S E D A R
Southeast Data, Assessment, and Review

SEDAR 17-AW09
Assessment Workshop Working Paper

Vermilion Snapper Surplus-production Model Results

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The Caribbean Fishery Management Council
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3.2 Surplus–Production Model

The logistic model for population growth is the simplest form of a differential equation which satisfies a number of ecologically realistic constraints, such as a carrying capacity (due to limited resources, for instance). When written in terms of stock biomass, this model specifies that

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2,$$

where B_t is biomass in year t, r is the intrinsic rate of increase in absence of density dependence, and K is population carrying capacity (Schaefer 1954; 1957). This equation may be rewritten to account for the effects of fishing by introducing an instantaneous fishing mortality term, F_t:

$$\frac{dB_t}{dt} = (r - F_t)B_t - \frac{r}{K}B_t^2.$$

By writing the term F_t as a function of catchability coefficients and effort expended by fishermen in different fisheries, Prager (1994) showed how to estimate model parameters from time series of yields and effort. These parameters can be estimated numerically using maximum likelihood, as with program ASPIC (Prager 1994; 1995).

3.2.1 Methods

A surplus production model was used as a supplement to the primary age-structured model. Production modeling used the ASPIC formulation and software of Prager (1994; 1995). This is an observation-error estimator of the continuous-time form of the Schaefer (logistic) production model Schaefer (1954; 1957).

Data included total landings in weight and a combined index based on commercial handline, MRFSS, and headboat surveys as well as the MARMAP fishery independent surveys using chevron traps and florida traps. Modeling was conditioned on effort since conditioning on catch would not produce reasonable model fits.

Fitting, achieved through maximum likelihood, was conditional on the statistical weights and constraints applied. Confidence intervals were estimated using bootstrap methods.

No projections were run using production model methods. Age-structured projections are considered more realistic and meaningful for management decisions.

3.2.1.1 Overview The production model CPUE data were adjusted to reflect the assumption of catchability increasing linearly at 2%/yr starting in 1976, the first year relative abundance estimates were available. The base run was structured to allow B_1/K to be estimated using maximum likelihood as the objective function (Table 1). Additional runs were made to examine model sensitivity to B_1/K values of 0.5 and 0.9. A sensitivity run was made using least absolute value (LAV) instead of maximum likelihood to reduce the fit to outliers. The catch times series was truncated to begin in 1976 since missing values of cpue are not allowed when conditioning on effort.

3.2.1.2 Data Sources

Landings The SEDAR 17 data workshop provided landings estimates for commercial data in whole pounds and recreational data in numbers of fish for years where data were available. Headboat and MRFSS recreational landings in numbers developed at the SEDAR 17–AW for input in numbers to the age structured model were the basis for developing landings for input into the surplus–production model. Landings estimtes in numbers were converted to pounds for each of the headboat and MRFSS surveys by multiplying by the average annual mean weight from the headboat fishery. Years prior the beginning of the headboat survey used the average annual mean weight from the first 5 years of the headboat survey (1972–1976). MRFSS mean weights were highly variable and were not used to convert MRFSS landings from numbers to weight in whole pounds.

Commercial Dead Discards The commercial working group suggested no discards prior to the first size limit implemented by management. The average weight of individual fish discarded from the commercial fishery was determined by finding the average length of fish below the size limit from annual length compositions prior to the size limit. The length–weight relationship was then used to determine the weight of the average discarded fish. The discard mortality rate suggested by the life history was applied to discard in numbers along with an additional mortality for fish kept for bait (see McCarthy working paper). The average weight was then multiplied by the dead discard estimate in numbers.

Recreational Dead Discards Discard estimates were provided by the SEDAR 17 DW panel for 2004–07 for the headboat survey and 1981–2007 for the MRFSS. Other values in the 1950–2007 time period were developed for the AW based on discard ratios from years where estimates were available and the landings estimates from the DW. In general the missing discard values were determined by 1)extrapolating discard ratios from appropriate years 2) applying the discard ratio to the landings in number, 3) multiplying by the discard mortality to give dead discards in number, and 4) converting from numbers to pounds using the average weight of fish below the appropriate size limit for each year.

Discard ratios were computed for years where landings and discards were estimated. Missing headboat discard ratios were determined for 1999–2003 by the average headboat discard ratio for 2004–2006. The 1992–1998 headboat discard ratio was computed as the 1999 discard ratio multiplied by the ratio of the average 1992–1998 MRFSS discard ratio divided by the 1999–2006 average MRFSS discard ratio. The pre–1992 headboat discard ratio was computed as the 1992 headbaot discard ratio multiplied by the ratio of the average 1981–1991 MRFSS discard ratio divided by the 1992–1998 average MRFSS discard ratio. The discard ratio time series for each fishery was applied to the landings in numbers to give discards in numbers. The recommended recreational discard mortality estimate was applied to the estimated discards along with the mortality estimated due to using vermilion snapper for bait (see McCarthy working paper SEDAR17-DW10). Annual mean weights by year were calculated by dividing the landings in weight by the number for each fishery. In 1992 the minimum size for vermilion snapper was set at 10 inches TL for recreational fishing and 12 inches TL for commercial. These minimum size limits correspond to approximately 25.5 and 30.5 cm. The VS_DW_summary.xls workbook provides length composition data from commercial hook and line, MRFSS, and headboat in 1 cm bins. The mean weight of fish discarded for each minimum size limit regulation was then calculated as $\sum_{1}^{r} P_i \, w_i / \sum_{1}^{r} P_i$ where (P_i) is the average proportion across years up to and including 1991 for each length bin(i) up to the minimum size limit (r) . The length–weight equation provided by the SEDAR 17 DW was used to estimate the weight in whole pounds at each length bin (w_i). The mean weight of discards was then multiplied by the discards in numbers to give discards in pounds. The dead discards were calculated as discards times the discard mortality suggested by the SEDAR 17 DW of 0.38 plus an additional mortality of 0.0535 attributed to using vermilion snapper as bait. The dead discards were combined with the total landings for input to the ASPIC model.

Relative abundance Estimates of relative abundance were provided by the SEDAR 17 DW for the headboat program, commercial logbooks, MRFSS, and MARMAP chevron traps and florida traps. These indices were combined into one index of catch per effort in pounds as described in SEDAR17–AW06.

The increase in catchability for all series of relative abundance was suggested to be 2% per year by the SEDAR 17 DW. We adjusted the relative abundance by dividing each year's relative abundance value by an annual catchability factor (1.0 in 1976 to 1.62 in 2007, incremented by 0.02 each year).

3.2.2 Model Results

3.2.2.1 Parameter Estimates and Associated Measures of Uncertainty

Parameter estimates for the base run (base)and sensitivity runs (B1K.05, B1K.09, and LAV) are presented in the ASPIC output, which is included as Appendix A, and in table 2. The model had difficulty fitting the data and was sensitive to small changes in the data when conditioned on catch. Therefore, all runs were conditioned on effort instead of catch. The base run estimates B_1/K and utilizes sum of squared errors as the objective function. The B1k0.5 run differs from the base run only in fixing B_1/K at 0.5. The B1k0.9 run differs from the base run only in fixing B_1/K at 0.9. These two runs bracketed the estimated B_1/K of 0.7

estimated by the base run. The "LAV" sensitivity was run to evaluate the effect of outliers on the fit and differs from the base run in that the least absolute value was set as the objective function. The sensitivity runs gave similar estimates of relative biomass and relative fishing rate compared to the base run (Figures 1 and 2). Overall, the final estimates of relative biomass and relative fishing rate are insensitive to the starting value of B_1/K. All of the runs fit the combined index reasonably well except that they had difficulty fitting the index since about 2000 (Figure 3). The base run fit the landings adequately (Figure 4).

We explored the base run using 1000 bootstrap runs to generate 80% confidence intervals (Figure 5) and evaluate the shape of the distribution (Figure 6) of the current relative fishing mortality rate F/F_{MSY} and biomass relative to the minimum spawning stock threshold B/MSST.

3.2.2.2 Stock Abundance and Fishing Mortality Estimates of biomass relative to B_{MSY} and fishing mortality rate relative to F_{MSY} from the production model are shown in figure 5. Table 2 shows results of runs that examine sensitivity to assumptions on starting biomass and choice of objective function.

3.2.3 Discussion

The ASPIC model fit the data and estimated B_1/K at 0.700 in 1976, which falls within the range of values expected. Combining the indices allowed the model to fit the data without the added difficulty of resolving conflicts among the indices. The lack of fit to the more recent part of the cpue time series may be due to an effect of the 1999 management measures on catch. Another possible run might split the index time series at 1999 if further exploration of the production model is warranted. The production model estimates that current stock size is slightly above B/MSST and that the current level of fishing is slightly above the limit reference point F_{MSY}. In general the surplus production model does not account for changes in the age or size structure of the population. The length and age composition suggest there have been shifts in the size and age structure of the population and an age structured model is may be more informative in assessing the vermilion snapper stock.

3.2.4 Tables

Table 1. Base model and sensitivity run model specification.

Run	B_1/K	Objective Function
B1K0.5	0.500	Maximum Likelihood
base	estimated	Maximum Likelihood
B1K0.9	0.900	Maximum Likelihood
LAV	estimated	Least Absolute Value

Table 2. ASPIC model results at fixed B_1/K values from 0.5 – 0.9 and estimated B_1/K values with sum squared error fit (base) and least absolute value fit (LAV)

Run	B_1/K	MSY	F_{MSY}	B_{MSY}	K	r	B/B_{MSY}	F/F_{MSY}	yield.eq
B1K0.5	0.500	1.43E+06	0.611	2.34E+06	4.69E+06	1.223	0.871	1.311	1.41E+06
base	0.700	1.42E+06	0.551	2.58E+06	5.16E+06	1.102	0.922	1.257	1.41E+06
B1K0.9	0.900	1.42E+06	0.549	2.59E+06	5.17E+06	1.098	0.958	1.212	1.42E+06
LAV	0.710	1.41E+06	0.584	2.41E+06	4.82E+06	1.167	0.837	1.359	1.37E+06

3.2.5 Figures

Figure 1. Vermilion Snapper in Atlantic: Production model estimates of relative biomass. Catchability increasing since 1976 and conditioned on effort. Base run (base) and least absolute value run (LAV) estimate B_1/K while B1K.5 and B1K.9 fix B_1/K at 0.5 and 0.9 respectively.

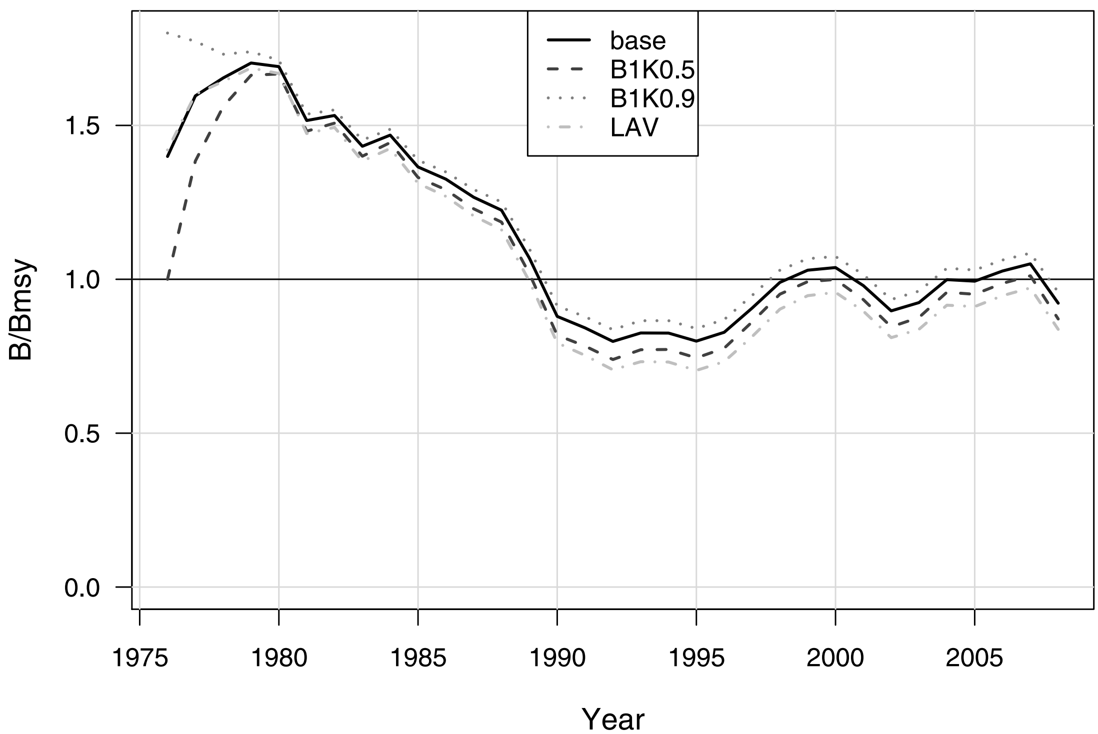


Figure 2. Vermilion Snapper in Atlantic: Production model estimiates of relative fishing mortality rate. Catchability increasing since 1976 and conditioned on effort. Base run (base) and least absolute value run (LAV) estimate B_1/K while B1K.5 and B1K.9 fix B_1/K at 0.5 and 0.9 respectively.

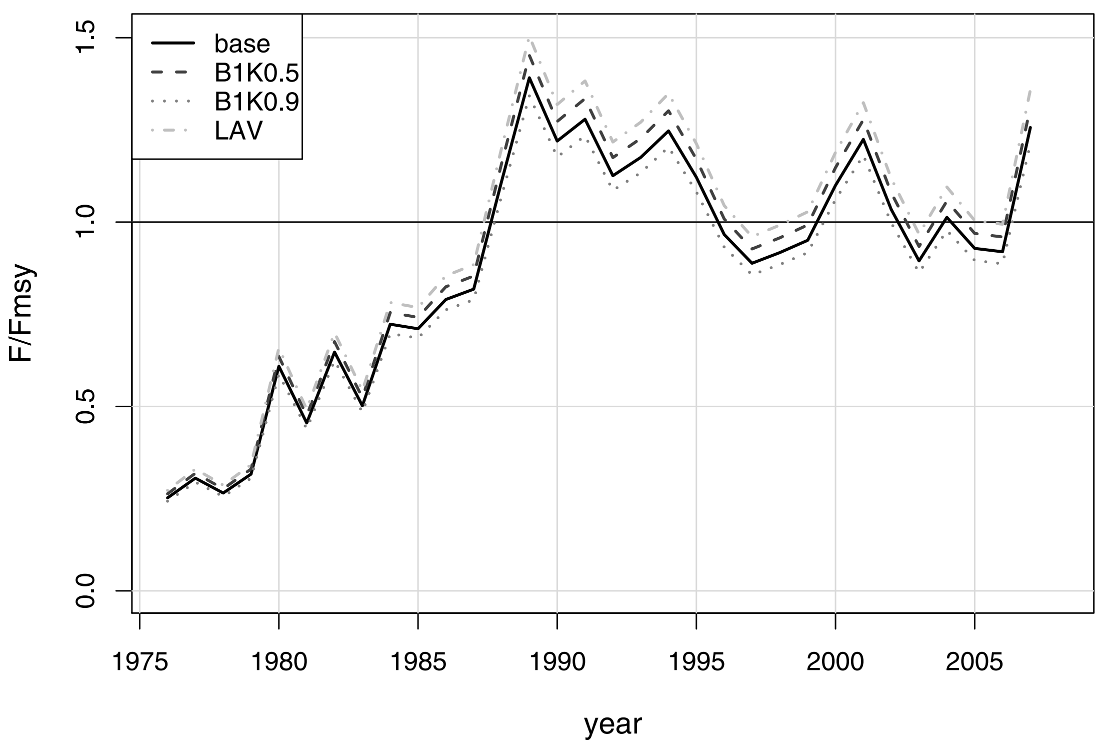


Figure 3. Vermilion Snapper in Atlantic: Fit of production models to combined index. Catchability increasing since 1976 and conditioned on effort. Base run (base) and least absolute value run (LAV) estimate B_1/K while B1K.5 and B1K.9 fix B_1/K at 0.5 and 0.9 respectively.

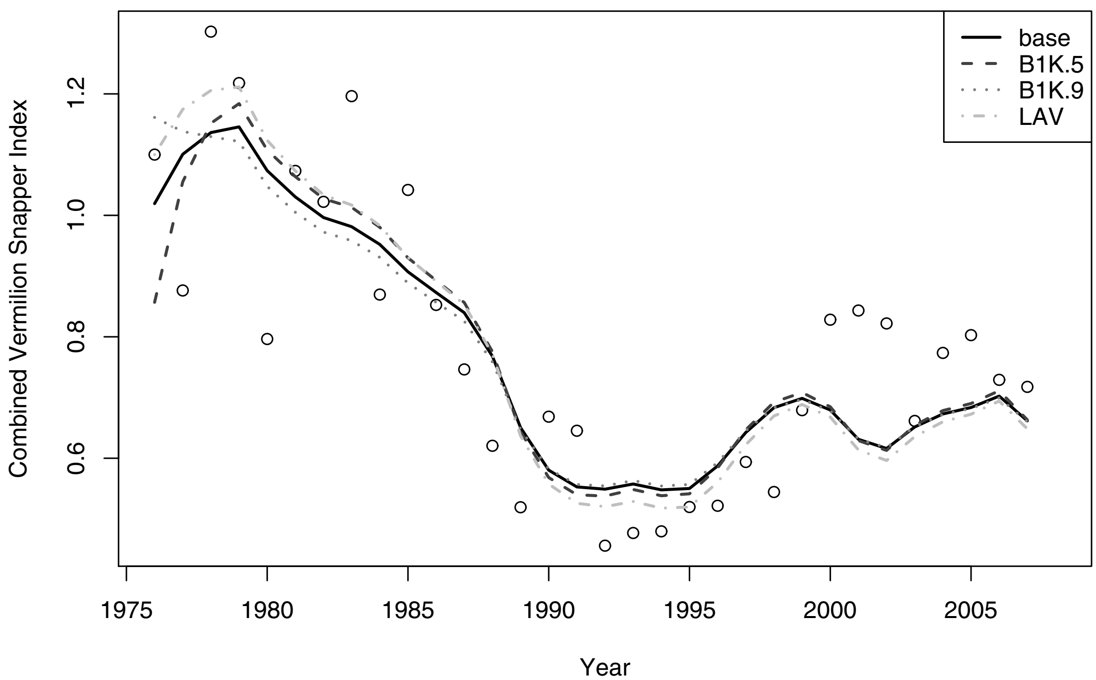


Figure 4. Vermilion Snapper in Atlantic: Production model fit to landings. Catchability increasing since 1976 and B_1/K estimated.

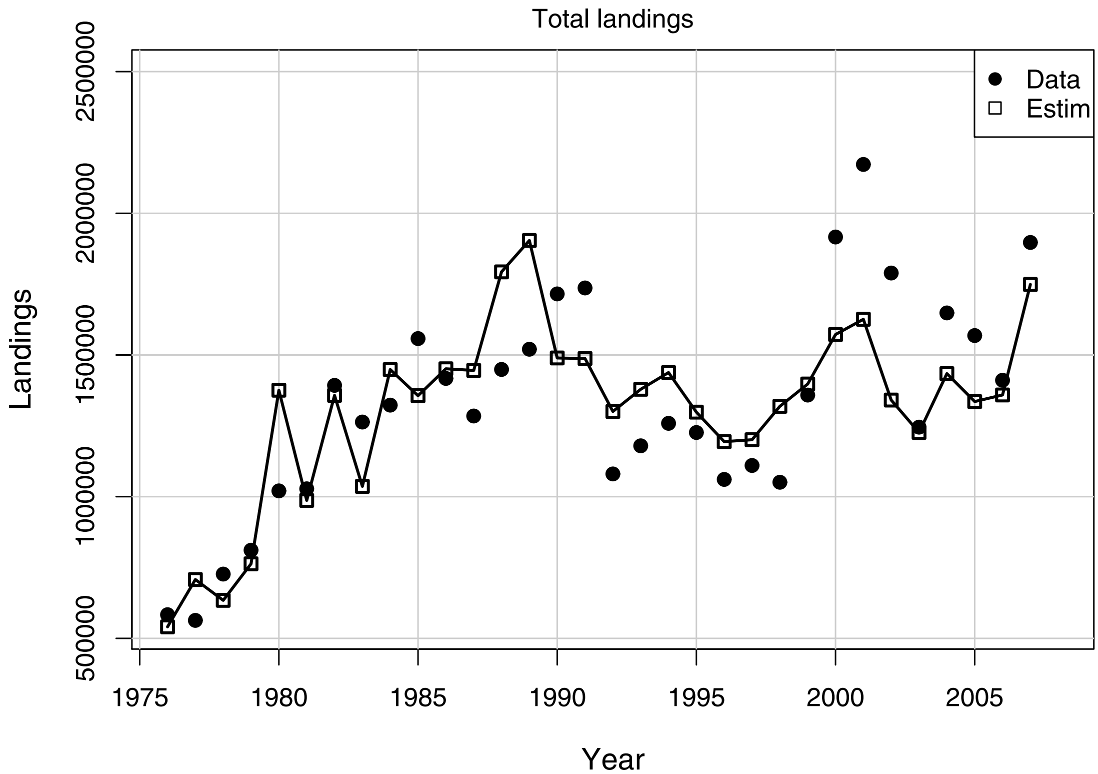


Figure 5. Vermilion Snapper in Atlantic: Production model estimates of biomass/MSST and F/Fmsy for the base run with B_1/K estimated. The 80% confidence interval is represented by the dotted line.

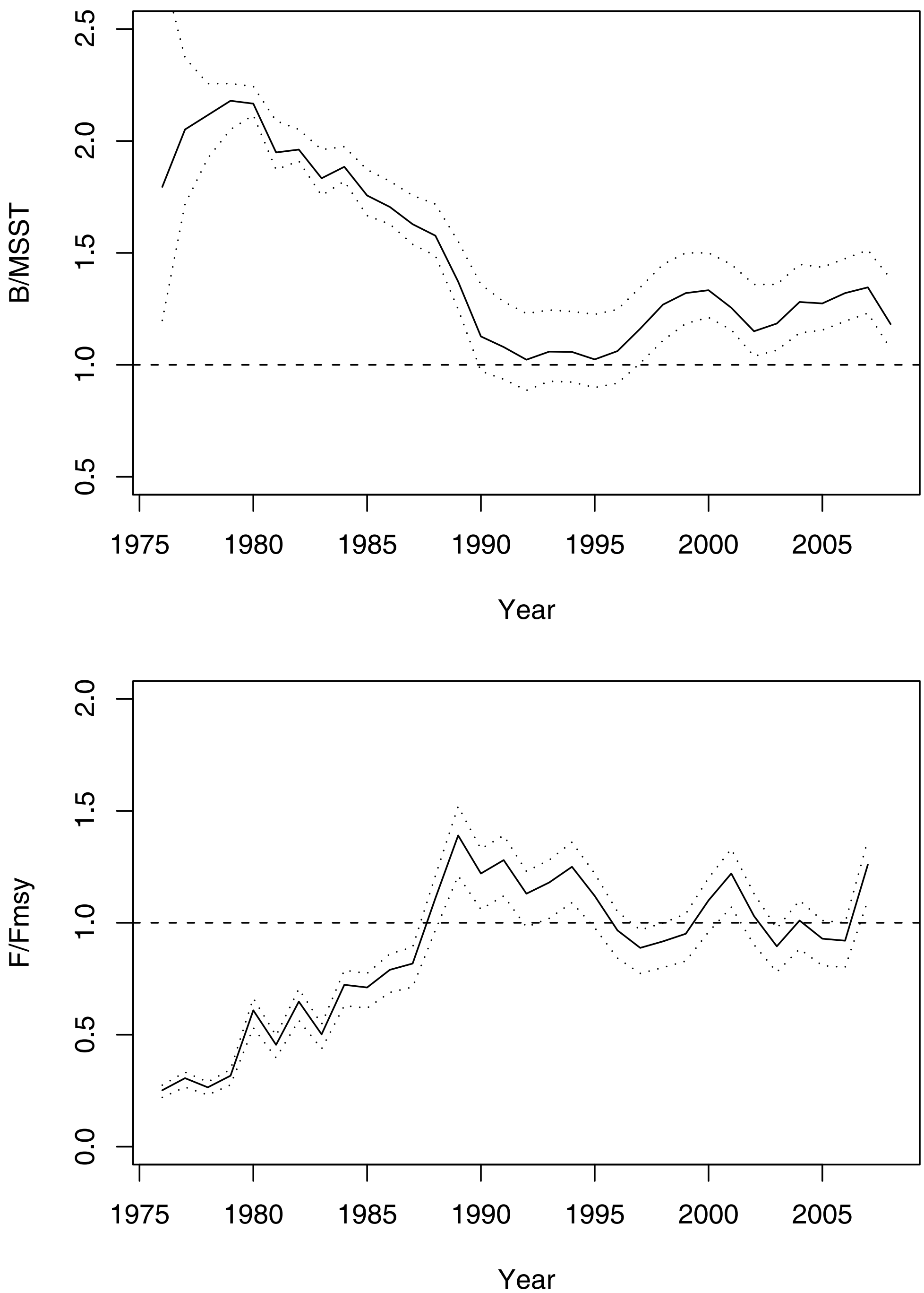
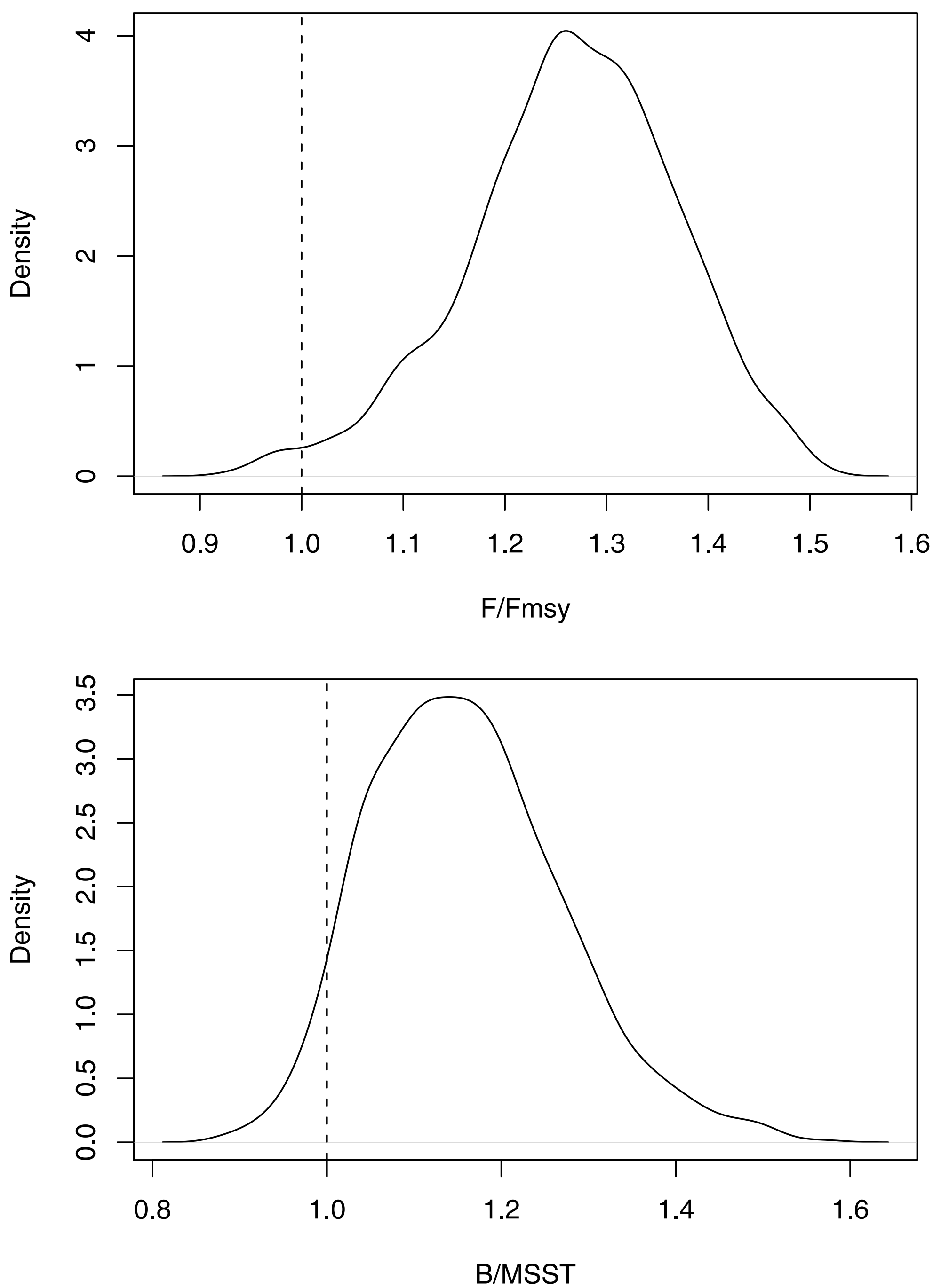


Figure 6. Vermilion Snapper in Atlantic: Kernel density plots of 1000 bootstrap runs of the base model for B/MSST and F/F_{MSY} with B_1/K estimated.



References

Prager, M. H. 1994. A suite of extensions to a nonequilibrium surplus–production model. Fishery Bulletin 92: 374–389.

Prager, M. H. 1995. User's manual for ASPIC: A stock-production model incorporating covariates, program version 3.6x. NMFS Southeast Fisheries Science Center, Miami Laboratory Document MIA–2/93–55, 4th ed.

Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bulletin of the Inter-American Tropical Tuna Commission 1(2): 27–56.

Schaefer, M. B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bulletin of the Inter-American Tropical Tuna Commission 2: 247–268.

Appendix A ASPIC (Production Model) Input – Output

A.1 Aspic Input – base run

```
bot                        Run Mode
'SAFMC Vermilion Snapper SEDAR 17 (2007) Landings and Combined Indices'
LOGISTIC EFT SSE       Modeltype, conditioning, loss fn
112                        Verbosity
1000                        N Bootstraps
1  100000                   Monte Carlo
1d-8                       Conv (fit)
3d-8  6                    Conv (restart), N restarts
1d-4  20                    Conv (F), steps/yr for generalized
8d0                         Max F allowed
0d0                         Weight for B1>K
1                         Number of series
1.0d0                 Series weights
0.5d0                      B1/K guess
2.0e6                      MSY guess
2.0e7                      K guess
5d-8                       q guess
1 1 1 1                  Estimate flags
2e4  2e7                   MSY bounds
1e6  1e9                   K bounds
82184571                   Random seed
32                       Number of years
"Combined Index (1950-2006), Total Ldgs whole pounds"
"CC"

1976 1.100024 583414
1977 0.876247059 563384
1978 1.302483654 726839
1979 1.21780283 811081
1980 0.79635963 1020397
1981 1.073162727 1027764
1982 1.022236607 1392756
1983 1.196282456 1263344
1984 0.869518103 1322975
1985 1.041830508 1557868
1986 0.852481667 1417236
1987 0.746255246 1284662
1988 0.620532419 1448931
1989 0.519260159 1520241
1990 0.668441719 1715556
1991 0.645261923 1736479
1992 0.456011061 1080203
1993 0.476882015 1179460
1994 0.479594779 1258760
1995 0.519694928 1226414
1996 0.521738143 1060844
1997 0.59382993 1110001
1998 0.544400417 1050848
1999 0.679140342 1358523
2000 0.828120946 1916343
2001 0.843245333 2172376
2002 0.821976974 1789222
2003 0.66145        1245289
2004 0.773426282 1648409
2005 0.802713924 1568545
```

```
2006 0.729148125 1410770
2007 0.717541358 1897132


Note: Source of data is file "SM_AW_input.xls" dated 14 aug 2008, prepared by RTC
This input file prepared by RTC, 14 AUG 2008 using the combined index per Paul Conn
```

A.2 Aspic Output – base run

```
SAFMC Vermilion Snapper SEDAR 17 (2007) Landings and Combined Indices                               Page 1
                                                                            Wednesday, 27 Aug 2008 at 14:41:25
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.30)
                                                                                              BOT program mode
Author:     Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research        LOGISTIC model mode
            101 Pivers Island Road; Beaufort, North Carolina  28516  USA                     EFT conditioning
            Mike.Prager@noaa.gov                                                             SSE optimization

Reference:  Prager, M. H. 1994. A suite of extensions to a nonequilibrium            ASPIC User's Manual is available
            surplus-production model.  Fishery Bulletin 92: 374-389.                       gratis from the author.

CONTROL PARAMETERS (FROM INPUT FILE)                 Input file: e:\sedar17-vs-aspic\vs2008_b1k_est_eft_2pct_bot.inp
------------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization with bootstrap.
Number of years analyzed:                         32          Number of bootstrap trials:                       1000
Number of data series:                             1          Bounds on MSY (min, max):       2.000E+04     2.000E+07
Objective function:                    Least squares          Bounds on K (min, max):         1.000E+06     1.000E+09
Relative conv. criterion (simplex):        1.000E-08          Monte Carlo search mode, trials:        1        100000
Relative conv. criterion (restart):        3.000E-08          Random number seed:                             82184571
Relative conv. criterion (effort):         1.000E-04          Identical convergences required in fitting:          6
Maximum F allowed in fitting:                    N/A


PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                               error code   0
------------------------------------------------------------------------------------------------------------------------
Normal convergence


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
------------------------------------------------------------------------------------------------------------------------
                                                    Weighted           Weighted      Current    Inv. var.    R-squared
Loss component number and title                          SSE      N         MSE       weight       weight      in CPUE

Loss(0)   Penalty for B1 > K                       0.000E+00      1         N/A    0.000E+00          N/A
Loss(1)   Combined Index (1950-2006), Total Ldgs   8.052E-01     32   2.684E-02    1.000E+00    1.000E+00        0.704
.............................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:          8.05173422E-01          2.876E-02    1.696E-01
Estimated contrast index (ideal = 1.0):               0.4523          C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):               1.0000          N* = 1 - |min(B-Bmsy)|/K


MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
------------------------------------------------------------------------------------------------------------------------
Parameter                                           Estimate    User/pgm guess    2nd guess    Estimated   User guess

B1/K      Starting relative biomass (in 1976)      6.996E-01         5.000E-01    7.912E-01            1            1
MSY       Maximum sustainable yield                1.421E+06         2.000E+06    1.125E+06            1            1
K         Maximum population size                  5.160E+06         2.000E+07    6.752E+06            1            1
phi       Shape of production curve (Bmsy/K)       0.5000            0.5000            ----            0            1

--------- Catchability Coefficients by Data Series ---------------
q(1)      Combined Index (1950-2006), Total Ldgs   2.618E-07         5.000E-08    4.750E-06            1            1


MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
------------------------------------------------------------------------------------------------------------------------
Parameter                                           Estimate              Logistic formula           General formula

MSY       Maximum sustainable yield                1.421E+06                          ----                      ----
```

Bmsy	Stock biomass giving MSY	2.580E+06	K/2	K*n**(1/(1-n))
Fmsy	Fishing mortality rate at MSY	5.509E-01	MSY/Bmsy	MSY/Bmsy
n	Exponent in production function	2.0000	----	----
g	Fletcher's gamma	4.000E+00	----	[n**(n/(n-1))]/[n-1]
B./Bmsy	Ratio: B(2008)/Bmsy	9.224E-01	----	----
F./Fmsy	Ratio: F(2007)/Fmsy	1.257E+00	----	----
Fmsy/F.	Ratio: Fmsy/F(2007)	7.958E-01	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2008	1.311E+06	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	9.224E-01	----	----
Ye.	Equilibrium yield available in 2008	1.413E+06	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	9.940E-01	----	----

--------- Fishing effort rate at MSY in units of each CE or CC series ---------

fmsy(1)	Combined Index (1950-2006), Total Ldgs	2.104E+06	Fmsy/q(1)	Fmsy/q(1)

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1976	0.139	3.610E+06	3.893E+06	5.834E+05	5.406E+05	1.048E+06	2.521E-01	1.399E+00
2	1977	0.168	4.117E+06	4.203E+06	5.634E+05	7.076E+05	8.579E+05	3.056E-01	1.596E+00
3	1978	0.146	4.268E+06	4.340E+06	7.268E+05	6.341E+05	7.594E+05	2.652E-01	1.654E+00
4	1979	0.174	4.393E+06	4.375E+06	8.111E+05	7.630E+05	7.325E+05	3.165E-01	1.703E+00
5	1980	0.335	4.363E+06	4.100E+06	1.020E+06	1.376E+06	9.240E+05	6.090E-01	1.691E+00
6	1981	0.251	3.911E+06	3.935E+06	1.028E+06	9.867E+05	1.029E+06	4.551E-01	1.516E+00
7	1982	0.357	3.953E+06	3.805E+06	1.393E+06	1.358E+06	1.099E+06	6.475E-01	1.532E+00
8	1983	0.277	3.695E+06	3.748E+06	1.263E+06	1.036E+06	1.130E+06	5.019E-01	1.432E+00
9	1984	0.398	3.788E+06	3.636E+06	1.323E+06	1.449E+06	1.182E+06	7.231E-01	1.468E+00
10	1985	0.392	3.521E+06	3.464E+06	1.558E+06	1.356E+06	1.254E+06	7.107E-01	1.365E+00
11	1986	0.435	3.419E+06	3.334E+06	1.417E+06	1.451E+06	1.299E+06	7.901E-01	1.325E+00
12	1987	0.451	3.268E+06	3.207E+06	1.285E+06	1.446E+06	1.337E+06	8.181E-01	1.267E+00
13	1988	0.611	3.159E+06	2.933E+06	1.449E+06	1.793E+06	1.392E+06	1.110E+00	1.225E+00
14	1989	0.767	2.758E+06	2.484E+06	1.520E+06	1.904E+06	1.415E+06	1.391E+00	1.069E+00
15	1990	0.672	2.269E+06	2.216E+06	1.716E+06	1.489E+06	1.393E+06	1.220E+00	8.794E-01
16	1991	0.705	2.172E+06	2.111E+06	1.736E+06	1.487E+06	1.374E+06	1.279E+00	8.420E-01
17	1992	0.620	2.059E+06	2.097E+06	1.080E+06	1.301E+06	1.372E+06	1.126E+00	7.981E-01
18	1993	0.648	2.130E+06	2.129E+06	1.179E+06	1.379E+06	1.378E+06	1.175E+00	8.256E-01
19	1994	0.687	2.129E+06	2.093E+06	1.259E+06	1.438E+06	1.371E+06	1.247E+00	8.252E-01
20	1995	0.618	2.062E+06	2.101E+06	1.226E+06	1.298E+06	1.372E+06	1.122E+00	7.991E-01
21	1996	0.532	2.136E+06	2.243E+06	1.061E+06	1.194E+06	1.396E+06	9.663E-01	8.278E-01
22	1997	0.489	2.338E+06	2.454E+06	1.110E+06	1.201E+06	1.417E+06	8.884E-01	9.062E-01
23	1998	0.505	2.554E+06	2.609E+06	1.051E+06	1.319E+06	1.421E+06	9.174E-01	9.900E-01
24	1999	0.524	2.656E+06	2.668E+06	1.359E+06	1.398E+06	1.420E+06	9.507E-01	1.030E+00
25	2000	0.606	2.678E+06	2.595E+06	1.916E+06	1.572E+06	1.421E+06	1.100E+00	1.038E+00
26	2001	0.675	2.527E+06	2.411E+06	2.172E+06	1.626E+06	1.414E+06	1.224E+00	9.794E-01
27	2002	0.570	2.315E+06	2.353E+06	1.789E+06	1.341E+06	1.410E+06	1.034E+00	8.974E-01
28	2003	0.493	2.385E+06	2.488E+06	1.245E+06	1.227E+06	1.419E+06	8.947E-01	9.243E-01
29	2004	0.558	2.577E+06	2.570E+06	1.648E+06	1.434E+06	1.421E+06	1.013E+00	9.989E-01
30	2005	0.512	2.564E+06	2.611E+06	1.569E+06	1.336E+06	1.421E+06	9.287E-01	9.939E-01
31	2006	0.507	2.650E+06	2.682E+06	1.411E+06	1.359E+06	1.419E+06	9.195E-01	1.027E+00
32	2007	0.692	2.710E+06	2.526E+06	1.897E+06	1.749E+06	1.419E+06	1.257E+00	1.050E+00
33	2008		2.380E+06						9.224E-01

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Combined Index (1950-2006), Total Ldgs w

Data type CC: CPUE-catch series Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log yield	Statist weight
1	1976	1.100E+00	1.019E+00	0.1389	5.834E+05	5.406E+05	0.07623	1.000E+00
2	1977	8.762E-01	1.101E+00	0.1683	5.634E+05	7.076E+05	-0.22794	1.000E+00
3	1978	1.302E+00	1.136E+00	0.1461	7.268E+05	6.341E+05	0.13650	1.000E+00
4	1979	1.218E+00	1.146E+00	0.1744	8.111E+05	7.630E+05	0.06106	1.000E+00
5	1980	7.964E-01	1.074E+00	0.3355	1.020E+06	1.376E+06	-0.29871	1.000E+00
6	1981	1.073E+00	1.030E+00	0.2508	1.028E+06	9.867E+05	0.04073	1.000E+00
7	1982	1.022E+00	9.964E-01	0.3567	1.393E+06	1.358E+06	0.02561	1.000E+00
8	1983	1.196E+00	9.813E-01	0.2765	1.263E+06	1.036E+06	0.19810	1.000E+00
9	1984	8.695E-01	9.521E-01	0.3984	1.323E+06	1.449E+06	-0.09074	1.000E+00
10	1985	1.042E+00	9.070E-01	0.3915	1.558E+06	1.356E+06	0.13860	1.000E+00
11	1986	8.525E-01	8.730E-01	0.4353	1.417E+06	1.451E+06	-0.02374	1.000E+00
12	1987	7.463E-01	8.397E-01	0.4507	1.285E+06	1.446E+06	-0.11796	1.000E+00
13	1988	6.205E-01	7.680E-01	0.6114	1.449E+06	1.793E+06	-0.21321	1.000E+00
14	1989	5.193E-01	6.504E-01	0.7666	1.520E+06	1.904E+06	-0.22514	1.000E+00
15	1990	6.684E-01	5.804E-01	0.6720	1.716E+06	1.489E+06	0.14131	1.000E+00
16	1991	6.453E-01	5.527E-01	0.7046	1.736E+06	1.487E+06	0.15477	1.000E+00
17	1992	4.560E-01	5.491E-01	0.6202	1.080E+06	1.301E+06	-0.18571	1.000E+00
18	1993	4.769E-01	5.576E-01	0.6476	1.179E+06	1.379E+06	-0.15632	1.000E+00
19	1994	4.796E-01	5.479E-01	0.6872	1.259E+06	1.438E+06	-0.13319	1.000E+00
20	1995	5.197E-01	5.502E-01	0.6179	1.226E+06	1.298E+06	-0.05695	1.000E+00
21	1996	5.217E-01	5.874E-01	0.5324	1.061E+06	1.194E+06	-0.11847	1.000E+00
22	1997	5.938E-01	6.425E-01	0.4894	1.110E+06	1.201E+06	-0.07873	1.000E+00
23	1998	5.444E-01	6.833E-01	0.5054	1.051E+06	1.319E+06	-0.22718	1.000E+00
24	1999	6.791E-01	6.986E-01	0.5238	1.359E+06	1.398E+06	-0.02831	1.000E+00
25	2000	8.281E-01	6.794E-01	0.6059	1.916E+06	1.572E+06	0.19789	1.000E+00
26	2001	8.432E-01	6.312E-01	0.6745	2.172E+06	1.626E+06	0.28969	1.000E+00
27	2002	8.220E-01	6.160E-01	0.5699	1.789E+06	1.341E+06	0.28842	1.000E+00
28	2003	6.614E-01	6.515E-01	0.4930	1.245E+06	1.227E+06	0.01519	1.000E+00
29	2004	7.734E-01	6.729E-01	0.5581	1.648E+06	1.434E+06	0.13919	1.000E+00
30	2005	8.027E-01	6.835E-01	0.5116	1.569E+06	1.336E+06	0.16071	1.000E+00
31	2006	7.291E-01	7.023E-01	0.5066	1.411E+06	1.359E+06	0.03746	1.000E+00
32	2007	7.175E-01	6.615E-01	0.6923	1.897E+06	1.749E+06	0.08135	1.000E+00

ESTIMATES FROM BOOTSTRAPPED ANALYSIS

Param name	Point estimate	Estimated bias in pt estimate	Estimated relative bias	Bias-corrected approximate confidence limits: 80% lower	80% upper	50% lower	50% upper	Inter-quartile range	Relative IQ range
B1/K	6.996E-01	8.381E-03	1.20%	4.676E-01	1.082E+00	5.706E-01	8.977E-01	3.271E-01	0.468
K	5.160E+06	3.115E+05	6.04%	2.623E+06	8.770E+06	3.761E+06	6.820E+06	3.059E+06	0.593
q(1)	2.618E-07	5.039E-08	19.25%	1.477E-07	4.966E-07	1.936E-07	3.520E-07	1.584E-07	0.605
MSY	1.421E+06	6.507E+03	0.46%	1.345E+06	1.483E+06	1.377E+06	1.449E+06	7.211E+04	0.051
Ye(2008)	1.413E+06	-8.376E+03	-0.59%	1.348E+06	1.502E+06	1.383E+06	1.463E+06	8.020E+04	0.057
Y.@Fmsy	1.311E+06	-1.802E+04	-1.37%	1.186E+06	1.602E+06	1.259E+06	1.465E+06	2.065E+05	0.157
Bmsy	2.580E+06	1.557E+05	6.04%	1.312E+06	4.385E+06	1.880E+06	3.410E+06	1.529E+06	0.593
Fmsy	5.509E-01	1.050E-01	19.06%	3.168E-01	1.065E+00	4.086E-01	7.434E-01	3.348E-01	0.608

fmsy(1)	2.104E+06	-1.986E+03	-0.09%	1.932E+06	2.414E+06	2.017E+06	2.250E+06	2.338E+05	0.111
B./Bmsy	9.224E-01	-1.737E-02	-1.88%	8.363E-01	1.080E+00	8.852E-01	1.012E+00	1.272E-01	0.138
F./Fmsy	1.257E+00	9.668E-03	0.77%	1.095E+00	1.369E+00	1.175E+00	1.312E+00	1.366E-01	0.109
Ye./MSY	9.940E-01	-1.039E-02	-1.05%	9.775E-01	1.000E+00	9.899E-01	9.997E-01	9.830E-03	0.010

INFORMATION FOR REPAST (Prager, Porch, Shertzer, & Caddy. 2003. NAJFM 23: 349-361)

Unitless limit reference point in F (Fmsy/F.): 0.7958
CV of above (from bootstrap distribution): 0.8465E-01

NOTES ON BOOTSTRAPPED ESTIMATES:

- Bootstrap results were computed from 1000 trials.
- Results are conditional on bounds set on MSY and K in the input file.
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The default 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- Bias estimates are typically of high variance and therefore may be misleading.

Trials replaced for lack of convergence: 0
Trials replaced for q out-of-bounds: 0
Trials replaced for K out-of-bounds: 0
Trials replaced for MSY out of bounds: 0
Residual-adjustment factor: 1.0690

Elapsed time: 0 hours, 1 minutes, 46 seconds.