Northwest Atlantic Fisheries Organization

Serial No. N4325 NAFO SCR Doc. 00/69

SCIENTIFIC COUNCIL MEETING – SEPTEMBER 2000
Workshop on Assessment Methods

Fisheries Assessment Compilation Toolbox (FACT)

1. ADAPT/VPA

Outlines and Data Sets

by

R.K. Mayo

National Marine Fisheries Service, Northeast Fisheries Science Center
Woods Hole, Massachusetts 02543 USA

Abstract

FACT is the Fishery Assessment Compilation Toolbox and the Woods Hole Assessment Toolbox's successor. Several existing assessment programs have been added to FACT making it a powerful and user-friendly tool. The assessment programs previously existed in a DOS or UNIX environment. These programs now have a user-friendly interface that makes editing of inputs and analyzing data easier, and completion of assessments more intuitive.

ADAPT is an age-structured, adaptable framework for estimating historical stock sizes of an exploited population. It is not a rigidly defined model in the mathematical sense, but rather a flexible set of modular tools designed to integrate data that may contain useful information on population size. The statistical basis of the ADAPTive approach is to minimize the discrepancy between observation of state variables and their predicted values. The observed state variables are usually (but are not limited to) age-specific indices of population size, e.g. from commercial catch-effort data, research surveys, mark-recapture experiments, etc. The predicted values are a function of a vector of estimated population size (age- specific) and catchability parameters.

This document shows how to run Adapt/VPA using a sample input file to complete a VPA. A description of the various files containing the VPA results is given. Details on the completion of a set of bootstrap analyses are also provided, and a description of the various files containing the bootstrap results is given.

Introduction

The overall purpose of FACT is to develop a set of standard tools for scientists to use for stock assessment. There is a growing need for a set of standardized and verified software for conducting stock assessments. The toolbox allows analysts to use a variety of assessment models to select options and produce diagnostics appropriate to a particular methodology. A suite of programs has been developed which includes modules for data input, formatting and error checking, and exploratory data analysis for a variety of assessment approaches.

The individual models of the toolbox were stand-alone, DOS or Unix based components which were recompiled into dynamic link libraries and integrated with a Windows interface. At present the available models include Virtual Population Analysis (VPA) with retrospective and bootstrapping capabilities (ADAPT), Age Projection (AGEPRO), Yield per Recruit and Spawning Biomass per Recruit, and A Stock-Production model Including Covariates (ASPIC) with projection, and Precautionary Approach software. A comprehensive on-line help is also available with FACT.

In this Workshop we will use two of the modules, ADAPT and AGEPRO. This document describes the use of the ADAPT module.

ADAPT

This module is the VPA implementation using the ADAPT approach towards minimizing sums of squares in a specified objective function. In ADAPT, there is a calibration block and an estimation block.

The calibration block is the set of indices x ages which are used to 'calibrate' the VPA terminal populations. A value of q is estimated for each index in the calibration block.

The estimation block is the set of ages for which you are estimating a terminal population stock size. In ADAPT, these are considered as survivors at the end (December 31) of the terminal year of the catch at age matrix, or at the beginning (January 1) of the year following the terminal year.

Input

All of the Workshop example data files for FACT are in: **C:\Workshop\Fact**

The ADAPT module requires the following input:

Catch-at-age
Mean catch weights-at-age
Mean stock weights-at-age
Tuning indices
Natural mortality
Maturation ogive

There are also several initialization specifications to be set before the VPA can run.

All of these data are in a single example file: **gmcod2000_base.inp**

This file can be imported directly into the ADAPT module using the File dialog box.
The VPA will run using all of the data as the default. You may also wish to change the indices depending on trends in the residuals.

Diagnostics

1. In addition to the residuals, one can look for a retrospective pattern in the estimates of F, stock size-at-age, and SSB. The retrospective may be selected from the Diagnostics dialog box.

2. The final formulation of the VPA may be run through a bootstrap procedure in which a normalized residual is drawn at random from the pool, and subtracted from an observed normalized survey index. This is done for each index in the calibration block. Generally, between 500 and 1,000 bootstrap runs are performed. This may take time, so 100 is recommended for the workshop.

Output

After the VPA has run successfully, formatted output will be written by default to a file based on the name of the input file, in this case: **gmcod2000_base.2.** This file should be brought into a word processor for viewing and printing. If a Retrospective Analysis has been selected, the results will be appended to the end of this file.

An ASCII 'Flat File' may also be output as an option. This file contains VPA results and residuals selected by the user. This file should be brought into a spreadsheet for further analysis, tabulation, and plotting.

After the Bootstrap procedure has run successfully, formatted output containing a summary of all bootstrapped variables will be written to a file based on the name of the input file, in this case: **gmcod2000_base.2boot**. This file should also be brought into a word processor for viewing and printing.

The Bootstrap procedure also produces 6 'data files' in free format containing all of the bootstrap results, in this case:

gmcod2000_base.2bootF	Fully recruited F in terminal year of the VPA
gmcod2000_base.2bootN	Estimated stock sizes at age at the end of the terminal year
gmcod2000_base.2bootSSB	Spawning Stock Biomass in all years of the VPA
gmcod2000_base.2bootMB	Mean Stock Biomass in the terminal year of the VPA
gmcod2000_base.2bootJB	Beginning-year Biomass in the terminal year of the VPA
gmcod2000_base.2bootBWF	Biomass-weighted F in the terminal year of the VPA

These files may be brought into a spreadsheet for further analysis, tabulation, and plotting. The file, **gmcod2000_base.2bootN** is used as input for the forward projection program, AGEPRO. The file, **gmcod2000_base.2bootSSB,** may also be required, depending on the recruitment generation model selected in AGEPRO.

VPA Introduction

Virtual Population Analysis (VPA) Method

ADAPT is an age-structured, adaptable framework of estimating historical stock sizes of an exploited population. It is not a rigidly defined model in the mathematical sense, but rather a flexible set of modular tools designed to integrate data that may contain useful information on population size.

The statistical basis of the ADAPTive approach is to minimize the discrepancy between observation of state variables and their predicted values. The observed state variables are usually (but are not limited to) age-specific indices of population size, e.g. from commercial catch-effort data, research surveys, mark-recapture experiments, etc. The predicted values are a function of a vector of estimated population size (age- specific) and catchability parameters. Sequential population analysis equations (Gulland's (MS 1965) VPA) and nonlinear least squares objective functions are employed to minimized the discrepancies.

The appellation ADAPT was introduced by Gavaris (MS 1988). However, the foundation of the method was developed over the preceding decade under an umbrella of research generally referred to as VPA tuning. Although not generally recognized, Parks (1976) was the first to tune a VPA using auxiliary data and a least squares objective function. He tuned VPA back-calculated fishing mortality rates (Fs) to Fs derived independently from tagging experiments. Gray (MS 1977) suggested a least squares approach to estimate mortality rates (both F and M) using a commercial catch-per-unit-effort (CPUE) index of abundance as auxiliary data.

Doubleday (1981) used age-specific research survey indices of abundance as auxiliary data to estimate survivors in the terminal year for each cohort. This appears to have been the first attempt to utilize multiple indices of abundance in a least squares tuning procedure.

Parrack (1986) expanded upon Doubleday's work by integrating indices of abundance from widely diverse sources into the least squares objective function. His formulation allowed indices from commercial fisheries, research surveys, larval surveys, etc. Indices could be either age-specific or represent several ageclasses. Indices could be expressed in either population number or biomass. Indices were related to population size either linearly or through a power function. Variance estimates were made assuming linearity at the optimal solution. He also recognized that not all indices are of equal value in measuring population abundance. Some indices will always be inherently more variable than others, and some may be biased. He introduced detailed examination of residuals and correlation statistics as an acceptance/rejection filter that each index needed to pass through in order to be used in the final tuning. The tuning procedure described by Parrack (1986) is the kernel of the method today known as ADAPT, both in terms of the objective function employed and in terms of the underlying philosophy.

The ADAPTive framework developed by Gavaris (MS 1988) generalized Parrack's procedure in several ways:

1. The adaptive aspects of the method were greatly enhanced through the use of a modular model structure and implementation in the APL programming language. This made it possible to modify the objective function significantly, as needed to rectify problems, even during the course of an assessment working group meeting.

2. A Marquardt algorithm (Bard 1974) was used for optimization of the least squares objective function. This allowed the simultaneous estimation of age-specific population sizes in the terminal year and catchabilities (Parrack estimated only the full F in the terminal year F vector). Additionally, the use of numerical derivatives in the Marquardt algorithm greatly

enhanced the adaptive philosophy by making objective function modifications easy to implement.

3. The more complete statistical model allowed for improved diagnostics. In addition to residual analysis, availability of the full variance-covariance matrix (assuming linearization at the optimal solution) provided variance estimates of all parameters, correlation among parameter estimates, and in general a better sense of which parameter were estimable from the available information.

The integration of many diverse sources of information focused attention on objective procedures to account for differences in the quality of information. Collie (1988) suggested that all indices of abundance should be included in the least squares objective function rather than employing Parrack's acceptance/rejective criteria. He recommended weighting the indices by the inverse of their variances. Vaughn et al. (1989) used Monte Carlo simulation to investigate the effect of weighting on the Fs estimated for bluefin tuna. They found that the F estimates were unbiased only when the indices were weighted. Conser and Powers (1990) developed a more general weighting procedure that allowed for two-way effects, i.e. index and year. Gavaris and Van Eeckhaute (MS 1991) employed a similar weighting procedure using an analysis of variance approach. Gassuikov (1990) suggested an alternative approach to weighting in ADAPT using the moving check procedure of Vapnik (1982).

The approach shows how to get started using Adapt/VPA using a sample input file to demonstrate a run. The book **Getting Started with Adapt/VPA**, includes a documented input file and output file. The *Explanation of the sample output file* provides links to explain the mathematical methods for the given results.

Input File

Output file

Demonstration with Sample Program

Adapt/VPA Model Overview

ADAPT is an age-structured, adaptable framework of estimating historical stock sizes of an exploited population. It is not a rigidly defined model in the mathematical sense, but rather a flexible set of modular tools designed to integrate all available data that may contain useful information on population size.

The statistical basis of the ADAPTive approach is to minimize the discrepancy between observation of state variables and their predicted values. The observed state variables are usually (but are not limited to) age-specific indices of population size, e.g. from commercial catch-effort data, research surveys, mark-recapture experiments, etc. The predicted values are a function of a vector of estimated population size (age- specific) and catchability parameters; and standard population dynamics equations (usually Gulland's (MS 1965) VPA). Nonlinear least squares objective functions are employed to minimize the discrepancies.

Model Overview

Adapt VPA model uses the application of a statistical technique, non-linear least squares, to determine the most appropriate estimate of the population matrix. Gavaris (1988) initially describes the Adapt objective function in general terms, as a minimization of the difference between observation of variables and the values of those variables predicted as functions of the population matrix (i.e. as function of the catch at age). That is,

$$\min \sum_{k}^{K} W_k (\theta_k - \hat{\theta}_k)^2$$

Where θ_k is the k_{th} observation

$\hat{\theta} = f(\Pi, \Omega)$ (user defined)

Π is the population matrix.

Ω are the other parameters which may be required.

W_k = weight for observed variable set k

K is the number of observations

In this implementation of ADAPT the error in the catch at age is assumed to be negligible relative to error in the indices of abundance. This appears to be reasonable. This above objective function has been used almost exclusively in the CAFSAC and NAFO assessments that have employed ADAPT (Gavaris, pers. Comm.)

Residual Sum of Squares

The objective function is employed in this ADAPT Version has the following form.

$$RSS = \sum_{k=1}^{K} \sum_{j=1}^{Y+1} \left[\frac{\ln I(k,j)}{\overline{I}(k)} - \ln \hat{I}(k,j) \right]^2 \bullet W(k,j)$$

where k is a general pointer that specifies a particular combination of age group index type, and tuning type. For example, k = 1 might specify the age 5 survey index from a fall survey tuned to Jan 1 abundance in year T+ 1.

K is the number of indices used, as selected by the user (**Available indices** tab).

j is the year and ranges from the first year to the terminal year plus one.

I(k, j) is the observed survey index with index number k in year j.

Î(k, j) is the predicted index with index number k in year j. This is calculated differently depending on the user's choice of tuning units (**Weight, Number**) and tuning date (**Jan1** and **Mean**) in the indices tab of the user's interface. See indices options.

W(k, j) is the weight associated with the observed indices at index number k in year j.

$\bar{I}(k)$ is the average over years for an index and is defined by the equation:

$$\bar{I}(k) = \frac{1}{Y+1} \sum_{j=1}^{Y+1} I(k,j)$$

When the index value is 0, that year is not included into the equation.

The Fitting procedure

The fitting procedure for terminal year + 1 population numbers (N) and catchabilities (q) in ADAPT/VPA uses the Marquardt algorithm. The algorithm uses initial guesses for stock size in year, Y + 1 and catchabilities to calculate fishing mortality (F) and population numbers using cohort equations. An iterative procedure is applied where q and N parameters are adjusted to minimize the objective function. Trial values for the parameters are adjusted at each calculation of the residual sum of squares (RSS) and compared to the previous RSS. The procedure is then repeated until the RSS is zero or effectively stops decreasing. For this ADAPT /VPA the successive RSS values are recalculated until the difference between consecutive RSS values are 0.00001 or 200 iterations have been performed. The parameters with the lowest RSS value are considered the "best fit" and are considered the most correct estimate.

One assumption in the ADAPT model is that the error in the indices is greater than the error in the catch at age. Since the statistical procedure does not deal with error in both variables, the model assumes error in the catch at age matrix, only in the survey indices. In addition, the model does not assume separability (F is represented as a fraction of catch to total stock size rather than assuming that F is a function of an age specific and year specific exploitation pattern.)

Statistical Weighting

The weights associated with each observations are not limited to the $1/\sigma^2$ type weights from research surveys, but include such weighting in addition to other weighting factors. Weighting in addition to log transformation fails to stabilize variance among the observations. Three types of weighting contribute multiplicatively to the weight assigned to each observation.

$$W(k,j) = \omega(k,j) \cdot \chi(k) \cdot \delta(j)$$

Where ω(k, j) are the $1/\sigma^2$ type weights from research surveys, multiplicative models using catch-effort data, or other exogenous information. See Omega weights.

χ(k) are weights designed to stabilize the variance across the various indices of abundance. See Chi weights.

δ(j) are weights designed to stabilize the variance across years to counteract the convergence properties of VPA. This process known as down-weighting allows the user to systematically assign linear, quadratic or cubic weights to a weighting function. See Downweighting.

The raw weights calculated by the above equation are normalized prior to use in the objective function, such that

$$\sum_{k}\sum_{j} W(k,j) = 1$$

For any given assessment, all of these weights, some subset of them, or none of them may be employed depending on the available data and the structure of the heteroscedasticity.

Omega weights - Inverse Variance Weights from Exogenous data (ω(k, j))

These weights are the type suggested by Gavaris (1988). Their use is intended to discount the effect of less reliable observations on the parameter estimates and to better satisfy the usual regression assumption of homogeneity of variance among all observations. When all observed indices of abundance are based on research surveys that have been carried out in a consistent manner, these weights alone may be sufficient to stabilize variance, both across years and across indices. However, when indices of abundance are derived from different data sources (e.g. research surveys and catch-effort data), it is unlikely that variances computed from the respective data sources will stabilize the variance across indices.

Omega weights are user-defined weights where each index is individually weighted. A value of 1 has no effect on the weighting. See Statistical weighting and VPA screen.

Chi weights - Inverse Variance weights from iterative re-weighting – X(**k)**

χ(k) are weights designed to stabilize the variance across the various indices of abundance.

Chi weights are set to 1 during the initial VPA run and are activated by **Reweighted VPA** of the **Run VPA** menu selection. The **Reweighting VPA** option can only be enabled after an initial VPA run. The output is appended to the VPA output file.

By invoking reweighting, the chi weights are calculated for each index and are used to re-weight the indices in the final residuals sum of squares (RSS) solution. The calculating procedure for weighting is as follows:

$$\chi(k) = \frac{\dfrac{\dfrac{1}{MSR(k)}}{\sum_{k=1}^{K}\dfrac{1}{MSR(k)}}}{\sum_{k=1}^{K}\left[\dfrac{\dfrac{1}{MSR(k)}}{\sum_{k=1}^{K}\dfrac{1}{MSR(k)}}\right]}$$

Where k is the index of indices and K is the number of indices used, as selected by the user (**Available indices tab**).

MSR is the mean square residual and is defined by the following equation:

$$MSR(k) = \frac{\sum_{j}^{Y+1} \mathrm{Res}(k,j)^2}{K_{Total} - [K + A_n]}$$

k is the index of indices, K_{Total} is the total number of non-zero indices and K is the number of catchabilities (q) estimated.

A_n is the number of ages the user enters into the **Ages to estimate** text box.

Res is the residual or the difference between the observed survey index I(k, j) and the predicted index Î(k,j). $\bar{I}(k)$ is the average over years for an index.

$$\mathrm{Re}\,s(k,j) = \frac{\ln I(k,j)}{\bar{I}(k)} - \ln \hat{I}(k,j)$$

See Residual Sum of Squares (RSS).

Down-weighting to counterbalance VPA convergence - δ(j)

Assuming that error in the catch-at-age estimates is negligible relative to error in the indices of abundance (Gavaris), the residuals from any VPA-based tuning method will tend to be smaller in the more recent years. In earlier years, where the VPA has converged, the differences between observed and predicted indices will not be affected greatly by various choices of the parameters in the terminal year. In contrast, the residuals from more recent years can be reduced appreciably by the tuning process. Adapt VPA has options to apply linear, quadratic or cubic weightings to the down-weighting function.

The following expression is used to calculate the down-weighting value.

$$\delta(j) = \left(1 - \left(\frac{Y+1-j}{Y_{DW}}\right)^{DW}\right)^{DW}$$

for years, j = 1 to Y+1

Y_{DW} is the number of years to down-weight (and DW specifies the type of down-weighting in which there are several options.

a. None or uniform = 0

b. Linear = 1

c. Biquadratic = 2

d. Tricubic = 3

ADAPT/VPA Input Data

File: gmcod2000_base.inp

```
Second FACT INPUT FILE    ADAPT/VPA
1
GoM Cod 2000 Base Run
0.0001 0.053 0.421 1 1 1
2 3 4 5 6
3000 3000 500 500 500
1
1982
0.01*21
FLAT
1*18
1000000
0
1
0
1*19
1,7 1,6 2,6 4,6
0.1667
0.1667
4 5 6
Backward
None or Uniform
 1982
```

Catch at Age

30	1380	1633	1143	633	69	230
0.001	866	2357	1058	638	422	155
4	446	1240	1500	437	194	136
0.001	407	1445	991	630	128	136
0.001	84	2164	813	250	177	95
2	216	595	1109	277	66	79
0.001	160	1443	953	406	43	30
0.001	337	1583	1454	449	81	56
0.001	205	3425	2064	430	157	99
0.001	344	934	4161	851	143	79
0.001	313	530	484	2018	202	84
0.001	76	1487	641	129	457	36
0.001	29	1016	1135	288	72	86
0.001	218	880	1153	194	12	34
0.001	65	584	1738	347	45	10
0.001	53	438	435	832	68	8
0.001	94	390	542	165	193	10
0.001	0.001	178	192	90	27	36

Weight at Age

0.9	1.156	1.664	2.764	4.77	6.739	11.33
0.9	1.164	1.66	2.475	3.778	5.962	9.755
0.9	1.159	1.67	2.721	3.677	5.898	10.176
0.9	1.26	1.746	2.84	4.466	5.525	9.721
0.9	1.304	1.837	2.923	4.619	6.067	10.295
0.9	1.313	1.684	3.283	4.831	6.824	10.241
0.9	1.268	1.881	2.426	5.166	6.767	11.233
0.9	1.247	1.776	2.993	3.864	4.872	12.2
0.9	1.071	1.692	2.271	4.265	7.645	13.747
0.9	1.13	1.568	2.512	4.136	7.309	11.449
0.9	1.533	1.922	2.714	3.061	5	10.614
0.9	1.293	1.889	2.513	4.356	6.174	11.063
0.9	1.45	1.943	3.151	3.444	6.132	10.018
0.9	1.652	1.921	2.775	5.142	8.29	12.969
0.9	1.687	2.136	2.376	3.648	7.376	11.647
0.9	1.733	2.233	3.007	3.193	4.649	12.479
0.9	1.277	2.089	2.979	4.191	4.211	10.262
0.9	1.277	1.774	2.704	4.02	5.727	7.901

Biomass Weights

0.791	0.965	1.364	2.364	4.267	5.67	11.33
0.793	1.024	1.385	2.029	3.231	5.333	9.755
0.761	1.021	1.394	2.125	3.017	4.72	10.176
0.748	1.065	1.423	2.178	3.486	4.507	9.721
0.745	1.083	1.521	2.259	3.622	5.205	10.295
0.758	1.087	1.482	2.456	3.758	5.614	10.241
0.765	1.068	1.572	2.021	4.118	5.718	11.233
0.825	1.059	1.501	2.373	3.062	5.017	12.2
0.803	0.982	1.453	2.008	3.573	5.435	13.747
0.69	1.008	1.296	2.062	3.065	5.583	11.449
0.751	1.175	1.474	2.063	2.773	4.548	10.614
0.709	1.079	1.702	2.198	3.438	4.347	11.063
0.664	1.142	1.585	2.44	2.942	5.168	10.018
0.657	1.219	1.669	2.322	4.025	5.343	12.969
0.649	1.232	1.878	2.136	3.182	6.159	11.647
0.756	1.249	1.941	2.534	2.754	4.118	12.479
0.756	1.072	1.903	2.579	3.55	3.667	10.262
0.756	1.072	1.505	2.377	3.461	4.899	7.901
0.741	1.072	1.521	2.091	3.076	4.67	7.901

SSB Weights

0.791	0.965	1.364	2.364	4.267	5.67	11.33
0.793	1.024	1.385	2.029	3.231	5.333	9.755
0.761	1.021	1.394	2.125	3.017	4.72	10.176
0.748	1.065	1.423	2.178	3.486	4.507	9.721
0.745	1.083	1.521	2.259	3.622	5.205	10.295
0.758	1.087	1.482	2.456	3.758	5.614	10.241
0.765	1.068	1.572	2.021	4.118	5.718	11.233
0.825	1.059	1.501	2.373	3.062	5.017	12.2
0.803	0.982	1.453	2.008	3.573	5.435	13.747
0.69	1.008	1.296	2.062	3.065	5.583	11.449
0.751	1.175	1.474	2.063	2.773	4.548	10.614
0.709	1.079	1.702	2.198	3.438	4.347	11.063
0.664	1.142	1.585	2.44	2.942	5.168	10.018
0.657	1.219	1.669	2.322	4.025	5.343	12.969
0.649	1.232	1.878	2.136	3.182	6.159	11.647
0.756	1.249	1.941	2.534	2.754	4.118	12.479
0.756	1.072	1.903	2.579	3.55	3.667	10.262
0.756	1.072	1.505	2.377	3.461	4.899	7.901
0.741	1.072	1.521	2.091	3.076	4.67	7.901

Indices									
WHSpr	WHSpr	WHSpr	WHSpr	WHSpr	WHAut	WHAut	WHAut	WHAut	
WHAut	MASpr	MASpr	MASpr	MAAut	MAAut	MAAut	CM_CPE	CM_CPE	
CM_CPE	CM_CPE	CM_CPE							
2	3	4	5	6	2	3	4	5	
	2	3	4	1	2	3	2	3	4
	5	6							
1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	
1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	mean	mean	
mean	mean	mean							
number	number	number	number	number	number	number	number	number	
number	number	number	number	number	number	number	number	number	
number	number	number							
1.019	0.516	0.694	0.864	0.117	0.619	0.382	0.549	0.474	
0.089	7.06	3.418	1.147	2.018	5.652	7.29	0.07432	0.07382	
0.04502	0.02168	0.00265							
0.978	0.833	0.641	0.357	0.181	0.7	3.142	2.473	1.167	
0.248	18.572	5.331	0.501	4.667	2.346	1.005	0.04767	0.10991	
0.04215	0.02094	0.01231							
1.033	1.147	0.741	0.19	0.053	1.66	0.977	0.852	0.139	
0.264	5.408	2.271	0.865	1.308	0.651	0.1	0.03313	0.04478	
0.04418	0.01179	0.00552							
0.238	0.622	0.665	0.677	0.095	0.384	0.421	0.565	0.399	
0.22	3.822	2.794	0.692	12.296	0.344	0.022	0.01372	0.04226	
0.02894	0.01793	0.00361							
0.33	0.647	0.387	0.074	0.046	0.378	0.91	0.763	0.209	
0.218	3.222	0.887	0.426	2.832	0.419	0.018	0.00409	0.06877	
0.02257	0.00661	0.00428							
0.638	0.486	0.3	0.128	0.011	0.301	0.49	0.654	0.333	
0.086	6.997	2.268	0.257	2.478	1.15	0.833	0.00738	0.01861	
0.02599	0.00572	0.00177							
1.053	0.633	0.355	0.217	0.087	0.599	1.324	0.6	0.257	
0.061	11.356	2.511	1.37	389.584	2.386	0.02	0.01455	0.0492	
0.02418	0.00932	0.00147							
0.649	0.79	0.632	0.09	0.077	1.951	2.245	0.96	0.528	
0.11	25.26	6.58	0.458	4.571	20.49	0.679	0.01698	0.0637	
0.03966	0.01059	0.00231							
0.19	1.327	0.627	0.167	0.032	0.416	2.391	1.356	0.294	
0.174	6.89	17.77	2.64	2.971	2.7	0.35	0.01098	0.15953	
0.07816	0.01219	0.0051							
0.209	0.355	1.477	0.268	0.024	0.029	0.367	1.643	0.623	
0.278	3.56	2.54	5.03	9.37	9.13	1.74	0.01943	0.04044	
0.13551	0.0217	0.00394							
0.23	0.24	0.28	1.31	0.22	0.142	0.142	0.221	0.632	
0.079	6.35	3.58	0.65	4.65	4.2	0.81	0.01494	0.01733	
0.0138	0.05147	0.00519							
0.5	0.8	0.33	0.09	0.48	0.29	0.45	0.14	0.04	
0.33	7.76	3.6	1.45	24.3	2.01	0.11	0.00267	0.04997	
0.02324	0.00407	0.01395							

0.316	0.387	0.213	0.095	0.047	0.198	0.569	0.363	0.032
0	5.67	2.46	0.52	49.92	3.32	0.61	0	0
0	0	0						
0.18	1.12	0.37	0.15	0.03	0.21	0.88	0.83	0.09
0.05	1.36	3.89	1.2	33.49	14.13	6.37	0	0
0	0	0						
0.02	0.59	1.33	0.4	0.06	0.07	0.28	1.23	0.33
0.08	0.97	2.11	0.81	2.56	0.64	0.54	0	0
0	0	0						
0.132	0.399	0.264	0.876	0.242	0.12	0.38	0.19	0.54
0.06	1	1.34	0.2	7.59	0.15	0.02	0	0
0	0	0						
0.224	0.33	0.517	0.142	0.421	0.297	0.086	0.16	0.182
0.149	1.17	0.89	1.17	2.02	0.02	0	0	0
0	0	0						
0.344	0.713	0.344	0.315	0.134	0.097	0.32	0.115	0.192
0.039	3.55	3.31	1.32	2.7	1.05	0.01	0	0
0	0	0						
0.725	0.438	0.457	0.107	0.101	0.431	0.363	0.59	0.243
0.132	7.34	4.03	2.3	6.63	0.84	0.14	0	0
0	0	0						

Maturity Matrix

0.07	0.26	0.61	0.88	0.97	1	1
0.07	0.26	0.61	0.88	0.97	1	1
0.07	0.26	0.61	0.88	0.97	1	1
0.04	0.48	0.95	1	1	1	1
0.04	0.48	0.95	1	1	1	1
0.04	0.48	0.95	1	1	1	1
0.04	0.48	0.95	1	1	1	1
0.04	0.48	0.95	1	1	1	1
0.11	0.28	0.56	0.81	0.93	0.98	1
0.11	0.28	0.56	0.81	0.93	0.98	1
0.11	0.28	0.56	0.81	0.93	0.98	1
0.11	0.28	0.56	0.81	0.93	0.98	1
0.04	0.38	0.89	0.99	1	1	1
0.04	0.38	0.89	0.99	1	1	1
0.04	0.38	0.89	0.99	1	1	1
0.04	0.38	0.89	0.99	1	1	1
0.04	0.38	0.89	0.99	1	1	1
0.04	0.38	0.89	0.99	1	1	1

M Matrix

0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2

ADAPT/VPA Output

File: gmcod2000_base.2

Fisheries Assessment Toolbox GoM Cod 2000 Base Run Run Number 1 8/25/2000 9:15:13 AM
FACT Version 1.3.6
GoM Cod 2000 Base Run 1982 - 2000
Input Parameters and Options Selected

Natural mortality is a matrix below
Oldest age (not in the plus group) is 6
For all years prior to the terminal year (18), backcalculated
stock sizes for the following ages used to estimate
total mortality (Z) for age 6 : 4 5 6
This method for estimating F on the oldest age is generally used when a
flat-topped partial recruitment curve is thought to be characteristic of the stock.
F for age 7 + is then calculated from the following
ratios of F[age 7 +] to F[age 6]

1982	1
1983	1
1984	1
1985	1
1986	1
1987	1
1988	1
1989	1
1990	1
1991	1
1992	1
1993	1
1994	1
1995	1
1996	1
1997	1
1998	1
1999	1

Stock size of the 7 + group is then calculated using
the following method: CATCH EQUATION
Partial recruitment estimate for 2000

1	0.0001
2	0.053
3	0.421
4	1
5	1
6	1

Objective function is Sum w*(LOG(OBS)-LOG(PRED))**2
Indices normalized (by dividing by mean observed value)
before tuning to VPA stocksizes
Downweighting is None or Uniform
Biomass estimates (other than SSB) reflect mean stock sizes.
SSB calculated as in the NEFSC projection program
(see note below SSB table for description of the algorithm).
Initial estimates of parameters for the Marquardt algorithm
and lower and upper bounds on the parameter estimates:

Par.	Initial Est	Lower Bnd	Upper Bnd
N 2	3.00E+03	0.00E+00	1.00E+06
N 3	3.00E+03	0.00E+00	1.00E+06
N 4	5.00E+02	0.00E+00	1.00E+06
N 5	5.00E+02	0.00E+00	1.00E+06
N 6	5.00E+02	0.00E+00	1.00E+06
q WHSpr2	1.00E-02	0.00E+00	1.00E+00
q WHSpr3	1.00E-02	0.00E+00	1.00E+00
q WHSpr4	1.00E-02	0.00E+00	1.00E+00
q WHSpr5	1.00E-02	0.00E+00	1.00E+00
q WHSpr6	1.00E-02	0.00E+00	1.00E+00
q WHAut2	1.00E-02	0.00E+00	1.00E+00
q WHAut3	1.00E-02	0.00E+00	1.00E+00
q WHAut4	1.00E-02	0.00E+00	1.00E+00
q WHAut5	1.00E-02	0.00E+00	1.00E+00
q WHAut6	1.00E-02	0.00E+00	1.00E+00
q MASpr2	1.00E-02	0.00E+00	1.00E+00
q MASpr3	1.00E-02	0.00E+00	1.00E+00
q MASpr4	1.00E-02	0.00E+00	1.00E+00
q MAAut1	1.00E-02	0.00E+00	1.00E+00

```
q MAAut2      1.00E-02     0.00E+00     1.00E+00
q MAAut3      1.00E-02     0.00E+00     1.00E+00
q CM_CPE2     1.00E-02     0.00E+00     1.00E+00
q CM_CPE3     1.00E-02     0.00E+00     1.00E+00
q CM_CPE4     1.00E-02     0.00E+00     1.00E+00
q CM_CPE5     1.00E-02     0.00E+00     1.00E+00
q CM_CPE6     1.00E-02     0.00E+00     1.00E+00
The following indices of abundance are available
 1            WHSpr2
 2            WHSpr3
 3            WHSpr4
 4            WHSpr5
 5            WHSpr6
 6            WHAut2
 7            WHAut3
 8            WHAut4
 9            WHAut5
 10           WHAut6
 11           MASpr2
 12           MASpr3
 13           MASpr4
 14           MAAut1
 15           MAAut2
 16           MAAut3
 17           CM_CPE2
 18           CM_CPE3
 19           CM_CPE4
 20           CM_CPE5
 21           CM_CPE6
 The Indices that will be used in this run are:
 1            WHSpr2
 2            WHSpr3
 3            WHSpr4
 4            WHSpr5
 5            WHSpr6
 6            WHAut2
 7            WHAut3
 8            WHAut4
 9            WHAut5
 10           WHAut6
 11           MASpr2
 12           MASpr3
 13           MASpr4
 14           MAAut1
 15           MAAut2
 16           MAAut3
 17           CM_CPE2
 18           CM_CPE3
 19           CM_CPE4
 20           CM_CPE5
 21           CM_CPE6
Obs Indices (before transformation) by index and year; with Index means
```

	1982	1983	1984	1985	1986	1987	1988
WHSpr2	1.02	0.98	1.03	0.24	0.33	0.64	1.05
WHSpr3	0.52	0.83	1.15	0.62	0.65	0.49	0.63
WHSpr4	0.69	0.64	0.74	0.67	0.39	0.30	0.36
WHSpr5	0.86	0.36	0.19	0.68	0.07	0.13	0.22
WHSpr6	0.12	0.18	0.05	0.10	0.05	0.01	0.09
WHAut2	0.62	0.70	1.66	0.38	0.38	0.30	0.60
WHAut3	0.38	3.14	0.98	0.42	0.91	0.49	1.32
WHAut4	0.55	2.47	0.85	0.57	0.76	0.65	0.60
WHAut5	0.47	1.17	0.14	0.40	0.21	0.33	0.26
WHAut6	0.09	0.25	0.26	0.22	0.22	0.09	0.06
MASpr2	7.06	18.57	5.41	3.82	3.22	7.00	11.36
MASpr3	3.42	5.33	2.27	2.79	0.89	2.27	2.51
MASpr4	1.15	0.50	0.87	0.69	0.43	0.26	1.37
MAAut1	2.02	4.67	1.31	12.30	2.83	2.48	389.58
MAAut2	5.65	2.35	0.65	0.34	0.42	1.15	2.39

MAAut3	7.29	1.01	0.10	0.02	0.02	0.83	0.02
CM_CPE2	0.07	0.05	0.03	0.01	0.00	0.01	0.01
CM_CPE3	0.07	0.11	0.04	0.04	0.07	0.02	0.05
CM_CPE4	0.05	0.04	0.04	0.03	0.02	0.03	0.02
CM_CPE5	0.02	0.02	0.01	0.02	0.01	0.01	0.01
CM_CPE6	0.00	0.01	0.01	0.00	0.00	0.00	0.00

	1989	1990	1991	1992	1993	1994	1995
WHSpr2	0.65	0.19	0.21	0.23	0.50	0.32	0.18
WHSpr3	0.79	1.33	0.36	0.24	0.80	0.39	1.12
WHSpr4	0.63	0.63	1.48	0.28	0.33	0.21	0.37
WHSpr5	0.09	0.17	0.27	1.31	0.09	0.10	0.15
WHSpr6	0.08	0.03	0.02	0.22	0.48	0.05	0.03
WHAut2	1.95	0.42	0.03	0.14	0.29	0.20	0.21
WHAut3	2.25	2.39	0.37	0.14	0.45	0.57	0.88
WHAut4	0.96	1.36	1.64	0.22	0.14	0.36	0.83
WHAut5	0.53	0.29	0.62	0.63	0.04	0.03	0.09
WHAut6	0.11	0.17	0.28	0.08	0.33	0.00	0.05
MASpr2	25.26	6.89	3.56	6.35	7.76	5.67	1.36
MASpr3	6.58	17.77	2.54	3.58	3.60	2.46	3.89
MASpr4	0.46	2.64	5.03	0.65	1.45	0.52	1.20
MAAut1	4.57	2.97	9.37	4.65	24.30	49.92	33.49
MAAut2	20.49	2.70	9.13	4.20	2.01	3.32	14.13
MAAut3	0.68	0.35	1.74	0.81	0.11	0.61	6.37
CM_CPE2	0.02	0.01	0.02	0.01	0.00	0.00	0.00
CM_CPE3	0.06	0.16	0.04	0.02	0.05	0.00	0.00
CM_CPE4	0.04	0.08	0.14	0.01	0.02	0.00	0.00
CM_CPE5	0.01	0.01	0.02	0.05	0.00	0.00	0.00
CM_CPE6	0.00	0.01	0.00	0.01	0.01	0.00	0.00

	1996	1997	1998	1999	2000	Average
WHSpr2	0.02	0.13	0.22	0.34	0.73	0.474
WHSpr3	0.59	0.40	0.33	0.71	0.44	0.651
WHSpr4	1.33	0.26	0.52	0.34	0.46	0.559
WHSpr5	0.40	0.88	0.14	0.32	0.11	0.343
WHSpr6	0.06	0.24	0.42	0.13	0.10	0.129
WHAut2	0.07	0.12	0.30	0.10	0.43	0.468
WHAut3	0.28	0.38	0.09	0.32	0.36	0.848
WHAut4	1.23	0.19	0.16	0.12	0.59	0.750
WHAut5	0.33	0.54	0.18	0.19	0.24	0.353
WHAut6	0.08	0.06	0.15	0.04	0.13	0.148
MASpr2	0.97	1.00	1.17	3.55	7.34	6.701
MASpr3	2.11	1.34	0.89	3.31	4.03	3.767
MASpr4	0.81	0.20	1.17	1.32	2.30	1.211
MAAut1	2.56	7.59	2.02	2.70	6.63	29.787
MAAut2	0.64	0.15	0.02	1.05	0.84	3.770
MAAut3	0.54	0.02	0.00	0.01	0.14	1.148
CM_CPE2	0.00	0.00	0.00	0.00	0.00	0.022
CM_CPE3	0.00	0.00	0.00	0.00	0.00	0.062
CM_CPE4	0.00	0.00	0.00	0.00	0.00	0.044
CM_CPE5	0.00	0.00	0.00	0.00	0.00	0.016
CM_CPE6	0.00	0.00	0.00	0.00	0.00	0.005

Catch at age (thousands) - D:\NAFO\SeptWS\gmcod\gmcod2000_base.2

	1982	1983	1984	1985	1986	1987	1988
1	30	00	04	00	00	02	00
2	1380	866	446	407	84	216	160
3	1633	2357	1240	1445	2164	595	1443
4	1143	1058	1500	991	813	1109	953
5	633	638	437	630	250	277	406
6	69	422	194	128	177	66	43
7	230	155	136	136	95	79	30
1+	5118	5496	3957	3737	3583	2344	3035

	1989	1990	1991	1992	1993	1994	1995
1	00	00	00	00	00	00	00
2	337	205	344	313	76	29	218
3	1583	3425	934	530	1487	1016	880
4	1454	2064	4161	484	641	1135	1153
5	449	430	851	2018	129	288	194
6	81	157	143	202	457	72	12
7	56	99	79	84	36	86	34
1+	3960	6380	6512	3631	2826	2626	2491

	1996	1997	1998	1999
1	00	00	00	00
2	65	53	94	00
3	584	438	390	178
4	1738	435	542	192
5	347	832	165	90
6	45	68	193	27
7	10	08	10	36
1+	2789	1834	1394	523

CAA Summary for ages 4 - 7

1982	1983	1984	1985	1986	1987	1988
2075	2273	2267	1885	1335	1531	1432

1989	1990	1991	1992	1993	1994	1995
2040	2750	5234	2788	1263	1581	1393

1996	1997	1998	1999
2140	1343	910	345

Weight at age (mid year) in kg - D:\NAFO\SeptWS\gmcod\gmcod2000_base.2

	1982	1983	1984	1985	1986	1987	1988
1	0.900	0.900	0.900	0.900	0.900	0.900	0.900
2	1.156	1.164	1.159	1.260	1.304	1.313	1.268
3	1.664	1.660	1.670	1.746	1.837	1.684	1.881
4	2.764	2.475	2.721	2.840	2.923	3.283	2.426
5	4.770	3.778	3.677	4.466	4.619	4.831	5.166
6	6.739	5.962	5.898	5.525	6.067	6.824	6.767
7	11.330	9.755	10.176	9.721	10.295	10.241	11.233

	1989	1990	1991	1992	1993	1994	1995
1	0.900	0.900	0.900	0.900	0.900	0.900	0.900
2	1.247	1.071	1.130	1.533	1.293	1.450	1.652
3	1.776	1.692	1.568	1.922	1.889	1.943	1.921
4	2.993	2.271	2.512	2.714	2.513	3.151	2.775
5	3.864	4.265	4.136	3.061	4.356	3.444	5.142
6	4.872	7.645	7.309	5.000	6.174	6.132	8.290
7	12.200	13.747	11.449	10.614	11.063	10.018	12.969

	1996	1997	1998	1999
1	0.900	0.900	0.900	0.900
2	1.687	1.733	1.277	1.277
3	2.136	2.233	2.089	1.774
4	2.376	3.007	2.979	2.704
5	3.648	3.193	4.191	4.020
6	7.376	4.649	4.211	5.727
7	11.647	12.479	10.262	7.901

January 1 Biomass Weights - D:\NAFO\SeptWS\gmcod\gmcod2000_base.2

	1982	1983	1984	1985	1986	1987	1988
1	0.791	0.793	0.761	0.748	0.745	0.758	0.765
2	0.965	1.024	1.021	1.065	1.083	1.087	1.068
3	1.364	1.385	1.394	1.423	1.521	1.482	1.572
4	2.364	2.029	2.125	2.178	2.259	2.456	2.021
5	4.267	3.231	3.017	3.486	3.622	3.758	4.118
6	5.670	5.333	4.720	4.507	5.205	5.614	5.718
7	11.330	9.755	10.176	9.721	10.295	10.241	11.233

	1989	1990	1991	1992	1993	1994	1995
1	0.825	0.803	0.690	0.751	0.709	0.664	0.657
2	1.059	0.982	1.008	1.175	1.079	1.142	1.219
3	1.501	1.453	1.296	1.474	1.702	1.585	1.669
4	2.373	2.008	2.062	2.063	2.198	2.440	2.322
5	3.062	3.573	3.065	2.773	3.438	2.942	4.025
6	5.017	5.435	5.583	4.548	4.347	5.168	5.343
7	12.200	13.747	11.449	10.614	11.063	10.018	12.969

	1996	1997	1998	1999
1	0.649	0.756	0.756	0.756
2	1.232	1.249	1.072	1.072
3	1.878	1.941	1.903	1.505
4	2.136	2.534	2.579	2.377
5	3.182	2.754	3.550	3.461
6	6.159	4.118	3.667	4.899
7	11.647	12.479	10.262	7.901

SSB Weights - D:\NAFO\SeptWS\gmcod\gmcod2000_base.2

	1982	1983	1984	1985	1986	1987	1988
1	0.791	0.793	0.761	0.748	0.745	0.758	0.765
2	0.965	1.024	1.021	1.065	1.083	1.087	1.068
3	1.364	1.385	1.394	1.423	1.521	1.482	1.572
4	2.364	2.029	2.125	2.178	2.259	2.456	2.021
5	4.267	3.231	3.017	3.486	3.622	3.758	4.118
6	5.670	5.333	4.720	4.507	5.205	5.614	5.718
7	11.330	9.755	10.176	9.721	10.295	10.241	11.233

	1989	1990	1991	1992	1993	1994	1995
1	0.825	0.803	0.690	0.751	0.709	0.664	0.657
2	1.059	0.982	1.008	1.175	1.079	1.142	1.219
3	1.501	1.453	1.296	1.474	1.702	1.585	1.669
4	2.373	2.008	2.062	2.063	2.198	2.440	2.322
5	3.062	3.573	3.065	2.773	3.438	2.942	4.025
6	5.017	5.435	5.583	4.548	4.347	5.168	5.343
7	12.200	13.747	11.449	10.614	11.063	10.018	12.969

	1996	1997	1998	1999
1	0.649	0.756	0.756	0.756
2	1.232	1.249	1.072	1.072
3	1.878	1.941	1.903	1.505
4	2.136	2.534	2.579	2.377
5	3.182	2.754	3.550	3.461
6	6.159	4.118	3.667	4.899
7	11.647	12.479	10.262	7.901

Computed (Rivard)from midyear weights: Jan 1 Weights - D:\NAFO\SeptWS\gmcod\gmcod2000

	1982	1983	1984	1985	1986	1987	1988
1	0.791	0.793	0.761	0.748	0.745	0.758	0.765
2	0.965	1.024	1.021	1.065	1.083	1.087	1.068
3	1.364	1.385	1.394	1.423	1.521	1.482	1.572
4	2.364	2.029	2.125	2.178	2.259	2.456	2.021
5	4.267	3.231	3.017	3.486	3.622	3.758	4.118
6	5.670	5.333	4.720	4.507	5.205	5.614	5.718
7	11.330	9.755	10.176	9.721	10.295	10.241	11.233

	1989	1990	1991	1992	1993	1994	1995
1	0.825	0.803	0.690	0.751	0.709	0.664	0.657
2	1.059	0.982	1.008	1.175	1.079	1.142	1.219
3	1.501	1.453	1.296	1.474	1.702	1.585	1.669
4	2.373	2.008	2.062	2.063	2.198	2.440	2.322
5	3.062	3.573	3.065	2.773	3.438	2.942	4.025
6	5.017	5.435	5.583	4.548	4.347	5.168	5.343
7	12.200	13.747	11.449	10.614	11.063	10.018	12.969

	1996	1997	1998	1999	2000
1	0.649	0.756	0.756	0.756	0.741
2	1.232	1.249	1.072	1.072	1.072
3	1.878	1.941	1.903	1.505	1.521
4	2.136	2.534	2.579	2.377	2.091
5	3.182	2.754	3.550	3.461	3.076
6	6.159	4.118	3.667	4.899	4.670
7	11.647	12.479	10.262	7.901	7.901

Percent Mature (females)- D:\NAFO\SeptWS\gmcod\gmcod2000_base.2

	1982	1983	1984	1985	1986	1987	1988
1	07	07	07	04	04	04	04
2	26	26	26	48	48	48	48
3	61	61	61	95	95	95	95
4	88	88	88	100	100	100	100
5	97	97	97	100	100	100	100
6	100	100	100	100	100	100	100
7	100	100	100	100	100	100	100

	1989	1990	1991	1992	1993	1994	1995
1	04	11	11	11	11	04	04
2	48	28	28	28	28	38	38
3	95	56	56	56	56	89	89
4	100	81	81	81	81	99	99
5	100	93	93	93	93	100	100
6	100	98	98	98	98	100	100
7	100	100	100	100	100	100	100

	1996	1997	1998	1999
1	04	04	04	04
2	38	38	38	38
3	89	89	89	89
4	99	99	99	99
5	100	100	100	100
6	100	100	100	100
7	100	100	100	100

Natural Mortality D:\NAFO\SeptWS\gmcod\gmcod2000_base.2

	1982	1983	1984	1985	1986	1987	1988
1	.200	.200	.200	.200	.200	.200	.200
2	.200	.200	.200	.200	.200	.200	.200
3	.200	.200	.200	.200	.200	.200	.200
4	.200	.200	.200	.200	.200	.200	.200
5	.200	.200	.200	.200	.200	.200	.200
6	.200	.200	.200	.200	.200	.200	.200
7	.200	.200	.200	.200	.200	.200	.200

	1989	1990	1991	1992	1993	1994	1995
1	.200	.200	.200	.200	.200	.200	.200
2	.200	.200	.200	.200	.200	.200	.200
3	.200	.200	.200	.200	.200	.200	.200
4	.200	.200	.200	.200	.200	.200	.200
5	.200	.200	.200	.200	.200	.200	.200
6	.200	.200	.200	.200	.200	.200	.200
7	.200	.200	.200	.200	.200	.200	.200

	1996	1997	1998	1999
1	.200	.200	.200	.200
2	.200	.200	.200	.200
3	.200	.200	.200	.200
4	.200	.200	.200	.200
5	.200	.200	.200	.200
6	.200	.200	.200	.200
7	.200	.200	.200	.200

Sex Ratio (Percent Female) - D:\NAFO\SeptWS\gmcod\gmcod2000_base.2

	1982	1983	1984	1985	1986	1987	1988
1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
3	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
7	0.5	0.5	0.5	0.5	0.5	0.5	0.5

	1989	1990	1991	1992	1993	1994	1995
1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
3	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
7	0.5	0.5	0.5	0.5	0.5	0.5	0.5

	1996	1997	1998	1999
1	0.5	0.5	0.5	0.5
2	0.5	0.5	0.5	0.5
3	0.5	0.5	0.5	0.5
4	0.5	0.5	0.5	0.5
5	0.5	0.5	0.5	0.5
6	0.5	0.5	0.5	0.5
7	0.5	0.5	0.5	0.5

pF is 0.1667
pM is 0.1667

Fishing Mortality

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1995	0.60	0.89	0.93	1.13	1.07	1.13	0.93	0.93	0.88	0.94	1.10	0.89	1.68	0.71				
1996	0.60	0.89	0.93	1.13	1.07	1.13	0.93	0.93	0.88	0.94	1.11	0.91	1.81	0.86	0.57			
1997	0.60	0.89	0.93	1.13	1.07	1.13	0.93	0.93	0.88	0.95	1.11	0.91	1.87	1.01	0.75	0.53		
1998	0.60	0.89	0.93	1.13	1.07	1.13	0.93	0.93	0.88	0.95	1.11	0.92	1.91	1.07	0.89	0.75	0.57	
1999	0.60	0.89	0.93	1.13	1.07	1.13	0.93	0.93	0.88	0.95	1.11	0.92	1.92	1.10	0.95	0.93	0.75	0.28

Spawning Stock Biomass

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1995	22786	18061	13984	15272	14562	14372	17737	26212	22616	20381	13657	11314	14341	18926				
1996	22786	18061	13984	15272	14561	14371	17734	26200	22598	20340	13542	11077	13634	17338	16772			
1997	22786	18061	13984	15272	14561	14371	17733	26195	22590	20323	13470	10857	12835	15714	14899	11817		
1998	22786	18061	13984	15272	14561	14371	17732	26192	22586	20314	13442	10730	12338	14416	13158	10479	8714	
1999	22786	18061	13984	15272	14561	14370	17732	26191	22585	20311	13432	10690	12175	13924	12285	9517	8029	8179

Population Numbers Age: 1

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1995	6162	5534	7747	4914	7411	9959	21676	3394	3408	6101	6339	9629	6479	1870	00				
1996	6162	5534	7747	4914	7411	9956	21660	3381	3401	5947	5981	9878	4370	1863	1323	00			
1997	6162	5534	7746	4914	7410	9955	21652	3379	3393	5919	5451	9249	3912	2420	1437	1516	00		
1998	6162	5534	7746	4914	7410	9954	21648	3376	3392	5888	5334	8377	3307	2960	1965	1857	2866	00	
1999	6162	5534	7746	4914	7410	9954	21647	3375	3391	5879	5283	8137	2870	2947	2113	2536	3345	5363	00

Population Numbers Age: 2.

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1995	9108	5018	4531	6339	4023	6068	8152	17747	2778	2791	4995	5190	8047	5305	1531				
1996	9108	5018	4530	6339	4023	6067	8150	17734	2768	2784	4869	4897	8087	3578	1525	1083			
1997	9108	5018	4530	6339	4023	6067	8149	17727	2766	2778	4846	4463	7572	3203	1981	1176	1241		
1998	9108	5018	4530	6339	4023	6067	8148	17724	2764	2777	4820	4367	6859	2708	2424	1608	1520	2347	
1999	9108	5018	4530	6339	4023	6067	8148	17723	2763	2776	4813	4325	6662	2350	2413	1730	2076	2738	4391

Population Numbers Age: 3

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1995	4328	6208	3325	3306	4821	3218	4773	6530	14225	2089	1973	3807	4180	6562	4146				
1996	4328	6208	3325	3306	4821	3218	4772	6528	14214	2081	1968	3703	3940	6595	2732	1190			
1997	4328	6208	3325	3306	4821	3218	4772	6527	14209	2079	1963	3684	3585	6174	2425	1563	915		
1998	4328	6208	3325	3306	4821	3218	4772	6526	14206	2078	1962	3663	3507	5589	2020	1926	1269	1160	
1999	4328	6208	3325	3306	4821	3218	4772	6526	14206	2077	1962	3657	3472	5428	1727	1917	1369	1615	2242

Population Numbers Age: 4

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1995	2666	2066	2950	1600	1399	1989	2096	2602	3914	8547	865	1136	1771	2503	4576				
1996	2666	2066	2950	1600	1399	1989	2096	2601	3912	8539	859	1132	1687	2307	4603	1708			
1997	2666	2066	2950	1600	1399	1989	2096	2601	3911	8534	857	1128	1671	2016	4258	1457	883		
1998	2666	2066	2950	1600	1399	1989	2096	2601	3911	8532	856	1127	1654	1952	3780	1125	1180	686	
1999	2666	2066	2950	1600	1399	1989	2096	2601	3911	8531	855	1126	1649	1924	3648	885	1173	768	1161

Population Numbers Age: 5

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1995	1661	1149	734	1058	413	410	625	854	814	1337	3233	271	350	423	1006				
1996	1661	1149	734	1058	413	410	625	854	814	1335	3226	265	347	354	845	2196			
1997	1661	1149	734	1058	413	410	625	854	814	1335	3222	264	343	341	607	1914	799		
1998	1661	1149	734	1058	413	410	625	854	814	1334	3220	263	343	327	555	1522	527	476	
1999	1661	1149	734	1058	413	410	625	854	814	1334	3220	262	342	323	532	1414	331	470	455

Population Numbers Age: 6

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1995	166	787	363	206	296	112	85	145	293	278	324	821	105	26	171				
1996	166	787	363	206	296	112	85	145	293	277	323	815	100	23	114	378			
1997	166	787	363	206	296	112	85	145	293	277	323	812	99	21	104	183	814		
1998	166	787	363	206	296	112	85	145	293	277	323	811	98	20	92	140	493	283	
1999	166	787	363	206	296	112	85	145	293	277	322	810	98	20	89	121	405	122	303

Population Numbers Age: 7

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1995	547	284	250	214	156	132	58	98	182	151	132	64	122	73	40				
1996	547	284	250	214	156	132	58	98	182	151	132	63	117	65	25	64			
1997	547	284	250	214	156	132	58	98	182	151	131	63	115	57	23	21	99		
1998	547	284	250	214	156	132	58	98	182	151	131	63	114	55	20	16	25	241	
1999	547	284	250	214	156	132	58	98	182	151	131	63	114	55	19	14	21	162	175

Age 2 + stock size (N)

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1995	18477	15512	12153	12722	11109	11929	15790	27975	22206	15193	11524	11288	14576	14892	11470				
1996	18477	15512	12153	12722	11109	11928	15786	27960	22183	15168	11377	10875	14278	12922	9845	6620			
1997	18477	15512	12153	12722	11109	11928	15785	27952	22175	15155	11343	10414	13387	11812	9398	6315	4752		
1998	18477	15512	12153	12722	11109	11927	15784	27948	22170	15149	11313	10293	12575	10651	8890	6338	5016	5192	
1999	18477	15512	12153	12722	11109	11927	15784	27947	22168	15147	11304	10244	12338	10099	8428	6082	5374	5874	8727

ADAPT/VPA Bootstrap Output

File: gmcod2000_base.2boot

The number of bootstraps: 100

Bootstrap Output Variable: N hat

	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
N 2	4391	4457	1592	0.36
N 3	2242	2357	635	0.28
N 4	1161	1242	341	0.29
N 5	455	464	157	0.35
N 6	303	330	124	0.41

	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
N 2	.67	159	1.52	4324	0.368318	2564	6190
N 3	115	63	5.11	2127	0.298377	1308	2919
N 4	82	34	7.03	1079	0.315954	684	1553
N 5	09	16	2.01	446	0.353130	325	792
N 6	27	12	8.76	277	0.449921	164	492

Bootstrap Output Variable: Q_unscaled

	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
q WHSpr2	0.0000789	0.0000813	0.0000154	0.19
q WHSpr3	0.0001766	0.0001758	0.0000355	0.20
q WHSpr4	0.0002607	0.0002616	0.0000476	0.18
q WHSpr5	0.0003404	0.0003363	0.0000643	0.19
q WHSpr6	0.0004341	0.0004445	0.0000898	0.21
q WHAut2	0.0000680	0.0000686	0.0000138	0.20
q WHAut3	0.0001688	0.0001705	0.0000328	0.19
q WHAut4	0.0002927	0.0003097	0.0000618	0.21
q WHAut5	0.0003750	0.0003840	0.0000754	0.20
q WHAut6	0.0006108	0.0006193	0.0001095	0.18
q MASpr2	0.0010758	0.0011056	0.0001972	0.18
q MASpr3	0.0008737	0.0008904	0.0001683	0.19
q MASpr4	0.0004771	0.0004840	0.0001001	0.21
q MAAut1	0.0013482	0.0013375	0.0002738	0.20
q MAAut2	0.0003353	0.0003417	0.0000617	0.18
q MAAut3	0.0000698	0.0000697	0.0000123	0.18
q CM_CPE2	0.0000031	0.0000030	0.0000006	0.21
q CM_CPE3	0.0000169	0.0000173	0.0000038	0.23
q CM_CPE4	0.0000269	0.0000277	0.0000065	0.24
q CM_CPE5	0.0000265	0.0000270	0.0000059	0.22
q CM_CPE6	0.0000269	0.0000274	0.0000067	0.25

	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
q WHSpr2	0.00000232	0.000001536	2.941	0.000076626	0.20	0.0000579	0.0000968
q WHSpr3	-0.00000080	0.000003546	-0.456	0.000177375	0.20	0.0001354	0.0002199
q WHSpr4	0.00000083	0.000004762	0.318	0.000259914	0.18	0.0002074	0.0003273
q WHSpr5	-0.00000408	0.000006428	-1.199	0.000344453	0.19	0.0002739	0.0004425
q WHSpr6	0.00001038	0.000008975	2.392	0.000423735	0.21	0.0003295	0.0005553
q WHAut2	0.00000057	0.000001382	0.832	0.000067432	0.20	0.0000521	0.0000924
q WHAut3	0.00000172	0.000003282	1.019	0.000167090	0.20	0.0001354	0.0002222
q WHAut4	0.00001702	0.000006180	5.815	0.000275701	0.22	0.0002214	0.0003767
q WHAut5	0.00000900	0.000007539	2.401	0.000366042	0.21	0.0003135	0.0005427
q WHAut6	0.00000857	0.000010947	1.403	0.000602192	0.18	0.0004777	0.0007961
q MASpr2	0.00002980	0.000019721	2.770	0.001046014	0.19	0.0007848	0.0013173
q MASpr3	0.00001664	0.000016827	1.904	0.000857091	0.20	0.0006550	0.0010604
q MASpr4	0.00000690	0.000010014	1.447	0.000470175	0.21	0.0004004	0.0006712
q MAAut1	-0.00001065	0.000027381	-0.790	0.001358838	0.20	0.0011042	0.0018513
q MAAut2	0.00000648	0.000006168	1.933	0.000328775	0.19	0.0002602	0.0004070
q MAAut3	-0.00000012	0.000001227	-0.166	0.000069885	0.18	0.0000572	0.0000895
q CM_CPE2	-0.00000010	0.000000065	-3.180	0.000003179	0.20	0.0000027	0.0000050
q CM_CPE3	0.00000038	0.000000382	2.253	0.000016543	0.23	0.0000112	0.0000207
q CM_CPE4	0.00000086	0.000000646	3.218	0.000026007	0.25	0.0000189	0.0000378
q CM_CPE5	0.00000054	0.000000594	2.029	0.000025924	0.23	0.0000196	0.0000331
q CM_CPE6	0.00000043	0.000000666	1.614	0.000026502	0.25	0.0000205	0.0000347

Bootstrap Output Variable: N t1

	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
Age 1	5068.4	5076.3	156.2	0.0308
Age 2	4390.5	4457.5	1592.5	0.3627
Age 3	2242.0	2356.6	634.8	0.2831
Age 4	1160.9	1242.4	341.0	0.2937
Age 5	454.8	463.9	157.4	0.3460
Age 6	303.2	329.8	124.5	0.4105
Age 7	175.3	175.0	44.9	0.2562

	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
Age 1	7.84	15.62	0.155	5060.58	0.03	4814.2	5218.5
Age 2	66.90	159.25	1.524	4323.64	0.37	2564.2	6190.5
Age 3	114.62	63.48	5.112	2127.37	0.30	1308.0	2919.5
Age 4	81.59	34.10	7.028	1079.27	0.32	683.8	1552.6
Age 5	9.13	15.74	2.008	445.63	0.35	325.4	791.5
Age 6	26.57	12.45	8.763	276.63	0.45	164.4	492.4
Age 7	-0.28	4.49	-0.158	175.53	0.26	138.6	254.4

Bootstrap Output Variable: F t

	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
Age 1	0.0000	0.0000	0.0000	0.40
Age 2	0.0000	0.0000	0.0000	0.28
Age 3	0.1299	0.1308	0.0379	0.29
Age 4	0.3235	0.3427	0.0903	0.28
Age 5	0.2379	0.2473	0.0870	0.37
Age 6	0.2807	0.2950	0.0649	0.23
Age 7	0.2807	0.2950	0.0649	0.23

	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
Age 1	0.0000000	0.0000000	11.102	0.0000002	0.45	0.0000	0.0000
Age 2	0.0000000	0.0000000	2.061	0.0000004	0.28	0.0000	0.0000
Age 3	0.0009154	0.0037909	0.705	0.1290096	0.29	0.0971	0.1965
Age 4	0.0191060	0.0090312	5.905	0.3044409	0.30	0.1845	0.4237
Age 5	0.0093784	0.0086969	3.942	0.2285263	0.38	0.1513	0.3723
Age 6	0.0142422	0.0064933	5.073	0.2664836	0.24	0.1895	0.3396
Age 7	0.0142422	0.0064933	5.073	0.2664836	0.24	0.1895	0.3396

Bootstrap Output Variable: F full t

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
0.2807	0.2950	0.0649	0.23

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
0.01424	0.00649	5.07	0.26648	0.24	0.1895	0.3396

Bootstrap Output Variable: N t1

	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
Age 1	5068.4	5076.3	156.2	0.0308
Age 2	4390.5	4457.5	1592.5	0.3627
Age 3	2242.0	2356.6	634.8	0.2831
Age 4	1160.9	1242.4	341.0	0.2937
Age 5	454.8	463.9	157.4	0.3460
Age 6	303.2	329.8	124.5	0.4105
Age 7	175.3	175.0	44.9	0.2562

	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
Age 1	7.84	15.62	0.155	5060.58	0.03	4814.2	5218.5
Age 2	66.90	159.25	1.524	4323.64	0.37	2564.2	6190.5
Age 3	114.62	63.48	5.112	2127.37	0.30	1308.0	2919.5
Age 4	81.59	34.10	7.028	1079.27	0.32	683.8	1552.6
Age 5	9.13	15.74	2.008	445.63	0.35	325.4	791.5
Age 6	26.57	12.45	8.763	276.63	0.45	164.4	492.4
Age 7	-0.28	4.49	-0.158	175.53	0.26	138.6	254.4

Bootstrap Output Variable: F t

	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
Age 1	0.0000	0.0000	0.0000	0.40
Age 2	0.0000	0.0000	0.0000	0.28
Age 3	0.1299	0.1308	0.0379	0.29
Age 4	0.3235	0.3427	0.0903	0.28
Age 5	0.2379	0.2473	0.0870	0.37
Age 6	0.2807	0.2950	0.0649	0.23
Age 7	0.2807	0.2950	0.0649	0.23

	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
Age 1	0.0000000	0.0000000	11.102	0.0000002	0.45	0.0000	0.0000
Age 2	0.0000000	0.0000000	2.061	0.0000004	0.28	0.0000	0.0000
Age 3	0.0009154	0.0037909	0.705	0.1290096	0.29	0.0971	0.1965
Age 4	0.0191060	0.0090312	5.905	0.3044409	0.30	0.1845	0.4237
Age 5	0.0093784	0.0086969	3.942	0.2285263	0.38	0.1513	0.3723
Age 6	0.0142422	0.0064933	5.073	0.2664836	0.24	0.1895	0.3396
Age 7	0.0142422	0.0064933	5.073	0.2664836	0.24	0.1895	0.3396

Bootstrap Output Variable: F full t

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
0.2807	0.2950	0.0649	0.23

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
0.01424	0.00649	5.07	0.26648	0.24	0.1895	0.3396

Bootstrap Output Variable: SSB f mean

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
3605.2593	4297.8627	670.4795	0.19

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
692.603	67.048	19.21	2912.656	0.23	2947.5296	3711.4627

Bootstrap Output Variable: SSB spawn t

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
8178.8261	8495.8262	1257.3919	0.15

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
317.00	125.74	3.88	7861.83	0.16	6032.3126	9442.0787

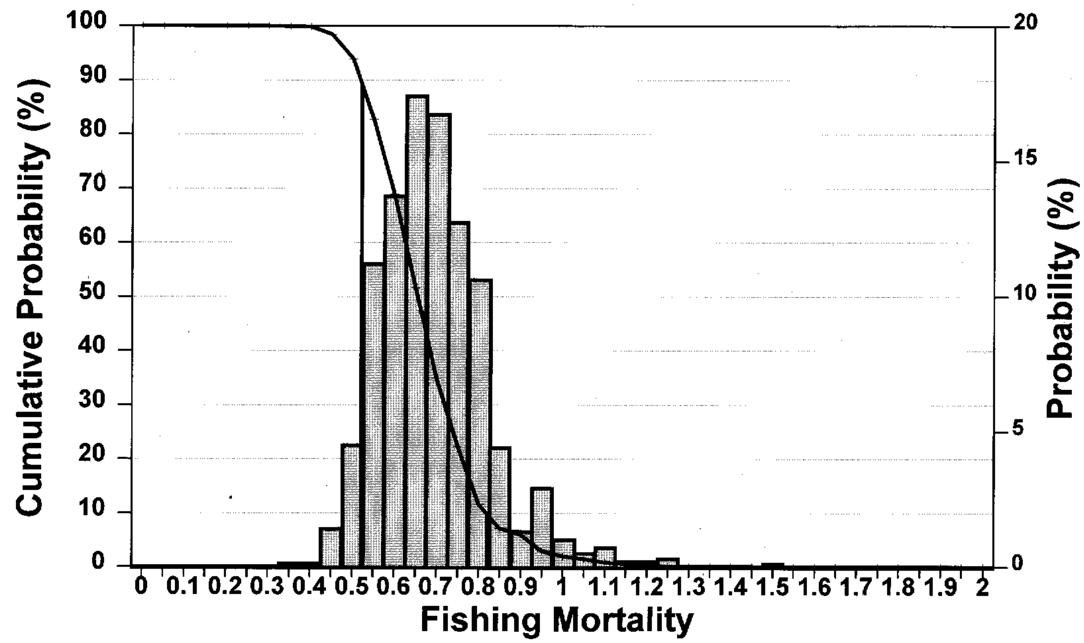
Bootstrap Output Variable: Jan 1 biomass

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP StdError	C.V. FOR NLLS SOLN
14743.7195	15242.0697	2036.2864	0.14

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V. FOR CORRECTED ESTIMATE	LOWER 80%CI	UPPER 80%CI
498.35	203.63	3.38	14245.37	0.14	11483.96	16397.45

Gulf of Maine Cod

Precision of 1998 F Estimate



Precision of 1998 SSB Estimate