1543.5750	1625.2205	1698.1130	1772.5600	1820.0600	1914.8200
23	3146.4760	3291.9360	3382.5970	3559.2970	3754.8165	3936.7560	4095.3120	4189.6340	4358.4400
24	4302.6310	4534.9940	4694.2430	4921.3080	5158.4490	5403.6320	5610.7460	5727.4110	5972.5750
25	1570.4490	1686.4470	1756.3220	1888.7530	2020.3265	2157.9960	2283.2870	2359.0020	2477.5030
26+	19203.1100	19464.1500	19595.2800	19818.4200	20074.3900	20336.5900	20580.7000	20722.6300	20971.3700

2009

Age	1%	5%	10%	25%	50%	75%	90%	95%	99%

1	1629.0870	2073.8880	2558.1460	6556.5670	29244.6100	60621.2500	77762.2000	89143.9200	285090.4000
2	1554.6660	1986.1750	2429.6810	6157.6460	27846.3800	58854.6700	74247.8600	86165.1800	272313.6000
3	1478.2020	1881.8260	2308.9790	5801.3760	26575.8850	56592.1100	70711.6700	82099.0200	260995.7000
4	1405.0330	1797.1580	2196.0090	5542.6200	25208.0350	52282.5500	67025.0400	77746.7000	247680.5000
5	1336.0210	1709.6020	2089.5760	5282.4850	24051.2350	50713.6200	63778.7500	73742.9900	234020.4000
6	10060.6600	14404.3200	16767.4300	19819.2000	23105.5650	26670.6800	29864.6500	31656.1400	35867.1700
7	8490.3400	11370.8700	12994.9000	15838.9000	18788.8250	21487.0700	24124.5200	25739.3400	28969.5000
8	8838.5860	10799.1700	12459.8600	14639.7600	17024.8100	19709.0700	21927.7300	23080.6400	25587.6800
9	10736.7100	13478.7000	14818.0800	16980.7900	19486.9900	21775.3200	24071.2100	25478.9600	27905.5600
10	28537.4000	34606.1800	36969.6100	42159.8000	47825.8650	54108.5200	59654.5400	62620.1500	68084.7900
11	54832.5600	62666.1100	66942.7300	76586.7500	85740.7750	94632.6300	102793.9000	106599.6000	115060.3000
12	29782.7500	35997.2200	38758.7600	43745.6000	49758.1450	55094.3800	59918.6200	63508.3000	69382.5600
13	12631.0100	14577.5000	15591.5700	17472.9100	19347.0800	21302.4300	22952.2600	24023.0400	26225.9200
14	9185.7300	10275.2900	10937.8700	11982.9500	12975.2400	13940.7200	15008.3100	15659.3700	16561.5900
15	16455.1300	17616.3200	18264.4300	19611.7900	21093.1000	22533.4100	24001.2900	24718.8000	26109.6700
16	21101.8400	22739.5600	23849.0800	25359.4200	27057.9350	28932.3500	30471.6100	31552.8000	33597.4400
17	107627.7000	109831.8000	111092.2000	113314.6000	115867.0000	118248.9000	120365.3000	121780.4000	124595.4000
18	14063.8400	14810.0000	15175.1600	15961.3800	16767.6000	17632.0100	18286.6200	18670.6400	19425.3000
19	2647.7930	2863.9190	2982.3350	3214.9730	3449.5570	3689.4040	3894.4640	4006.7490	4236.8940
20	16915.2000	17592.8000	18060.2900	18801.2000	19658.0250	20512.8500	21289.1700	21792.0100	22768.7100
21	5254.2520	5765.7040	6021.1940	6536.6240	7105.4475	7648.2030	8134.3950	8474.6100	9014.3330
22	1036.3350	1117.8810	1157.2690	1226.5760	1308.9590	1390.9280	1466.8110	1508.9080	1588.6030
23	1238.6270	1324.1780	1368.3550	1438.8980	1515.1955	1583.6540	1653.1420	1697.6120	1786.4740
24	2932.8290	3068.0800	3153.6430	3318.6100	3501.3740	3671.4330	3819.0730	3906.8520	4067.5890
25	4010.3320	4228.4660	4374.9310	4587.5370	4809.2845	5039.2940	5232.3320	5342.5880	5569.4730
26+	19643.0700	19939.6000	20079.1500	20315.2000	20604.2150	20895.2500	21148.2000	21307.6800	21594.5400

Probability Spawning Stock Biomass Exceeds Threshold 236.700 (1000 MT)

Year	Probability
2004	0.000000
2005	0.000000
2006	0.000000
2007	0.000000
2008	0.000010
2009	0.001940

Probability Threshold Exceeded at Least Once = 0.0019

Probability Total Fishing Mortality Exceeds Threshold 0.0400

Year	Probability
2004	0.000000
2005	0.000000
2006	0.000000
2007	0.000000
2008	0.000000
2009	0.000000

Probability Threshold Exceeded at Least Once = 0.0000--

<u>Example 2.</u> The second example is a fishing mortality and landings quota projection for Gulf of Maine haddock with a PStar analysis in 2018. The time horizon is 2014-2020. The fishery is comprised of one fleet. This is PStar projection analysis with 1000 bootstraps and 10 simulations per bootstrap based on an ASAP stock assessment analysis. The model output shows that total allowable catch amounts in 2018 to produce probabilities of overfishing of 10%, 20%, 30%, 40% and 50% at the overfishing level of F=0.35. The total allowable catches to produce overfishing probabilities of 10%, 20%, 30%, 40% and 50% are calculated to be 1780, 1998, 2176, 2332, and 2497 mt, respectively. The model output includes a stock summary of numbers at age and also outputs a percentile analysis for key outputs at the 90th percentile.

Running example2.inp produces the output file example2.out:

AGEPRO VERSION 4.25

GoM haddock ASAP_final (1977-2011 recruitment)

Date & Time of Run: 01 Dec 2025 08:44

Input File Name: example2.inp

First Age Class:	1
Number of Age Classes:	9
Number of Years in Projection:	7
Number of Fleets:	1
Number of Recruitment Models:	1
Number of Bootstraps:	1000
Number of Simulations:	10

Bootstrap File Name: Example2.BSN

Number of Feasible Solutions: 10000 of 10000 Realizations

Input Harvest Scenario

Year	Type	Value
2014	Landings	500
2015	F-Mult	0.2000
2016	F-Mult	0.2000
2017	F-Mult	0.2000
2018	Removals	2497
2019	F-Mult	0.2000
2020	F-Mult	0.2000

Recruits 1000 Fish

Year Class	Average	StdDev
2014	2113.8225	2387.2409
2015	2095.2435	2388.6322
2016	2161.9981	2415.4853
2017	2154.6634	2430.4964
2018	2141.7581	2406.3266
2019	2156.4185	2450.1039
2020	2183.0481	2465.0965

Recruits Distribution

Year Class	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	150.1671	205.1791	227.5903	331.1452	1120.8200	2542.1990	6162.8810	6484.1110	11028.6100
2015	149.3512	204.6887	228.6934	334.4683	1120.1820	2541.2640	6152.7080	6487.6110	11048.1000
2016	154.2960	203.8387	225.7294	361.4124	1129.3905	2545.1890	6212.6520	6501.7350	10886.1000
2017	152.0371	210.7372	232.7332	359.0538	1129.9945	2544.1510	6190.1710	6506.0160	11309.1700
2018	153.6666	204.7484	227.5898	349.5553	1122.8935	2544.3130	6203.1390	6499.2570	11243.7600
2019	152.0957	209.2503	231.1399	342.5836	1125.1445	2543.9000	6212.2790	6536.6520	11337.6800
2020	150.5870	206.1237	230.0479	360.4650	1132.4435	2544.9890	6226.1050	6535.5360	11422.0900

Spawning Stock Biomass x 1000 MT

Year	Average	StdDev
2014	6.6153	1.5860
2015	11.0899	2.9220
2016	12.8636	3.4163
2017	12.6038	3.2662
2018	11.3916	3.0953
2019	9.7421	3.0356
2020	9.0292	2.7831

Spawning Stock Biomass Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	3.5200	4.3275	4.7137	5.4851	6.4722	7.5894	8.7222	9.4729	10.9446
2015	5.4666	6.9514	7.6632	8.9364	10.7412	12.9279	14.9858	16.4572	19.3031
2016	6.4490	8.0138	8.8712	10.3627	12.4238	15.0340	17.4631	19.0611	22.6196
2017	6.5380	7.9215	8.7276	10.2139	12.2223	14.6495	17.0540	18.4992	21.5570
2018	5.6092	6.9035	7.6665	9.1293	11.0387	13.3430	15.5845	16.9557	19.8974
2019	4.0236	5.3269	6.0556	7.5435	9.4281	11.6586	13.8259	15.2291	17.8403
2020	3.8158	4.9913	5.6425	6.9951	8.7759	10.8011	12.7350	14.0313	16.5065

JAN-1 Stock Biomass x 1000 MT

Year	Average	StdDev
2014	11.4167	2.9021
2015	13.9657	3.6246
2016	14.8968	3.8103
2017	14.6414	3.6817
2018	13.7025	3.4096
2019	11.6265	3.4733
2020	10.8758	3.2285

JAN-1 Stock Biomass Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	5.8387	7.3015	8.0296	9.3083	11.0600	13.2142	15.2749	16.6707	19.5190
2015	7.1894	8.8204	9.7234	11.2971	13.5244	16.2526	18.8028	20.6046	24.1617
2016	7.7881	9.4605	10.4082	12.1233	14.4212	17.2943	20.0188	21.8708	25.6910
2017	7.7478	9.3316	10.2328	11.9419	14.2320	16.9148	19.6778	21.2949	24.6684
2018	7.2064	8.7307	9.5603	11.2420	13.3875	15.8500	18.2481	19.8581	22.8287
2019	4.9782	6.5211	7.4069	9.0983	11.3092	13.8388	16.3219	17.7958	20.9340
2020	4.7593	6.1337	6.9781	8.5232	10.5738	12.9143	15.2091	16.6590	19.4733

Mean Biomass x 1000 MT

Year	Average	StdDev
2014	13.5594	3.5654
2015	15.0921	4.0054
2016	15.3716	3.9588
2017	14.6866	3.7276
2018	12.9499	3.5927
2019	11.4205	3.4391
2020	10.7213	3.2607

Mean Biomass Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	6.7743	8.5594	9.4054	10.9301	13.1275	15.7951	18.3751	20.0235	23.4287
2015	7.5738	9.4465	10.3652	12.1587	14.5926	17.5658	20.4590	22.3897	26.2371
2016	7.9903	9.7496	10.6488	12.4953	14.9115	17.8132	20.7241	22.5648	26.2661
2017	7.6799	9.2810	10.1779	11.9493	14.2831	17.0375	19.6923	21.2855	24.9087
2018	6.1034	7.6719	8.5812	10.3214	12.6155	15.2101	17.6818	19.3861	22.5858
2019	4.9062	6.3754	7.2373	8.9247	11.0836	13.6122	15.9977	17.5320	20.7117
2020	4.6255	5.9719	6.7819	8.3407	10.4020	12.7506	15.0877	16.4991	19.5794

Combined Catch Biomass x 1000 MT

Year	Average	StdDev
2014	0.5000	0.0000
2015	0.8803	0.2338
2016	1.1420	0.3043
2017	1.4560	0.3947
2018	2.4966	0.0000
2019	1.3033	0.4176
2020	1.2978	0.4060

Combined Catch Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

2015	0.4340	0.5427	0.6046	0.7113	0.8555	1.0264	1.1884	1.3045	1.5357
2016	0.5651	0.7098	0.7834	0.9215	1.1052	1.3265	1.5480	1.6929	1.9909
2017	0.7298	0.9039	0.9911	1.1700	1.4071	1.6944	1.9823	2.1726	2.6016
2018	2.4966	2.4966	2.4966	2.4966	2.4966	2.4966	2.4966	2.4966	2.4966
2019	0.5368	0.7012	0.8076	0.9984	1.2549	1.5584	1.8669	2.0601	2.4484
2020	0.5392	0.7114	0.8088	1.0025	1.2569	1.5518	1.8438	2.0309	2.3896

Landings x 1000 MT

Year	Average	StdDev
2014	0.5000	0.0000
2015	0.8803	0.2338
2016	1.1420	0.3043
2017	1.4560	0.3947
2018	2.4966	0.0000
2019	1.3033	0.4176
2020	1.2978	0.4060

Landings Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
2015	0.4340	0.5427	0.6046	0.7113	0.8555	1.0264	1.1884	1.3045	1.5357
2016	0.5651	0.7098	0.7834	0.9215	1.1052	1.3265	1.5480	1.6929	1.9909
2017	0.7298	0.9039	0.9911	1.1700	1.4071	1.6944	1.9823	2.1726	2.6016
2018	2.4966	2.4966	2.4966	2.4966	2.4966	2.4966	2.4966	2.4966	2.4966
2019	0.5368	0.7012	0.8076	0.9984	1.2549	1.5584	1.8669	2.0601	2.4484
2020	0.5392	0.7114	0.8088	1.0025	1.2569	1.5518	1.8438	2.0309	2.3896

Total Fishing Mortality

Year	Average	StdDev
2014	0.2105	0.0583
2015	0.2000	0.0000
2016	0.2000	0.0000
2017	0.2000	0.0000
2018	0.3687	0.1159
2019	0.2000	0.0000
2020	0.2000	0.0000

Total Fishing Mortality Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	0.1148	0.1340	0.1461	0.1696	0.2014	0.2412	0.2857	0.3139	0.3952
2015	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
2016	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
2017	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
2018	0.1825	0.2189	0.2408	0.2860	0.3500	0.4296	0.5190	0.5799	0.7405
2019	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
2020	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000

Requested Percentile Report

Percentile = 90.00 %

	2014	2015	2016	2017	2018	2019	2020
Recruits	6162.8810	6152.7080	6212.6520	6190.1710	6203.1390	6212.2790	6226.1050
Spawning Stock Biomass	8.7222	14.9858	17.4631	17.0540	15.5845	13.8259	12.7350
Jan-1 Stock Biomass	15.2749	18.8028	20.0188	19.6778	18.2481	16.3219	15.2091
Mean Biomass	18.3751	20.4590	20.7241	19.6923	17.6818	15.9977	15.0877
Combined Catch Biomass	0.5000	1.1884	1.5480	1.9823	2.4966	1.8669	1.8438
Landings	0.5000	1.1884	1.5480	1.9823	2.4966	1.8669	1.8438
FMort	0.2857	0.2000	0.2000	0.2000	0.5190	0.2000	0.2000

PStar Summary Report

Overfishing F = 0.3500 Target Year = 2018

PStar	TAC
0.1000	1780
0.2000	1998
0.3000	2176
0.4000	2332
0.5000	2497

Example 3. The third example is a fishing mortality and landings quota projection for Gulf of Maine haddock with a rebuilding analysis for 2014-2020. The fishery is comprised of one fleet with process error in fishery selectivity. This is rebuilding projection with 1000 bootstraps and 10 simulations per bootstrap based on an ASAP stock assessment analysis. The model output shows the constant fishing mortality to rebuild the stock is $F_{REBUILD} = 0.045$. The model output includes a stock summary of numbers at age and also outputs a percentile analysis for key outputs at the 90th percentile.

Running example3.inp produces the output file example3.out:

AGEPRO VERSION 4.25

GoM haddock ASAP_final FREBUILD Projection

Date & Time of Run: 01 Dec 2025 08:45

Input File Name: example3.inp

First Age Class:	1
Number of Age Classes:	9
Number of Years in Projection:	7
Number of Fleets:	1
Number of Recruitment Models:	1
Number of Bootstraps:	1000
Number of Simulations:	10

Bootstrap File Name: Example3.BSN

Number of Feasible Solutions: 10000 of 10000 Realizations

Input Harvest Scenario

Year	Type	Value
2014	Landings	500
2015	F-Mult	0.3000
2016	F-Mult	0.3000
2017	F-Mult	0.3000
2018	F-Mult	0.3000
2019	F-Mult	0.3000
2020	F-Mult	0.3000

Recruits 1000 Fish

Year Class	Average	StdDev
2014	2170.8200	2441.8617
2015	2144.2492	2416.6899
2016	2150.4373	2418.5021
2017	2077.7020	2359.7104
2018	2169.2781	2458.9123
2019	2146.2591	2453.9399
2020	2109.8574	2409.5591

Recruits Distribution

Year Class	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	153.7521	208.0085	229.3621	347.0616	1132.0955	2545.3470	6225.6320	6522.2980	11133.4100
2015	152.8537	207.5118	228.9794	352.4027	1126.1215	2542.6540	6181.5870	6500.1300	11200.0900
2016	152.0864	205.9702	227.0639	334.5421	1120.9140	2544.0470	6196.3710	6505.2510	10864.6400
2017	153.9306	204.6065	223.9934	335.6253	1120.2075	2541.6660	6154.7360	6491.9800	10947.3800
2018	151.7663	206.4086	227.8564	353.3611	1136.3925	2544.5000	6227.9310	6534.0640	11412.9500
2019	150.6260	205.4969	229.0507	342.5477	1120.8380	2543.5260	6205.1600	6521.0480	11515.9200
2020	152.6280	209.8481	230.9342	348.8617	1120.4415	2541.6850	6179.7760	6495.6550	11322.8800

Spawning Stock Biomass x 1000 MT

Year	Average	StdDev
2014	6.6170	1.5864
2015	11.2472	2.9734
2016	13.6893	3.6225
2017	14.2545	3.6743
2018	14.2000	3.5843
2019	13.8474	3.4929
2020	13.5056	3.3958

Spawning Stock Biomass Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	3.5078	4.3130	4.7139	5.4741	6.4677	7.5996	8.7246	9.5079	10.8959
2015	5.5792	7.0419	7.7295	9.0558	10.8637	13.1037	15.2164	16.6561	19.6791
2016	6.8389	8.5537	9.4430	11.0420	13.2202	15.9565	18.5612	20.2245	23.9665
2017	7.3671	8.9936	9.9199	11.6008	13.8159	16.5604	19.2488	20.9204	24.5266
2018	7.4340	9.0080	9.8747	11.5974	13.8368	16.4445	18.9478	20.6655	24.1175
2019	7.2135	8.7442	9.6034	11.3116	13.5319	16.0556	18.4609	20.0106	23.2609
2020	7.1247	8.5118	9.3369	11.0000	13.2158	15.6735	18.0730	19.5799	22.4662

JAN-1 Stock Biomass x 1000 MT

Year	Average	StdDev
2014	11.4174	2.8996
2015	13.9853	3.6385
2016	15.5776	3.9671
2017	16.1162	4.0252
2018	16.0743	3.9486
2019	15.7028	3.8651
2020	15.3638	3.7809

JAN-1 Stock Biomass Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	5.9561	7.3305	8.0160	9.3127	11.0570	13.2145	15.2783	16.6890	19.4895
2015	7.0768	8.8151	9.7325	11.3215	13.5287	16.2558	18.8747	20.6014	24.4138
2016	8.1564	9.8810	10.8909	12.7070	15.0950	18.1127	20.8555	22.7520	26.5053
2017	8.5564	10.2829	11.2717	13.1921	15.6896	18.6290	21.5091	23.3583	27.0562
2018	8.5860	10.3039	11.2642	13.1568	15.7288	18.5593	21.3129	23.1065	26.8372
2019	8.3366	10.0510	10.9747	12.8914	15.3734	18.1349	20.8302	22.5606	26.1722
2020	8.1237	9.7586	10.7283	12.5950	15.0481	17.7564	20.3938	22.0870	25.1322

Mean Biomass x 1000 MT

Year	Average	StdDev
2014	13.5499	3.5542
2015	15.4331	4.0737
2016	16.4904	4.2029
2017	16.6939	4.1849
2018	16.3128	4.0289
2019	15.7412	3.9122
2020	15.4252	3.8993

Mean Biomass Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	6.8296	8.5113	9.3948	10.9509	13.0968	15.7592	18.2887	20.0230	23.4237

2015	7.8519	9.6342	10.6250	12.5018	14.9013	17.9378	20.8969	22.8972	27.2031
2016	8.6093	10.4184	11.4735	13.4336	16.0525	19.1332	22.1543	24.0733	28.1761
2017	8.7683	10.6194	11.6720	13.6335	16.2788	19.3000	22.2328	24.2065	28.2042
2018	8.6469	10.3838	11.3612	13.3676	15.9913	18.8559	21.6646	23.4337	27.1639
2019	8.3179	9.9544	10.9414	12.8538	15.4182	18.2748	20.9306	22.6906	26.1512
2020	7.9700	9.6937	10.6649	12.5609	15.0972	17.9037	20.6399	22.3327	25.8592

Combined Catch Biomass x 1000 MT

Year	Average	StdDev
2014	0.5000	0.0000
2015	0.2016	0.0530
2016	0.2789	0.0737
2017	0.3796	0.1018
2018	0.4419	0.1161
2019	0.4422	0.1156
2020	0.4748	0.1232

Combined Catch Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
2015	0.1003	0.1249	0.1392	0.1633	0.1963	0.2339	0.2728	0.2977	0.3469
2016	0.1394	0.1741	0.1925	0.2250	0.2708	0.3237	0.3775	0.4135	0.4824
2017	0.1914	0.2364	0.2608	0.3046	0.3669	0.4417	0.5168	0.5646	0.6686
2018	0.2283	0.2769	0.3047	0.3575	0.4290	0.5124	0.5971	0.6567	0.7565
2019	0.2287	0.2767	0.3051	0.3569	0.4295	0.5137	0.5978	0.6517	0.7612
2020	0.2444	0.2973	0.3263	0.3852	0.4629	0.5511	0.6407	0.6968	0.8046

Landings x 1000 MT

Year	Average	StdDev
2014	0.5000	0.0000
2015	0.2016	0.0530
2016	0.2789	0.0737
2017	0.3796	0.1018
2018	0.4419	0.1161
2019	0.4422	0.1156
2020	0.4748	0.1232

Landings Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
2015	0.1003	0.1249	0.1392	0.1633	0.1963	0.2339	0.2728	0.2977	0.3469
2016	0.1394	0.1741	0.1925	0.2250	0.2708	0.3237	0.3775	0.4135	0.4824
2017	0.1914	0.2364	0.2608	0.3046	0.3669	0.4417	0.5168	0.5646	0.6686
2018	0.2283	0.2769	0.3047	0.3575	0.4290	0.5124	0.5971	0.6567	0.7565
2019	0.2287	0.2767	0.3051	0.3569	0.4295	0.5137	0.5978	0.6517	0.7612
2020	0.2444	0.2973	0.3263	0.3852	0.4629	0.5511	0.6407	0.6968	0.8046

Total Fishing Mortality

Year	Average	StdDev
2014	0.2102	0.0578
2015	0.0445	0.0000
2016	0.0445	0.0000
2017	0.0445	0.0000
2018	0.0445	0.0000
2019	0.0445	0.0000
2020	0.0445	0.0000

Total Fishing Mortality Distribution

Year	1%	5%	10%	25%	50%	75%	90%	95%	99%
2014	0.1162	0.1334	0.1462	0.1696	0.2015	0.2408	0.2839	0.3145	0.3851
2015	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445
2016	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445
2017	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445
2018	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445

2019	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445
2020	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445

Requested Percentile Report

Percentile = 90.00 %

	2014	2015	2016	2017	2018	2019	2020
Recruits	6225.6320	6181.5870	6196.3710	6154.7360	6227.9310	6205.1600	6179.7760
Spawning Stock Biomass	8.7246	15.2164	18.5612	19.2488	18.9478	18.4609	18.0730
Jan-1 Stock Biomass	15.2783	18.8747	20.8555	21.5091	21.3129	20.8302	20.3938
Mean Biomass	18.2887	20.8969	22.1543	22.2328	21.6646	20.9306	20.6399
Combined Catch Biomass	0.5000	0.2728	0.3775	0.5168	0.5971	0.5978	0.6407
Landings	0.5000	0.2728	0.3775	0.5168	0.5971	0.5978	0.6407
FMort	0.2839	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445

Summary

This reference manual documents AGEPRO version 4.25, a stochastic age-structured projection model and software package designed to evaluate fishery harvest strategies under uncertainty. It describes how AGEPRO simulates population abundance, survival, spawning biomass, catch, landings, discards, and fishing mortality at age for one or more fleets, while explicitly incorporating uncertainty from recruitment, initial population size, and time-varying biological and fishery processes. The manual details a suite of twenty-one recruitment models, including empirical, parametric, and covariate-driven formulations, and explains how model probabilities are used to implement recruitment model averaging when projecting future stock trajectories. It further outlines the two harvest control types (effort-based and quota-based), the treatment of biomass and fishing mortality thresholds for policy evaluation, and the three projection modes—standard, rebuilding, and P* (overfishing-probability-based) analyses. Practical guidance is provided on constructing AGEPRO input files, interpreting standard and auxiliary outputs (including updated AuxiliaryOutputFlag behavior and optional R export), and using worked examples to implement typical projection problems. Overall, the manual serves as a comprehensive technical guide for configuring, running, and interpreting AGEPRO 4.25 projections to support quantitative fishery management decisions.

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References

Beverton, R.J.H., and Holt, S.J. 1957. On the dynamics of exploited fish populations. Chapman and Hall, London. Fascimile reprint, 1993.

Brodziak, J. and P. Rago. Manuscript 1994. A general approach for short-term stochastic projections in age-structured fisheries assessment models. Methods working group, Population dynamics branch. Northeast Fisheries Science Center. Woods Hole, Massachusetts, 02543.

Brodziak, J., P. Rago, and R. Conser. 1998. A general approach for making short-term stochastic projections from an age-structured fisheries assessment model. In F. Funk, T. Quinn II, J. Heifetz, J. Ianelli, J. Powers, J. Schweigert, P. Sullivan, and C.-I. Zhang (Eds.), *Proceedings of the International Symposium on Fishery Stock Assessment Models for the 21st Century*. Alaska Sea Grant College Program, Univ. of Alaska, Fairbanks.

Brodziak, J., Traver, M., Col, L., and Sutherland, S. 2006. Stock assessment of Georges Bank haddock, 1931-2004. NEFSC Ref. Doc. 06-11. Available at: http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0611/

Mayo, R.K. and Terceiro, M., editors. 2005. Assessment of 19 Northeast groundfish stocks through 2004. 2005 Groundfish Assessment Review Meeting (2005 GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, 15-19 August 2005. U.S. Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc. 05-13, 499 p.

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES J. Mar. Sci. 56,473–488.

New England Fishery Management Council [NEFMC]. 1994. Amendment 5 to the Northeast Multispecies Fishery Management Plan. NEFMC, Newburyport, MA.

NEFMC. 1996. Amendment 7 to the Northeast Multispecies Fishery Management Plan. NEFMC, Newburyport, MA.

Northeast Fisheries Science Center [NEFSC]. 1994. Report of the 18th Northeast Regional Stock Assessment Workshop: Stock Assessment Review Committee Consensus Summary of Assessments. NEFSC Ref. Doc. 94-22, Woods Hole, MA 02543, 199 p.

NEFSC. 2002. Final Report of the Working Group on Re Evaluation of Biological Reference Points for New England Groundfish. NEFSC Ref. Doc. 02 04, p. 254. Available at: http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0204/

NEFSC. 2008a. Assessment of 19 Northeast Groundfish Stocks through 2007: Report of the 3rd Groundfish Assessment Review Meeting (GARM III), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. US Dep Commer, NOAA Fisheries, Northeast Fish Sci Cent Ref Doc. 08-15; 884 p + xvii.

NEFSC. 2008b. Appendix to the Report of the 3rd Groundfish Assessment Review Meeting (GARM III): Assessment of 19 Northeast Groundfish Stocks through 2007, Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. US Dep Commer, NOAA Fisheries, Northeast Fish Sci Cent Ref Doc. 08-16; 1056 p.

Quinn, T.J., II, and R. B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, New York, 542 p.

Ricker, W.E. 1954. Stock and recruitment. J. Fish. Res. Board. Can. 11:559-623.

Shepherd, J.G. 1982. A versatile new stock-recruitment relationship for fisheries and the construction of sustainable yield curves. J. Cons. Int. Explor. Mer 40:67-75.

Table 1. Glossary of variables in the AGEPRO module.

Variable	Description
A	Age of plus-group (fish age-A and older) and last index value for $\underline{N}$
$B_S(t)$	Spawning biomass in year *t*
$\overline{B}(t)$	Mean stock biomass in year *t*
$B_T(t)$	Total stock biomass on January 1^{st} of year *t*
B	Number of input initial population vectors $\underline{N}(t)$
$C_a(t)$	Total catch number of age-a fish that are caught in year *t*
$C_{a,v}(t)$	Number of age-a fish caught by fleet *v* in year *t*
$D(t)$	Total weight of fish discarded fish in year *t*
$F(t)$	Instantaneous fully-selected fishing mortality rate in year *t*
$F_a(t)$	Total fishing mortality rate for age-a fish in year *t*
$F_{a,v}(t)$	Fishing mortality rate on age-a fish by fleet *v* in year *t*
$F_B(t)$	Instantaneous fishing mortality weighted by mean biomass in year *t*
$H(t)$	Harvest index for year *t* If $H(t)$= 1, then harvest is based on a landings quota $Q(t)$ in metric tons Else if $H(t)$= 0, then harvest is based on a fishing mortality rate $F(t)$
$L_v(t)$	Total weight of fish landed by fleet *v* in year *t*
$M_a(t)$	Instantaneous natural mortality rate of age-a fish in year *t*
$N_a(t)$	Number of age-a fish alive on January 1^{st} of year *t*
N_M	Number of recruitment models used in the projection
$d_{a,v}(t)$	Proportion of age-a fish caught by fleet *v* and discarded in year *t*
$S_{a,v}(t)$	Fishery selectivity for age-a fish by fleet *v* in year *t*
$P_{R,i}(t)$	Probability that the i^{th} recruitment model is applied in year *t*
$p_a(t)$	Fraction of age-a fish that are sexually mature in year *t*
$\varphi(t)$	Fraction of total mortality occurring prior to spawning in year *t*
$Q_v(t)$	Landings quota (mt) for fleet *v* in year *t*
$R(t)$	Recruitment (number of age-1 fish on January 1^{st}) in year *t*
$w_{P,a}(t)$	Average population weight of an age-a fish on January 1^{st} in year *t*
$w_{L,a,v}(t)$	Average landed (catch) weight of an age-a fish by fleet *v* in year *t*
$w_{S,a}(t)$	Average spawning weight of an age-a fish in year *t*
$w_{MY,a}(t)$	Average mid-year weight of an age-a fish in year *t*
$w_{D,a,v}(t)$	Average weight of an age-a fish discarded by fleet *v* in year *t*
Y	Number of years in projection time horizon where *t* = 1, 2, ..., *Y*

Table 2. Table of AGEPRO input file keywords.

KEYWORD	PURPOSE
GENERAL	Input general model parameters
CASEID	Input title identifying model attributes
BOOTSTRAP	Input information for bootstrap numbers at age file
HARVEST	Input information for harvest intensity (*F* or *Q*) by fleet
RETROADJUST	Input information for retrospective bias adjustment
NATMORT	Input information for natural mortality rate (M) at age
BIOLOGICAL	Input information on seasonal spawning timing for *F* and *M*
MATURITY	Input information on maturity at age
STOCK_WEIGHT	Input information on stock weights (Jan 1^{st}) at age
SSB_WEIGHT	Input information on spawning biomass weights at age
MEAN_WEIGHT	Input information on mean weights at age
FISHERY	Input information on fishery selectivity at age by fleet
DISCARD	Input information on discard fraction of numbers at age
CATCH_WEIGHT	Input information on catch weights at age
DISC_WEIGHT	Input information on discard weights at age
RECRUIT	Input information on recruitment model
BOUNDS	Input bounds on simulated fish weights and natural mortality rates
OPTIONS	Input information on projection output

Table 2. Table of AGEPRO input file keywords, continued.

KEYWORD	PURPOSE
SCALE	Input information on scaling factors for biomass, recruitment, and stock size
PERC	Input information for setting a specific percentile for the distributions of outputs
REFPOINT	Input information for reference points
REBUILD	Input information for calculating F to rebuild spawning biomass
PSTAR	Input information for calculating TAC to produce P* which is the probability of overfishing in the target projection year

Table 3. Structure of an AGEPRO version 4.25 input file by keyword. Inputs are space delimited.

KEYWORD	INPUT VARIABLE
GENERAL	1. **NFyear** (I) – this is the first year of the projection 2. **NXYear** (I) – this is the last year of the projection 3. **NFAge** (I) – this is the first age in the population model 4. **NXAge** (I) – this is the plus-group age in the population model 5. **NSims** (I) – this is the number of simulations to conduct for each bootstrap replicate of initial population size 6. **NFleet** (I) – this is the number of fleets in the harvest model 7. **NRecModel** (I) – this is the number of recruitment submodels in the population model 8. **DiscFlag** (I) – this is a logical flag to indicate whether discards are included in the harvest model (1=true, 0=false) 9. **ISeed** (I) – this is a positive integer seed to initialize the random number generator
CASEID	1. **Model** (S) – this is a string that describes the projection model run
BOOTSTRAP	1. **NBoot** (I)- this is the number of bootstrap replicates of initial population size 2. **BootFac** (F) – this is the multiplicative factor to convert the relative bootstrap population numbers at age to absolute numbers at age 3. **BootFile** (S) – this is the name of the bootstrap filename including the file path
HARVEST	1. **HarvestIndex**[0:NYears-1] (F) – this is the harvest specification by year vector where an input of zero indicates an F-based harvest rate and any positive input indicates a quota-based harvest rate (that is, input=0 for F and input>0 for catch biomass) 2. **HarvestValue**[0:NYears-1][0:Nfleet-1] (F) – this is the harvest amount by year and fleet array where an input row is the set of annual F values or catches (in metric tons) depending on the harvest specification by year.

Table 3. Structure of an AGEPRO version 4.25 input file by keyword, continued.

KEYWORD	INPUT VARIABLE
RETROADJUST	1. **RetroAdjust**[0:NAges-1] (F) – this is the vector of age-specific numbers at age multipliers for an initial population size at age vector if retrospective bias adjustment is applied
NATMORT	1. **NatMortFlag** (I) – this is the logical flag that indicates if the average natural mortality rate at age vector is to be read from an existing data file (input=1) or not (input≠) 2. **NatMortTimeFlag** (I) – this is the logical flag that indicates if the average natural mortality rate at age vector is a time-varying array (input =1) ordered by year (row) and age (column); otherwise the average natural mortality rate at age vector does not vary by year 3. If (**NatMortFlag** = 1) then read **DataFiles**[*] (S) Else if (**NatMortTimeFlag** = 1) then Read **AvgNatMort**[0:NAges-1][0:NYears-1] (F) Else Read **AvgNatMort**[0:NAges-1][0] (F) This is the logic for the average natural mortality rate at age vector inputs 4. **NatMortErr**[0:NAges-1] (F) This is the vector of age-specific CVs for sampling the natural mortality rate at age vector with lognormal process error
BIOLOGICAL	1. **ZFracTimeFlag** (I) – this is the logical flag that indicates if the <u>within-year</u> <u>fractions</u> of <u>fishing</u> (**TF**) and <u>natural</u> (**TM**) <u>mortality</u> <u>that</u> <u>occur</u> <u>from</u> <u>January</u> <u>1st</u> <u>to</u> <u>the</u> <u>spawning</u> <u>season</u> are a time-varying array (input =1) or constant values (input≠1) where 0≤ **TF**≤1 and 0≤ **TM**≤1 . For example, if the spawning season begins in July and input=0 then **TF**=**TM**=½ 2. If (**ZFracTimeFlag** = 1) then read **TF**[0:NYears-1] (F) and read **TM**[0:NYears-1] (F) Else read **TF** (F) and read **TM** (F)

Table 3. Structure of an AGEPRO version 4.25 input file by keyword, continued.

KEYWORD	INPUT VARIABLE
MATURITY	1. **MaturityFlag** (I) – this is the logical flag that indicates if the average fraction mature at age vector is to be read from an existing data file (input =1) or not (input≠1) 2. **MaturityTimeFlag** (I) – this is the logical flag that indicates if the average fraction mature at age vector is a time-varying array (input =1) ordered by year (row) and age (column); otherwise the average fraction mature at age vector does not vary by year 3. If (**MaturityFlag** = 1) then read **DataFiles**[*] (S) Else if (**MaturityTimeFlag** = 1) then read **AvgMaturity** [0:NAges-1][0:NYears-1] (F) Else read **AvgMaturity**[0:NAges-1][0] (F)) – this is the logic for the average fraction mature at age vector inputs 4. **MaturityErr**[0:NAges-1] (F) – this is the vector of age-specific CVs for sampling the fraction mature at age vector with lognormal process error
STOCK_WEIGHT	1. **StockWtFlag** (I) – this is the logical flag that indicates if the average stock weight at age vector is to be read from an existing data file (input =1) or not (input≠1) 2. **StockWtTimeFlag** (I) – this is the logical flag that indicates if the average stock weight at age vector is a time-varying array (input =1) ordered by year (row) and age (column); otherwise the average stock weight at age vector does not vary by year 3. If (**StockWtFlag** = 1) then read **DataFiles**[*] (S) Else if (**StockWtTimeFlag** = 1) then read **AvgStockWeight** [0:NAges-1][0:NYears-1] (F) Else read **AvgStockWeight** [0:NAges-1][0] (F) – this is the logic for the average stock weight at age vector inputs 4. **StockWtErr**[0:NAges-1] (F) – this is the vector of age-specific CVs for sampling the stock weight at age vector with lognormal process error

Table 3. Structure of an AGEPRO version 4.25 input file by keyword, continued.

KEYWORD	INPUT VARIABLE
SSB_WEIGHT	1. **SpawnWtFlag** (I) – this is the logical flag that indicates if the average spawning weight at age vector is to be read from an existing data file (input>0) or to be read from the input file (input=0) or to be set equal to the average stock weight at age vector (input=-1) 2. **SpawnWtTimeFlag** (I) – this is the logical flag that indicates if the average spawning weight at age vector is a time-varying array (input =1) ordered by year (row) and age (column); otherwise the average spawning weight at age vector does not vary by year 3. If (**SpawnWtFlag** >0) then read **DataFiles**[*] (S) Else if (**SpawnWtFlag** = -1) then set average spawning weight at age vector to equal the average stock weight at age vector Else if (**SpawnWtTimeFlag** = 1) then read **AvgSpawnWeight** [0:NAges-1][0:NYears-1] (F) Else read **AvgSpawnWeight** [0:NAges-1][0] (F) – this is the logic for the average spawning weight at age vector inputs 4. **SpawnWtErr**[0:NAges-1] (F) – this is the vector of age-specific CVs for sampling the spawning weight at age vector with lognormal process error
MEAN_WEIGHT	1. **MeanStockWtFlag** (I) – this is the logical flag that indicates if the average mean weight at age vector is to be read from an existing data file (input>0) or not (input=0) 2. **MeanStockWtTimeFlag** (I) – this is the logical flag that indicates if the average mean weight at age vector is a time-varying array (input=1) ordered by year (row) and age (column); otherwise the average mean weight at age vector does not vary by year 3. If (**MeanStockWtFlag** >0) then read **DataFiles**[*] (S) Else if (**MeanStockWtTimeFlag** = 0) then read **AvgMeanStockWeight** [0:NAges-1][0:NYears-1] (F) Else read **AvgMeanStockWeight** [0:NAges-1][0] (F) – this is the logic for the average mean weight at age vector inputs 4. **MeanStockWtErr**[0:NAges-1] (F) – this is the vector of age-specific CVs for sampling the mean weight at age vector with lognormal process error

Table 3. Structure of an AGEPRO version 4.25 input file by keyword, continued.

KEYWORD	INPUT VARIABLE
FISHERY	1. **FSelecFlag** (I) – this is the logical flag that indicates if the average fishery selectivity at age vectors by fleet are to be read from an existing data file (input=1) or not (input≠1) 2. **FSelecTimeFlag** (I) – this is the logical flag that indicates if the average fishery selectivity at age vectors by fleet are a time-varying array (input=1) ordered by fleet (index 1), year (index 2), and age (index 3); otherwise the average fishery selectivity at age vectors by fleet do not vary by year 3. If (**FSelecFlag** = 1) then read **DataFiles**[*] (S) Else if (**FSelecTimeFlag** = 1) then read **AvgFSelec**[0:NAges-1][0:NYears-1][0:NFleets-1] (F) Else read **AvgFSelec**[0:NAges-1][0][0:NFleets-1] (F) – this is the logic for the average fishery selectivity at age vectors by fleet inputs 4. **FSelecErr**[0:NAges-1][0:NFleets-1] (F) – this is the array of age-specific and fleet-specific CVs for sampling the fishery selectivity at age vectors by fleet with lognormal process error
DISCARD	1. **DiscFracFlag** (I) – this is the logical flag that indicates if the average discard fraction at age vectors by fleet are to be read from an existing data file (input=1) or not (input≠1) 2. **DiscFracTimeFlag** (I) – this is the logical flag that indicates if the average discard fraction at age vectors by fleet are a time-varying array (input =1) ordered by fleet (index 1), year (index 2), and age (index 3); otherwise the average discard fraction at age vectors by fleet do not vary by year 3. If (**DiscFracFlag** = 1) then read **DataFiles**[*] (S) Else if (**DiscFracTimeFlag** = 1) then read **AvgDiscFrac** [0:NAges-1][0:NYears-1][0:NFleets-1] (F) Else read **AvgDiscFrac**[0:NAges-1][0][0:NFleets-1] (F) – this is the logic for the average discard fraction at age vectors by fleet inputs 4. **DiscFracErr**[0:NAges-1][0:NFleets-1] (F) – this is the array of age-specific and fleet-specific CVs for sampling the discard fraction at age vectors by fleet with lognormal process error

Table 3. Structure of an AGEPRO version 4.25 input file by keyword, continued.

KEYWORD	INPUT VARIABLE
CATCH_WEIGHT	1. **CatchWtFlag** (I) – this is the logical flag that indicates if the average catch weight at age vectors by fleet are to be read from an existing data file (input>0) or to be read from the input file (input=0) or to be set equal to the average stock weight at age vector (input=-1) or to be set equal to the average spawning weight at age vector (input=-2) or to be set equal to the average mean weight at age vector (input=-3) 2. **CatchWtTimeFlag** (I) – this is the logical flag that indicates if the average catch weight at age vectors by fleet are a time-varying array (input =1) ordered by fleet (index 1), year (index 2), and age (index 3); otherwise the average catch weight at age vectors by fleet do not vary by year 3. If (**CatchWtFlag** >0) then read **DataFiles**[*] (S) Else if (**CatchWtFlag** = -1) then set average catch weight at age vector to equal the average stock weight at age vector Else if (**CatchWtFlag** = -2) then set average catch weight at age vector to equal the average spawning weight at age vector Else if (**CatchWtFlag** = -3) then set average catch weight at age vector to equal the average mean weight at age vector Else if (**CatchWtTimeFlag** = 0) then read **AvgCatchWeight** [0:NAges-1][0:NYears-1][0:NFleets-1] (F) Else read **AvgCatchWeight**[0:NAges-1][0][0:NFleets-1] (F) – this is the logic for the average catch weight at age vector inputs 4. **CatchWtErr**[0:NAges-1][0:NFleets-1] (F) – this is the array of age-specific and fleet-specific CVs for sampling the catch weight at age vectors by fleet with lognormal process error

Table 3. Structure of an AGEPRO version 4.25 input file by keyword, continued.

KEYWORD	INPUT VARIABLE
DISC_WEIGHT	1. **DiscWtFlag** (I) – this is the logical flag that indicates if the average discard weight at age vectors by fleet are to be read from an existing data file (input>0) or to be read from the input file (inpu =0) or to be set equal to the average stock weight at age vector (input=-1) or to be set equal to the average spawning weight at age vector (input=-2) or to be set equal to the average mean weight at age vector (input=-3) or to be set equal to the average catch weight at age vector (input=-4) 2. **DiscWtTimeFlag** (I)) – this is the logical flag that indicates if the average discard weight at age vectors by fleet are a time-varying array (input =1) ordered by fleet (index 1), year (index 2), and age (index 3); otherwise the average discard weight at age vectors by fleet do not vary by year 3. If (**DiscWtFlag** = 1) then read **DataFiles**[*] (S) Else if (**DiscWtFlag** = -1) then set average discard weight at age vector to equal the average stock weight at age vector Else if (**DiscWtFlag** = -2) then set average discard weight at age vector to equal the average spawning weight at age vector Else if (**DiscWtFlag** = -3) then set average discard weight at age vector to equal the average mean weight at age vector Else if (**DiscWtFlag** = -4) then set average discard weight at age vector to equal the average catch weight at age vector Else if (**DiscWtTimeFlag** = 1) then read **AvgDiscWeight** [0:NAges-1][0:NYears-1][0:NFleets-1] (F) Else read **AvgDiscWeight**[0:NAges-1][0][0:NFleets-1] (F) – this is the logic for the average discard weight at age vector inputs 4. **DiscWtErr**[0:NAges-1][0:NFleets-1] (F) – this is the array of age-specific and fleet-specific CVs for sampling the discard weight at age vectors by fleet with lognormal process error

Table 3. Structure of an AGEPRO version 4.25 input file by keyword, continued.

KEYWORD	INPUT VARIABLE
RECRUIT	1. **RecFac** (F) – this is the multiplier to convert recruitment submodel units for recruitment to absolute numbers of fish 2. **SSBFac** (F) – this is the multiplier to convert recruitment submodel units for spawning biomass to absolute spawning weight of fish in kilograms 3. **MaxRecObs** (I) – this is the maximum number of recruitment observations for an empirical recruitment submodel (up to the maximum value of a long int, or about 2 billion array elements) 4. **RecruitType**[0:NRecModel-1] (I) – this is the vector of recruitment submodel types in the projection 5. **RecruitProb**[0:NYears-1][0:NRecModel-1] (F) – this is the array of recruitment submodel probabilities ordered by year (row) and submodel (column) with row sums equal to unity 6. For J=0 to (NRecModel – 1) Call **ReadRecruitModelInput**(J,[RecruitType[J]) – this is the set of function calls to read in the input data needed for each recruitment submodel in the order they are specified in **RecruitType** where the required input data for each submodel are listed in Table 4.
BOUNDS	1. **MaxWeight** (F) – this is the maximum value of an fish weight, noting that there is lognormal sampling variation for weight at age values 2. **MaxNatMort** (F) – this is the maximum natural mortality rate, noting that there is lognormal sampling variation for natural mortality at age values
PERC	**PercReportValue** (F) – this is the user-selected percentile for reporting the percentile of the projected distribution of the following by year: spawning stock biomass, stock biomass on January 1^{st}, mean biomass, combined catch biomass, landings, fishing mortality, and stock numbers at age
REFPOINT	1. **SSBThresh** (F) – this is the spawning biomass threshold expressed in biomass output units 2. **StockBioThresh** (F) – this is the stock biomass threshold expressed in biomass output units 3. **MeanBioThresh** (F) – this is the mean biomass threshold expressed in biomass output units 4. **FMortThresh** (F) – this is the fishing mortality threshold

Table 3. Structure of an AGEPRO version 4.25 input file by keyword, continued.

KEYWORD	INPUT VARIABLE
OPTIONS	1. **AuxliaryOutputFlag** (I) – this is the logical flag to output stock summary information • I=0: No stock summary and auxiliary files 2-10 are output • I=1. Stock summary and auxiliary files 1-10 are output • I=2. No stock summary and no auxiliary files are output • I=3. Stock summary and no auxiliary files are output • I=4: Stock summary and auxiliary files 2-10 are output 2. **DataFlag** (I) – this is the logical flag to output population and fishery processes simulated with lognormal process error to auxiliary data output files **ExportRFlag** (I) – this is the logical flag to output projection results to an R dataframe
SCALE	1. **scalebio** (F) – the output units of biomass expressed in thousand metric tons 2. **scalerec** (F) – the output units of recruitment numbers 3. **scalestk** (F) – the output units of stock size numbers

Table 3. Structure of an AGEPRO version 4.25 input file by keyword, continued.

KEYWORD	INPUT VARIABLE
REBUILD	1. **TargetYear** (I) – this is the user-selected target year for rebuilding to the target value 2. **TargetValue** (F) – this is the target biomass value in units of thousands of metric tons 3. **TargetType** (I) – this is the index for the type of population biomass as the target where index=0 is spawning stock biomass, index=1 is stock biomass on January 1st, else target is mean biomass 1. **TargetPercent** (F) – this is the percent frequency of achieving the target value by the target year where the percent frequency is a value between 0 (indicating zero chance of achieving target) and 100 (indicating 100 percent chance of achieving target).
PSTAR	1. **KPStar** (I) – this is the user-selected number of PStar values to be evaluated in the target year 2. **PStar**[0:KPStar-1] (F) – these are the PStar values to evaluate where PStar is the probability of exceeding the overfishing level 3. **PStarF** (F) – this is the fishing mortality rate that defines the overfishing level 4. **TargetYear** (I) – this is the user-selected target year for which the total annual catch to produce the user-selected PStar values is calculated

Table 4. Required input data for AGEPRO recruitment models, where spawning biomass and recruitment inputs are measured in units of the conversion factors SSBFac and RecFac respectively, which typically have units of SSBFac=RecFac=1000.

Model Number	Recruitment Model	Recruitment Model Input Description
1	**Markov Matrix**	Input the number of recruitment states: K On the next line input the recruitment values: $R_1, R_2, \ldots, R_K$ On the next line input number of spawning biomass states: J On the next line input $J-1$ cut points: $B_{S,1}, B_{S,2}, \ldots, B_{S,J-1}$ On the next J lines input the conditional recruitment probabilities for the spawning biomass states: $p_{1,1}, p_{1,2}, \ldots, p_{1,K}$ $p_{2,1}, p_{2,2}, \ldots, p_{2,K}$ $\vdots$ $p_{J,1}, p_{J,2}, \ldots, p_{J,K}$
2	**Empirical Recruits Per Spawning Biomass Distribution**	Input the number of stock recruitment data points:T On the next line input the recruitments: $R_1, R_2, \ldots, R_T$ On the next line input the spawning biomasses: $B_{S,1}, B_{S,2}, \ldots, B_{S,T}$
3	**Empirical Recruitment Distribution**	Input the number of recruitment data points:T On the next line input the recruitments: $R_1, R_2, \ldots, R_T$
4	**Two-Stage Empirical Recruits Per Spawning Biomass Distribution**	Input the number of low and high recruits per spawning biomass data points:T_{Low}, T_{High} On the next line input the cutoff level of spawning biomass:B_S^* On the next line input the low state recruitments: $R_1, R_2, \ldots, R_{T_{Low}}$ On the next line input the low state spawning biomasses: $B_{S,1}, B_{S,2}, \ldots, B_{S,T_{Low}}$ On the next line input the high state recruitments: $R_1, R_2, \ldots, R_{T_{High}}$ On the next line input the high state spawning biomasses: $B_{S,1}, B_{S,2}, \ldots, B_{S,T_{High}}$

Table 4. Required input data for AGEPRO recruitment models, continued.

Model Number	Recruitment Model	Recruitment Model Input Description
5	**Beverton-Holt Curve with Lognormal Error**	Input the stock-recruitment parameters: $\alpha, \beta, \sigma_w^2$
6	**Ricker Curve with Lognormal Error**	Input the stock-recruitment parameters: $\alpha, \beta, \sigma_w^2$
7	**Shepherd Curve with Lognormal Error**	Input the stock-recruitment parameters: $\alpha, \beta, k, \sigma_w^2$
8	**Lognormal Distribution**	Input the log-scale mean and standard deviation: $\mu_{log(r)}, \sigma_{log(r)}$
10	**Beverton-Holt Curve with Autocorrelated Lognormal Error**	Input the stock-recruitment parameters: $\alpha, \beta, \sigma_w^2$ On the next line input the autoregressive parameters: ϕ, ε_0
11	**Ricker Curve with Autocorrelated Lognormal Error**	Input the stock-recruitment parameters: $\alpha, \beta, \sigma_w^2$ On the next line input the autoregressive parameters: ϕ, ε_0
12	**Shepherd Curve with Autocorrelated Lognormal Error**	Input the stock-recruitment parameters: $\alpha, \beta, k, \sigma_w^2$ On the next line input the autoregressive parameters: ϕ, ε_0

Table 4. Required input data for AGEPRO recruitment models, continued.

Model Number	Recruitment Model	Recruitment Model Input Description
13	**Autocorrelated Lognormal Distribution**	Input the log-scale mean and standard deviation: $\mu_{log(r)}, \sigma_{log(r)}$ On the next line input the autoregressive parameters: ϕ, ε_0
14	**Empirical Cumulative Distribution Function of Recruitment**	Input the number of recruitment data points:T On the next line input the recruitments: $R_1, R_2, \ldots, R_T$
15	**Two-Stage Empirical Cumulative Distribution Function of Recruitment**	Input the number of low and high recruits per spawning biomass data points:T_{Low}, T_{High} On the next line input the cutoff level of spawning biomass:B_S^* On the next line input the low state recruitments: $R_1, R_2, \ldots, R_{T_{Low}}$ On the next line input the high state recruitments: $R_1, R_2, \ldots, R_{T_{High}}$
16	**Linear Recruits Per Spawning Biomass Predictor with Normal Error**	Input the number of predictors:N_p On the next line input the intercept coefficient:β_0 On the next line input the slope coefficient for each predictor: $\beta_1, \beta_2, \ldots, \beta_{N_p}$ On the next line input the error variance:σ^2 On the next N_p lines input the expected value of the predictor through the projection time horizon: $X_1(1), \ldots, X_1(Y)$ $X_2(1), \ldots, X_2(Y)$ $\vdots$ $X_p(1), \ldots, X_p(Y)$

Table 4. Required input data for AGEPRO recruitment models, continued.

Model Number	Recruitment Model	Recruitment Model Input Description
17	**Linear Recruits Per Spawning Biomass Predictor with Lognormal Error**	Input the number of predictors: N_p On the next line input the intercept: β_0 On the next line input the linear coefficient for each predictor: $\beta_1, \beta_2, \ldots, \beta_{N_p}$ On the next line input the log-scale error variance: σ^2 And on the next N_p lines input the expected predictor values over the forecast time horizon 1,…,*Y*: $\begin{matrix} X_1(1) & X_1(2) & \ldots & X_1(Y) \\ X_2(1) & X_2(2) & \ldots & X_2(Y) \\ \vdots & \vdots & \vdots & \vdots \\ X_p(1) & X_p(2) & \ldots & X_p(Y) \end{matrix}$
18	**Linear Recruitment Predictor with Normal Error**	Input the number of predictors: N_p On the next line input the intercept: β_0 On the next line input the linear coefficient for each predictor: $\beta_1, \beta_2, \ldots, \beta_{N_p}$ On the next line input the error variance: σ^2 And on the next N_p lines input the expected predictor values over the forecast time horizon 1,…,*Y*: $\begin{matrix} X_1(1) & X_1(2) & \ldots & X_1(Y) \\ X_2(1) & X_2(2) & \ldots & X_2(Y) \\ \vdots & \vdots & \vdots & \vdots \\ X_p(1) & X_p(2) & \ldots & X_p(Y) \end{matrix}$

Table 4. Required input data for AGEPRO recruitment models, continued.

Model Number	Recruitment Model	Recruitment Model Input Description
19	**Loglinear Recruitment Predictor with Lognormal Error**	Input the number of predictors: N_p On the next line input the intercept: β_0 On the next line input the linear coefficient for each predictor: $\beta_1, \beta_2, \ldots, \beta_{N_p}$ On the next line input the log-scale error variance: σ^2 And on the next N_p lines input the expected predictor values over the forecast time horizon 1,…,Y: $\begin{matrix} X_1(1) & X_1(2) & \ldots & X_1(Y) \\ X_2(1) & X_2(2) & \ldots & X_2(Y) \\ \vdots & \vdots & \vdots & \vdots \\ X_p(1) & X_p(2) & \ldots & X_p(Y) \end{matrix}$
20	**Fixed Recruitment**	Input the number of recruitment data points:Y On the next line input the recruitments: $R_1, R_2, \ldots, R_Y$
21	**Empirical Cumulative Distribution Function of Recruitment with Linear Decline to Zero**	Input the number of observed recruitment values: T On the next line input the recruitment values: $R_1, R_2, \ldots, R_T$ And on the next line input spawning biomass threshold: B_S^*

Figure 1. Flowchart for AGEPRO

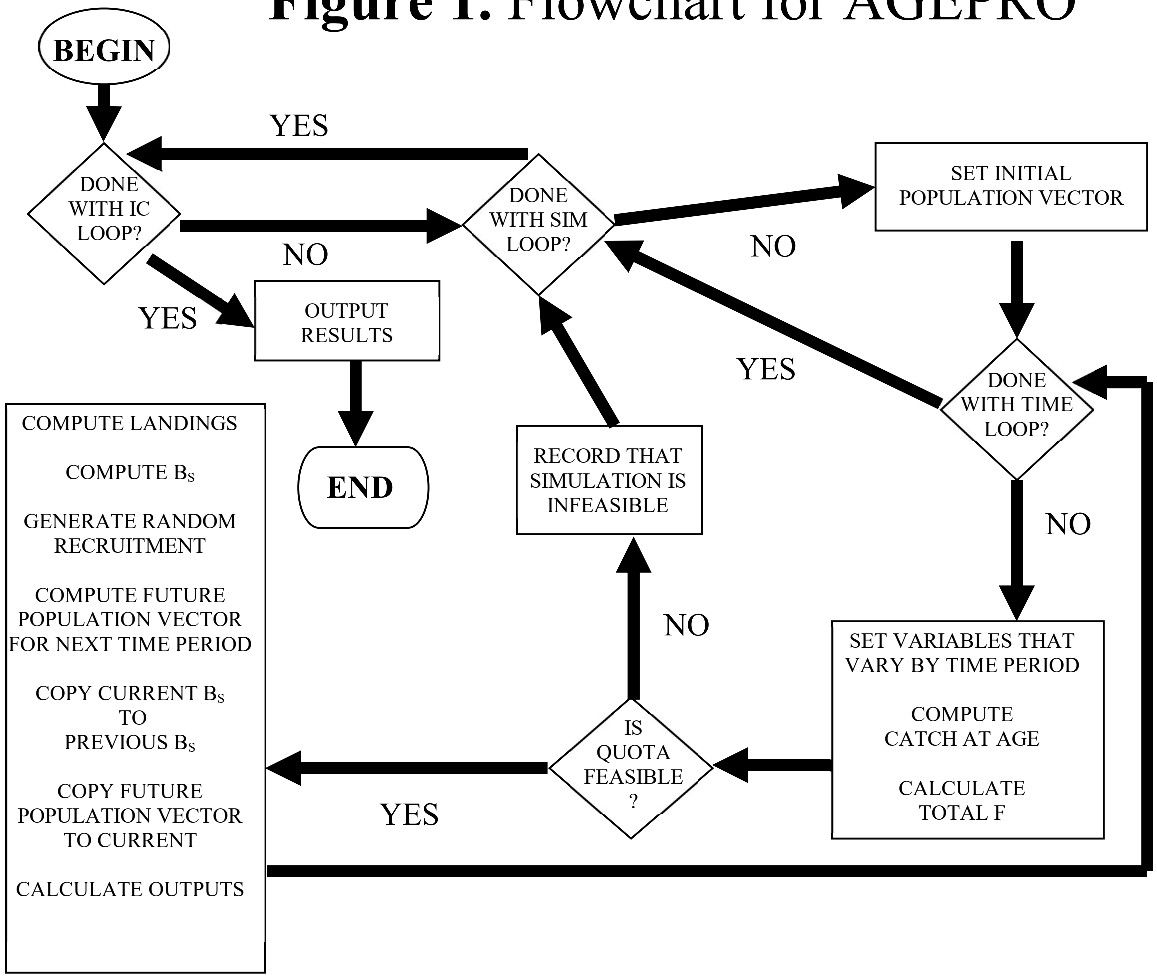
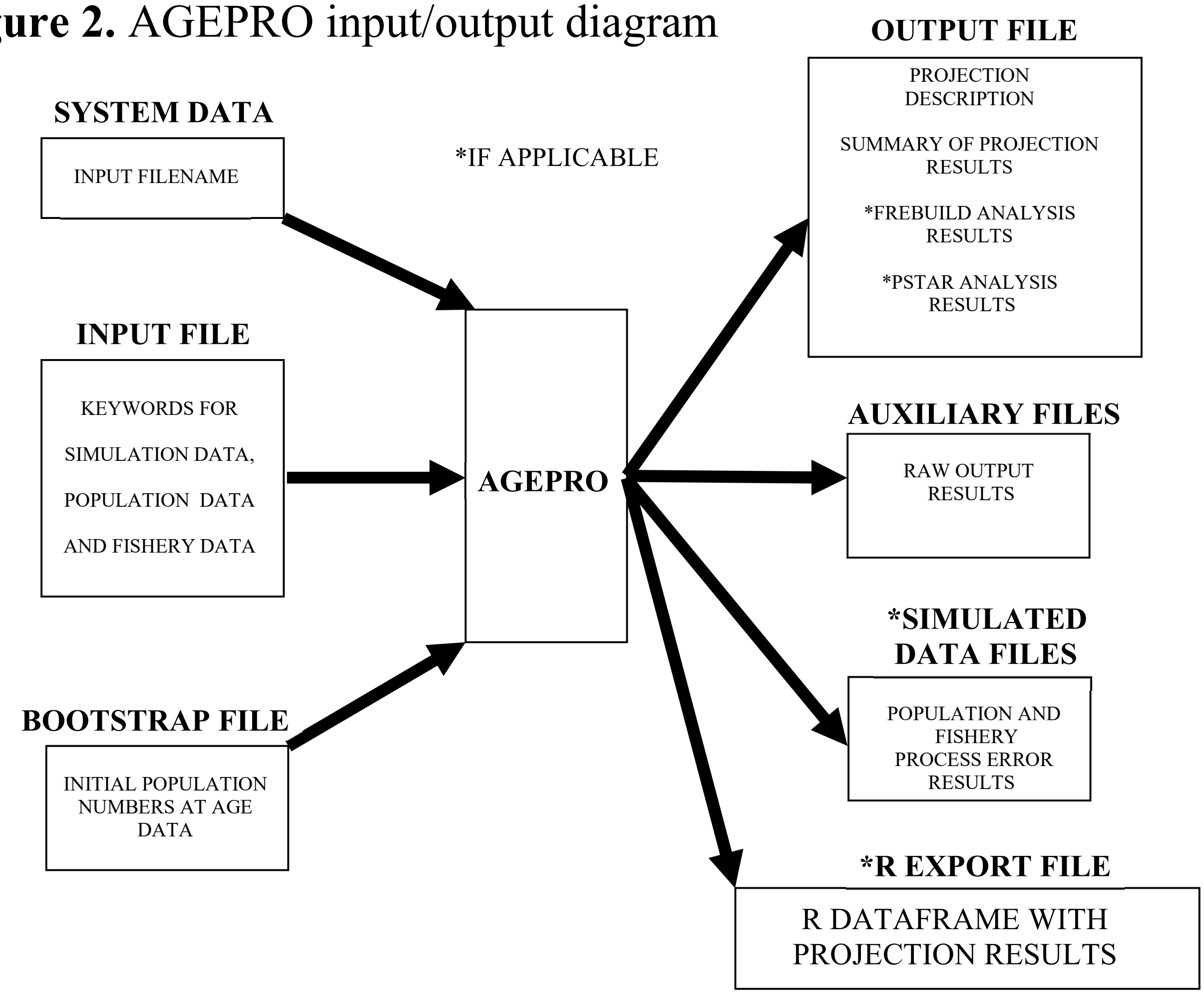


Figure 2. AGEPRO input/output diagram



Appendix

Example 1 Input File

```
AGEPRO VERSION 4.25
[CASEID]
REDFISH - RECRUITMENT MODEL 14
[GENERAL]
2004  2009  1  26  100  2  1  0  49667890
[BOOTSTRAP]
1000  1000
Example1.BSN
[STOCK_WEIGHT]
0  1
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001
[SSB_WEIGHT]
0  1
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001
[MEAN_WEIGHT]
0  1
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001
[CATCH_WEIGHT]
0  1
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
```

```
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.01  0.02  0.059  0.099  0.145  0.178  0.201  0.25  0.272  0.31  0.348  0.391  0.423  0.429  0.463  0.495  0.503  0.508  0.548  0.558
0.565  0.581  0.595  0.583  0.582  0.637
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001
[NATMORT]
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0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05
0.05  0.05
0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05
0.05  0.05
0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05
0.05  0.05
0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05
0.05  0.05
0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05
0.05  0.05
0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05
0.05  0.05
0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
[BIOLOGICAL]
0
0.4
0.4
[MATURITY]
0  1
0.01  0.02  0.05  0.15  0.36  0.64  0.85  0.95  0.98  0.99  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0.01  0.02  0.05  0.15  0.36  0.64  0.85  0.95  0.98  0.99  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0.01  0.02  0.05  0.15  0.36  0.64  0.85  0.95  0.98  0.99  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0.01  0.02  0.05  0.15  0.36  0.64  0.85  0.95  0.98  0.99  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0.01  0.02  0.05  0.15  0.36  0.64  0.85  0.95  0.98  0.99  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0.01  0.02  0.05  0.15  0.36  0.64  0.85  0.95  0.98  0.99  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001
[FISHERY]
0  1
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  0.783  0.656  0.522  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  0.783  0.656  0.522  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  0.783  0.656  0.522  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  0.783  0.656  0.522  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  0.783  0.656  0.522  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0  0.002  0.011  0.054  0.223  0.522  0.656  0.783  1  1  0.783  0.656  0.522  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
0.001  0.001  0.001  0.001  0.001  0.001  0.001
[RECRUIT]
```

```
1000000  1  75
14
1
1
1
1
1
1
53
73.5939  78.1845  70.6004  62.1267  66.0886  69.9814  49.9445  70.4022  42.6731  85.2977  48.2887  98.1364  76.867  33.8211
7.8195  4.3288  2.6275  2.7917  4.2174  249.227  6.5051  2.5329  1.9038  1.7011  1.5596  2.2002  52.7585  2.4754  2.8037  10.179
21.2349  8.6637  20.0313  11.1925  5.0913  4.3675  28.9894  51.3917  8.7334  35.7165  327.489  73.3318  35.0047  22.4337  24.9481
32.1726  34.4703  29.245  81.7098  30.5807  25.3895  26.28  30.1793
[HARVEST]
0  1  0  0  0  0
0.00239  350  0.01  0.01  0.01  0.01
0.00239  350  0.02  0.02  0.02  0.02
[REFPOINT]
236700  0  0  0.04
[OPTIONS]
3  0  1
```

Example 2 Input File

```
AGEPRO VERSION 4.25
[CASEID]
GoM haddock ASAP_final (1977-2011 recruitment)
[GENERAL]
2014  2020  1  9  10  1  1  0  854236
[BOOTSTRAP]
1000  1000
Example2.BSN
[STOCK_WEIGHT]
0  0
0.15  0.4  0.71  1  1.24  1.43  1.59  1.82  2.04
0.14  0.13  0.07  0.05  0.03  0.03  0.08  0.03  0.04
[SSB_WEIGHT]
-1  0
[MEAN_WEIGHT]
0  0
0.3  0.6  0.89  1.17  1.4  1.55  1.7  1.96  2.04
0.14  0.11  0.11  0.06  0.05  0.05  0.05  0.07  0.04
[CATCH_WEIGHT]
-3  0
[NATMORT]
0  0
0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
[BIOLOGICAL]
0
0.25
0.25
[MATURITY]
0  0
0.04  0.28  0.81  0.98  1  1  1  1  1
0.23  0.08  0.02  0.001  0.001  0.001  0.001  0.001  0.001
[FISHERY]
0  0
0  0.05  0.19  0.3  0.52  0.69  0.82  1  0.83
0.36  0.19  0.14  0.15  0.13  0.13  0.12  0.001  0.16
[RECRUIT]
1000  1000  50
14
1
1
1
1
1
1
1
35
5997  1476  6048  6435  4612  774  2445  1043  282  265  134  443  187  244  267  711  1318  2903  2540  1080  2179  2276  13429
2547  1121  1216  219  6281  386  1118  1218  215  301  966  6659
[HARVEST]
1  0  0  0  2  0  0
500  0.2  0.2  0.2  500  0.2  0.2
[PSTAR]
5
0.1  0.2  0.3  0.4  0.5
0.35
2018
[BOUNDS]
10  0.6
[OPTIONS]
2  0  0
[SCALE]
1000  1000  1000
[PERC]
90
```

Example 3 Input File

```
AGEPRO VERSION 4.25
[CASEID]
GoM haddock ASAP_final FREBUILD Projection
[GENERAL]
2014  2020  1  9  10  1  1  0  30076
[BOOTSTRAP]
1000  1000
Example3.BSN
[STOCK_WEIGHT]
0  0
0.15  0.4  0.71  1  1.24  1.43  1.59  1.82  2.04
0.14  0.13  0.07  0.05  0.03  0.03  0.08  0.03  0.04
[SSB_WEIGHT]
-1  0
[MEAN_WEIGHT]
0  0
0.3  0.6  0.89  1.17  1.4  1.55  1.7  1.96  2.04
0.14  0.11  0.11  0.06  0.05  0.05  0.05  0.07  0.04
[CATCH_WEIGHT]
-3  0
[NATMORT]
0  0
0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
[BIOLOGICAL]
0
0.25
0.25
[MATURITY]
0  0
0.04  0.28  0.81  0.98  1  1  1  1  1
0.23  0.08  0.02  0.001  0.001  0.001  0.001  0.001  0.001
[FISHERY]
0  0
0  0.05  0.19  0.3  0.52  0.69  0.82  1  0.83
0.36  0.19  0.14  0.15  0.13  0.13  0.12  0.001  0.16
[RECRUIT]
1000  1000  50
14
1
1
1
1
1
1
1
35
5997  1476  6048  6435  4612  774  2445  1043  282  265  134  443  187  244  267  711  1318  2903  2540  1080  2179  2276  13429
2547  1121  1216  219  6281  386  1118  1218  215  301  966  6659
[HARVEST]
1  0  0  0  0  0  0
500  0.3  0.3  0.3  0.3  0.3  0.3
[REBUILD]
2020  11000  0  75
[BOUNDS]
10  0.6
[OPTIONS]
2  0  0
[SCALE]
1000  1000  1000
[PERC]
90
```