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

SEDAR 17-AW10
Assessment Workshop Working Paper

Spanish Mackerel 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 from the commercial handline, commercial gillnet, commercial castnet, and commercial poundnet. Recreational landings were estimated in numbers from the MRFSS and headboat surveys and then converted to weights using annual mean weights. A combined index was developed based on commercial surveys from two series of FL gillnet, FL castnet, FL handlines, MRFSS, GA-NY gillnet, and GA-NY handline.

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 did not assume catchability increase as with other recent SEDAR assessments because advances in technology, primarily GPS, would not have as great an effect on spanish mackerel catchability. The base run was structured to allow B_1/K to be estimated with the objective function set to least absolute value (LAV) to minimize the influence of outliers in the combined index. Additional runs were made to examine model sensitivity to B_1/K values and selection of the objective function.

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. Headboat and MRFSS recreational landings in whole pounds were developed using the same method to generate the landings in number time series for input into the age structured model. The headboat landings in whole pounds for 1981–2007 were provided by the headboat survey. The 1946 value of headboat landings was set to 0 and the 1980 landings were computed as an average of the 1981–83 headboat landings. Linear interpolation was used to compute the landings from 1947–1979. The 1960, 65, and 70 MRFSS landings in pounds were estimated by subtracting the headboat landings in number for those years from the Salt–Water Angling Survey estimates and multiplying by the mean weight of MRFSS fish from 1981–1985. The 1950 landings were estimated as the average of the 1960, 65, and 70 MRFSS landings in pounds. The remaining missing years in the MRFSS landings time series were derived through linear interpolation between the available years.

Commercial Dead Discards Discard estimates were provided in numbers for commercial and recreational data sources by the SEDAR 17 DW. 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 weight of an age 0 fish (0.34 pounds) using the growth formula provided by the SEDAR 17 DW. The individual discard weight was then multiplied by the discard estimate in numbers and by the discard mortality estimate from the DW of 0.88.

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 developed for MRFSS and headboat. In years where both landings and discards were available the discard estimate was divided by the landings estimate. The 1981–2003 headboat discard ratios were computed as the average of the 2004–06 discard ratios. Headboat discards prior to 1981 were assumed to be 0. Discard estimates in numbers were computed for missing years as landings multiplied by the discard ratio for that year. MRFSS and headboat discards in whole pounds were derived by multiplying the average weight of discards for MRFSS in 1981 and 1982 prior to size regulations by the discard estimates in numbers.

The average weight of discarded fish from the MRFSS was determined by finding length of fish below the size limit from annual length compositions prior to the size limit, $\sum_1^r P_i\, w_i / \sum_1^r P_i$ where (P_i) is the average proportion across years 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 dead discards were calculated as discards times the discard mortality suggested by the SEDAR 17 DW of 0.88. 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 two series of FL gillnet, FL castnet, FL handlines, MRFSS, GA-NY gillnet, and GA-NY handline fisheries. These indices were combined into one index of catch per effort in pounds as described in SEDAR17–AW06.

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 (LAV.B1K.5, SSE.B1K.5, and SSE.B1K.est) are presented in the ASPIC output, which is included as Appendix A. All model runs were conditioned on catch. The base run estimates B_1/K and utilizes least absolute value (LAV) as the objective function. The SSE.B1K.5 and LAV.B1K.5 runs differs from the base run in fixing B_1/K at 0.5. The SSE.B1K.5 run uses maximum likelihood as the objective function. The LAV objective function was chosen to minimize the effect of outliers on the fit.

The two objective functions give a slightly different estimates of relative biomass (Figure 1). Each of the sensitivity runs differ only slightly from the base run in the estimated relative fishing rate Figure 2. Overall, the final estimates of relative biomass and relative fishing rate are insensitive to the starting value of B_1/K. The estimated combined index fits varied in the time period where no index was available. By about 1975 the variability in B_1/K does not effect the fit to the index with each of the types of objective functions. However, the different objective functions give a moderately different fit to the combined index (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 base run of 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 0.76 in 1950. Intuitively this estimate seems to be within the realm of probable values given the number of years of fishing prior to 1950. The current status appears to be insensitive to B_1/K. Combining the indices allowed the model to fit the data without the added difficulty of resolving conflicts among the indices. The size limit of 12 inches imposed in Florida in 1983 and coast wide in 1985 seems to have had a positive impact on the current stock status. The production model estimates that current stock size is above MSST and that the current level of fishing is below the limit reference point F_{MSY}. However, 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 more appropriate to assess the vermilion snapper stock.

3.2.4 Tables

Table 1. Base model and sensitivity run model specification.

Run	B_1/K	Objective Function
LAV.B1K.5	0.500	Least Absolute Value
base	estimated	Least Absolute Value
SSE.B1K.5	0.500	Maximum Likelihood
SSE.B1K.est	estimated	Maximum Likelihood

Table 2. ASPIC model results at a fixed B_1/K value of 0.5 (LAV.B1K.5 and SSE.B1K.5) and estimated B_1/K values using both the least absolute value fit (base) and sum squared error fit (SSE.B1K.est)

Run	B1.K	MSY	Fmsy	Bmsy	K	r	b.bmsy	F.Fmsy	yield.eq
LAV.B1K.5	0.500	1.44E+07	0.067	2.16E+08	4.32E+08	0.134	1.598	0.213	9.27E+06
base	0.755	1.24E+07	0.082	1.51E+08	3.02E+08	0.164	1.604	0.248	7.86E+06
SSE.B1K.5	0.500	1.57E+07	0.153	1.03E+08	2.06E+08	0.306	1.801	0.173	5.64E+06
SSE.B1K.est	0.725	1.60E+07	0.377	4.25E+07	8.50E+07	0.754	1.822	0.168	5.21E+06

3.2.5 Figures

Figure 1. Spanish Mackerel in Atlantic: Production model estimates of relative biomass. Base run (base) and maximum likelihood run (SSE.B1K.est)) estimate B_1/K while LAV.B1K.5 and SSE.B1K.5 fix B_1/K at 0.5.

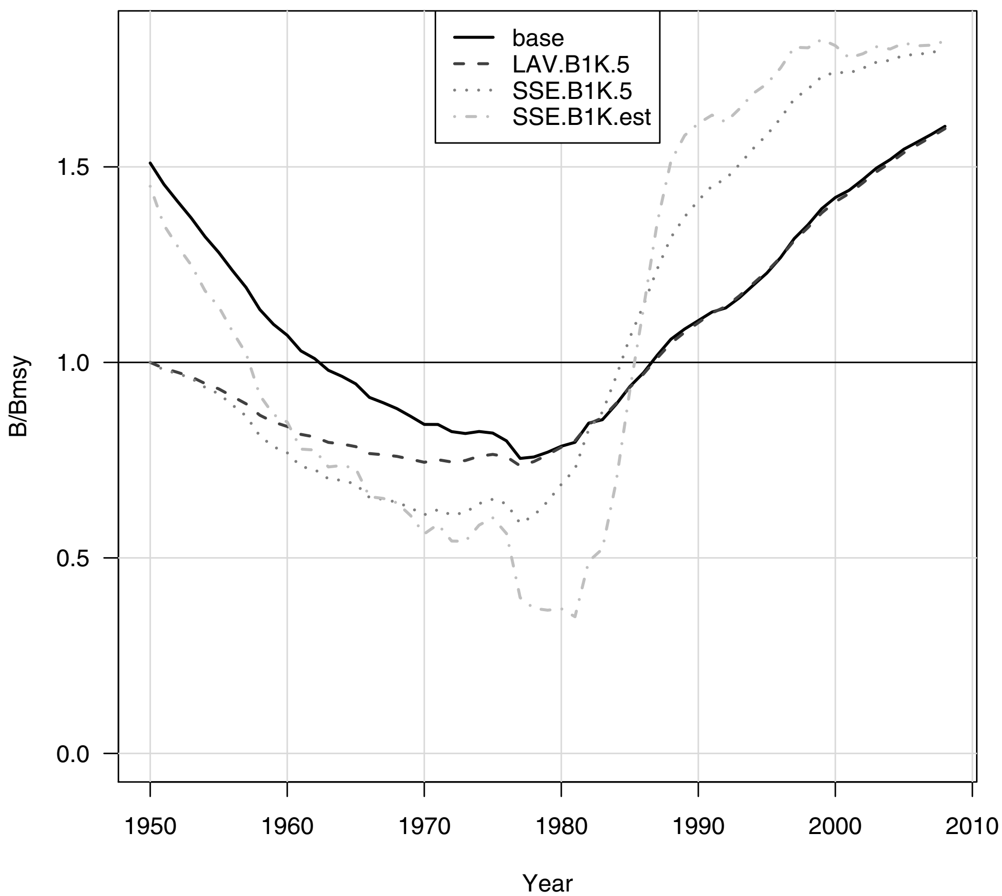


Figure 2. Spanish Mackerel in Atlantic: Production model estimates of relative fishing mortality rate. Base run (base) and maximum likelihood run (SSE.B1K.est)) estimate B_1/K while LAV.B1K.5 and SSE.B1K.5 fix B_1/K at 0.5.

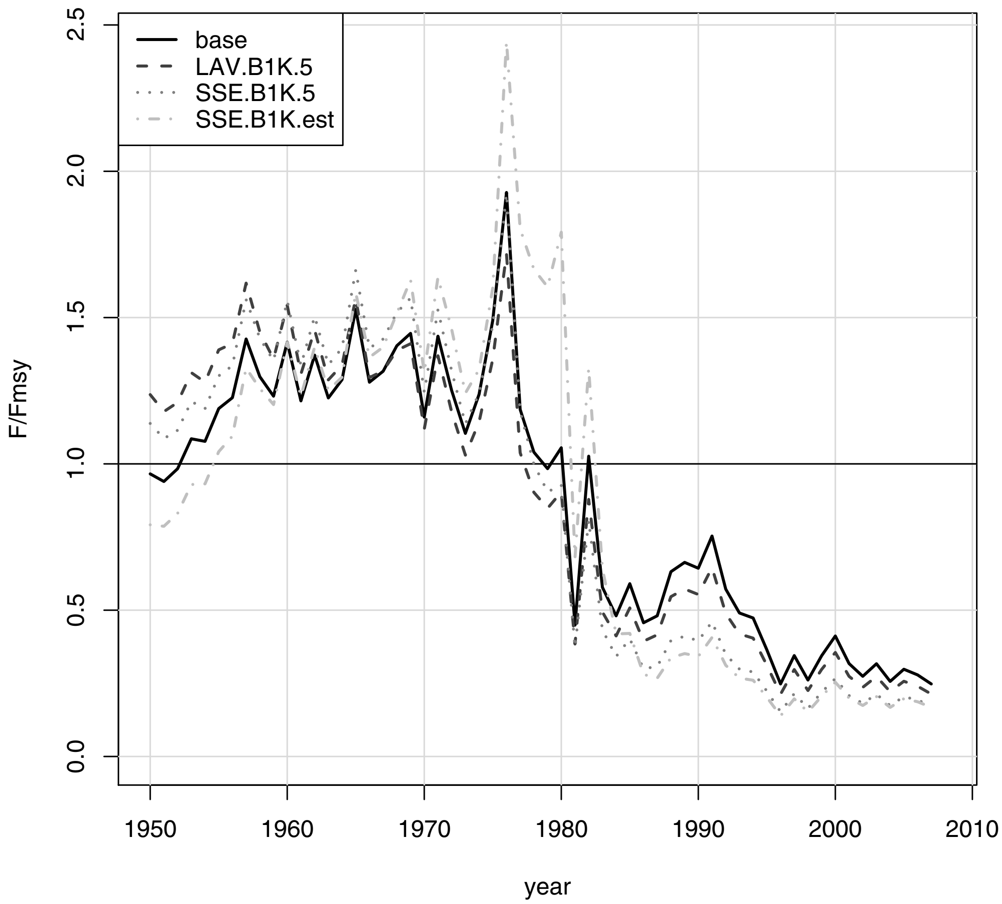


Figure 3. Spanish Mackerel in Atlantic: Fit of production models to combined index. Base run (base) and maximum likelihood run (SSE.B1K.est)) estimate B_1/K while LAV.B1K.5 and SSE.B1K.5 fix B_1/K at 0.5.

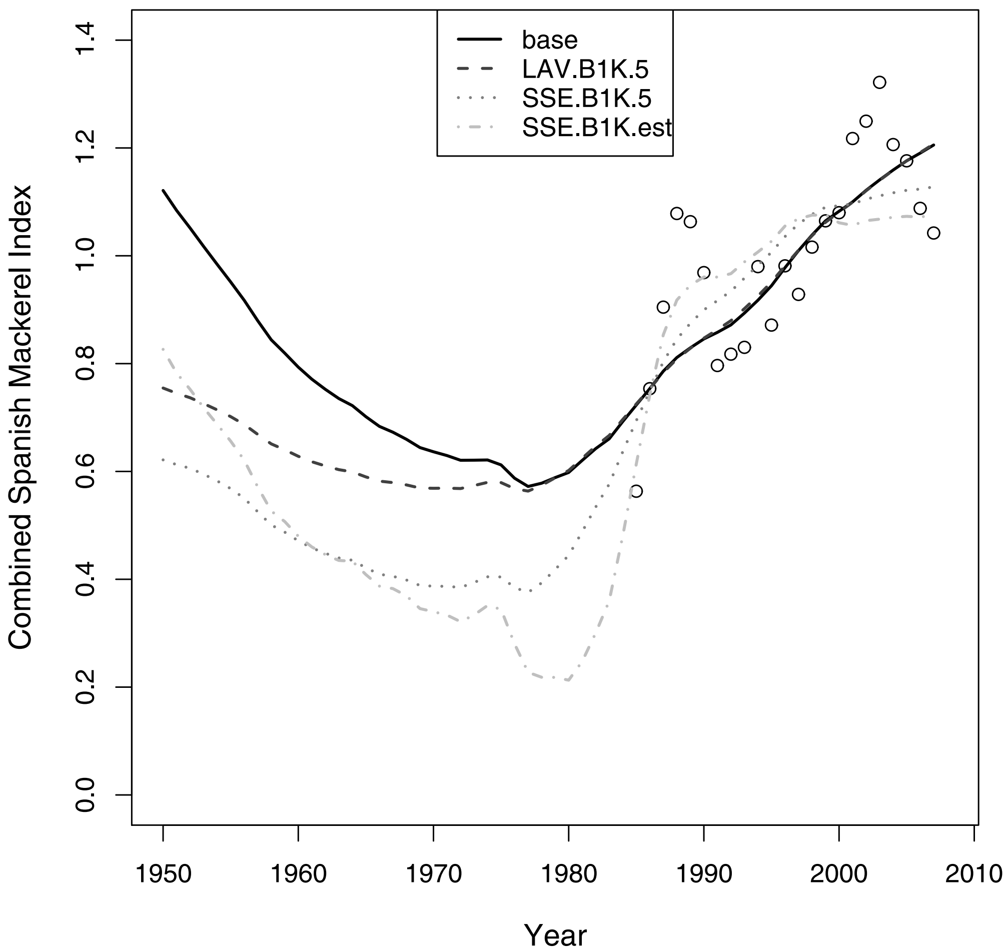


Figure 4. Spanish Mackerel in Atlantic: Production model fit to landings. Catchability increasing since 1976 and B_1/K estimated.

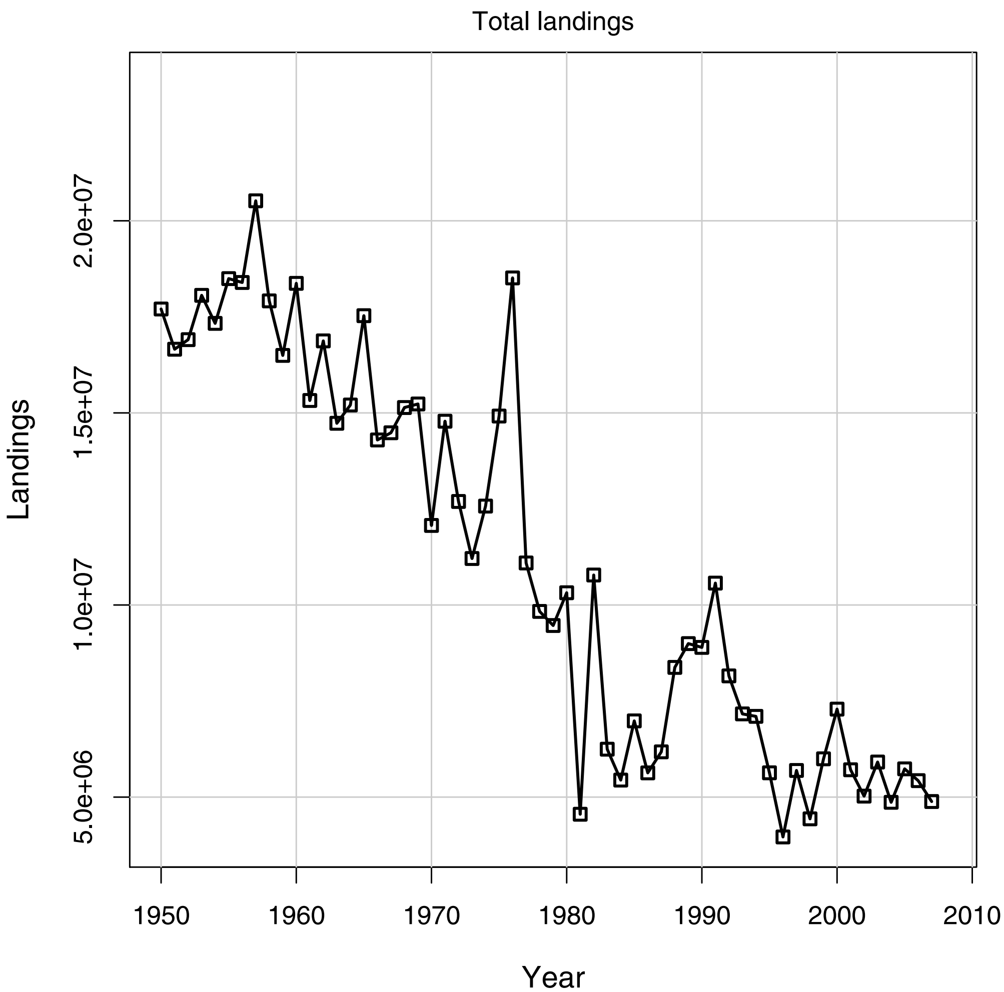


Figure 5. Spanish Mackerel in Atlantic: Production model estimates of biomass/MSST and F/Fmsy for the base run with LAV objective function and B_1/K estimated. The 80% confidence interval is represented by the dotted line.

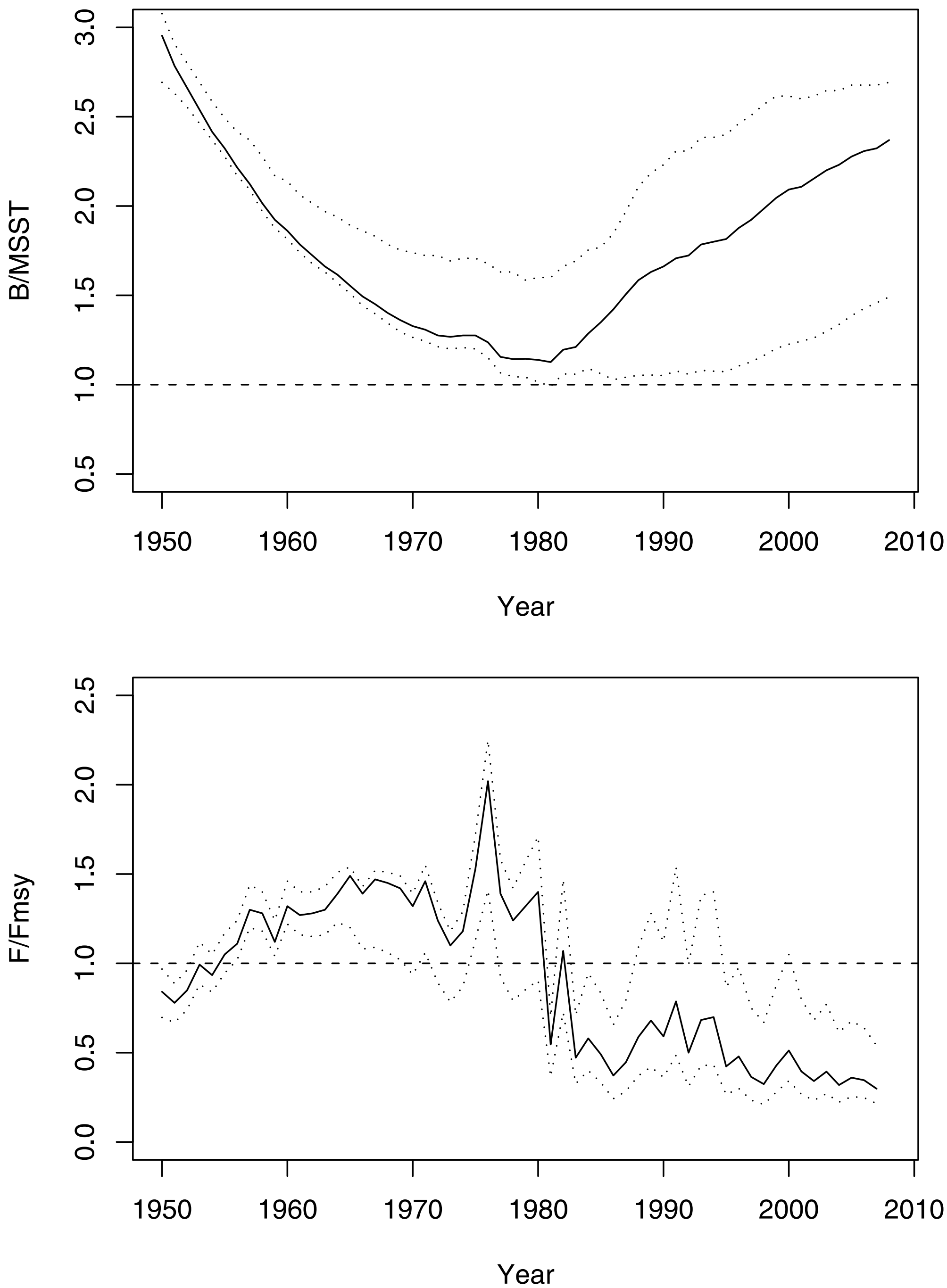
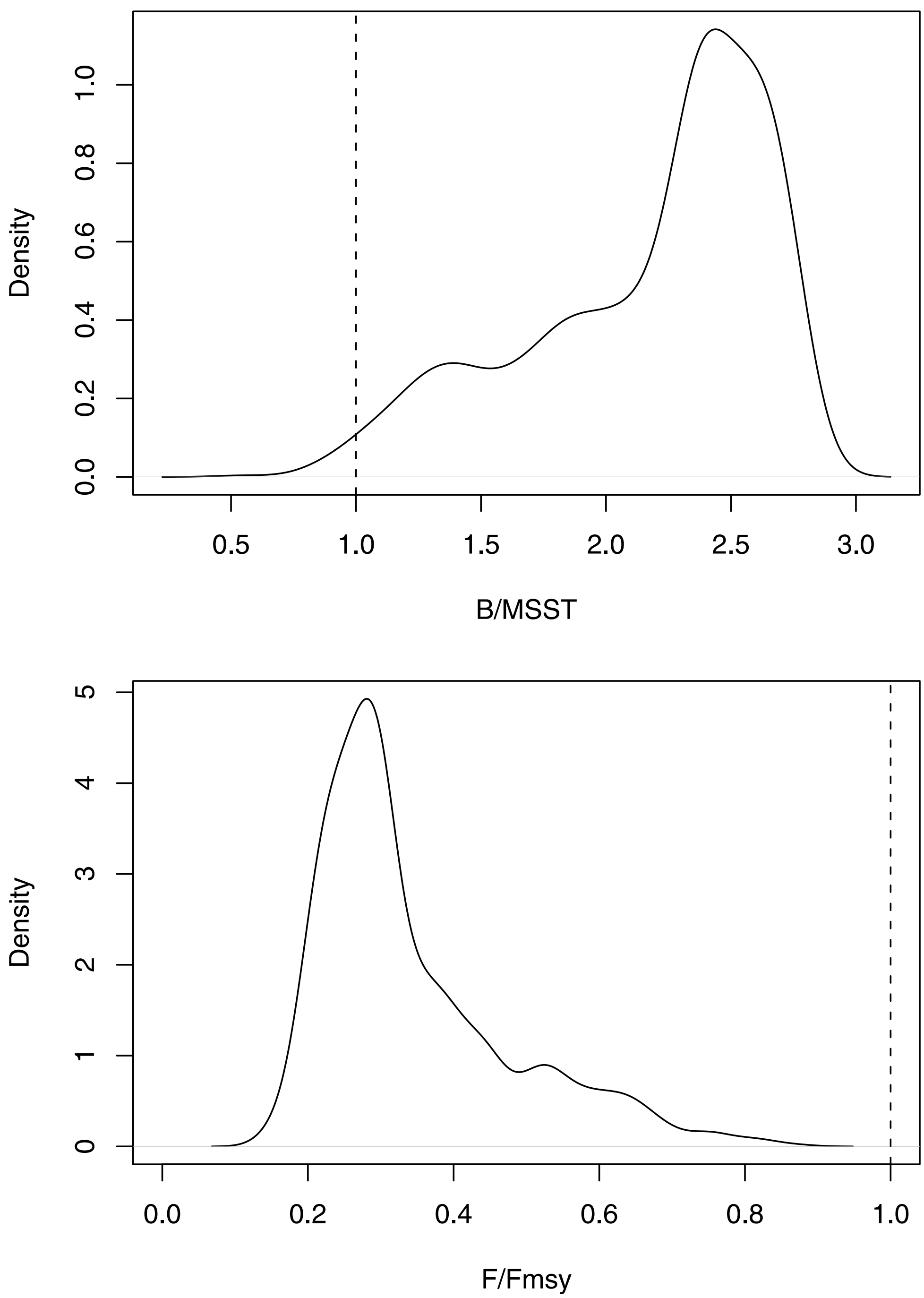


Figure 6. Spanish Mackerel in Atlantic: Kernel density plots of 1000 bootstrap runs of the base model for B/MSST and F/Fmsy with LAV objective function and B_1/K estimated.



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 Spansish Mackerel SEDAR 17 (2007) Landings and Combined Indices(with CV)'
LOGISTIC YLD LAV       Modeltype, conditioning, loss fn
112                        Verbosity
1000                        N Bootstraps
0  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
1d0                         Weight for B1>K
1                         Number of series
1.0d0  1.0d0               Series weights
0.50d0                      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
58                       Number of years
"Combined Index (1950-2006), Total Ldgs whole pounds"
"CC"

1950 -1              17704182
1951 -1              16657594
1952 -1              16906741
1953 -1              18059891
1954 -1              17330371
1955 -1              18495798
1956 -1              18394872
1957 -1              20520712
1958 -1              17915472
1959 -1              16496511
1960 -1              18372318
1961 -1              15322997
1962 -1              16874248
1963 -1              14729469
1964 -1              15205490
1965 -1              17530441
1966 -1              14296247
1967 -1              14483135
1968 -1              15139724
1969 -1              15232312
1970 -1              12070427
1971 -1              14783014
1972 -1              12694429
1973 -1              11210000
1974 -1              12574252
1975 -1              14918165
1976 -1              18513681
1977 -1              11093885
1978 -1              9832549
1979 -1              9465985
1980 -1              10318444
1981 -1              4553348
```

1982	-1	10780607
1983	-1	6246590
1984	-1	5442073
1985	0.5633219	6983003
1986	0.7535533	5630095
1987	0.9047252	6178058
1988	1.078462	8376070
1989	1.063249	8995048
1990	0.9688326	8896181
1991	0.7965118	10569830
1992	0.817554	8154481
1993	0.8302015	7165638
1994	0.9799069	7100815
1995	0.8714802	5632044
1996	0.9813545	3962407
1997	0.9283988	5692704
1998	1.016071	4434035
1999	1.064815	5996160
2000	1.079967	7289560
2001	1.217526	5710694
2002	1.24964	5024619
2003	1.321729	5912290
2004	1.206303	4864170
2005	1.176162	5734790
2006	1.087976	5427640
2007	1.042259	4884373

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 Spansish Mackerel SEDAR 17 (2007) Landings and Combined Indices(with CV)                   Page 1
                                                                      Wednesday, 27 Aug 2008 at 17:28:36
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                YLD conditioning
           Mike.Prager@noaa.gov                                                       LAV 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:\...17-sm-aspic\run75pctrec\sm2008_1950_b1k_est_lavbot.inp
-------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization with bootstrap.
Number of years analyzed:                        58          Number of bootstrap trials:                     1000
Number of data series:                            1          Bounds on MSY (min, max):      2.000E+04    2.000E+07
Objective function:            Least absolute values         Bounds on K (min, max):        1.000E+06    1.000E+09
Relative conv. criterion (simplex):       1.000E-08          Monte Carlo search mode, trials:       0       100000
Relative conv. criterion (restart):       3.000E-08          Random number seed:                         82184571
Relative conv. criterion (effort):        1.000E-04          Identical convergences required in fitting:        8
Maximum F allowed in fitting:                 8.000


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                         LAV     N         MSE       weight        weight      in CPUE

Loss(-1)  LAV in yield                            0.000E+00
Loss(0)   Penalty for B1 > K                      0.000E+00     1         N/A    1.000E+00         N/A
Loss(1)   Combined Index (1950-2006), Total Ldgs  2.162E+00    23         N/A    1.000E+00         N/A        0.560
...............................................................
TOTAL OBJECTIVE FUNCTION:                    2.16205547E+00
Estimated contrast index (ideal = 1.0):              0.4246         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 1950)     7.549E-01         5.000E-01    4.000E-01            1            1
MSY       Maximum sustainable yield               1.237E+07         2.000E+06    9.508E+06            1            1
K         Maximum population size                 3.016E+08         2.000E+07    5.705E+07            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  5.017E-09         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	1.237E+07	----	----
Bmsy	Stock biomass giving MSY	1.508E+08	K/2	K*n**(1/(1-n))
Fmsy	Fishing mortality rate at MSY	8.204E-02	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	1.604E+00	----	----
F./Fmsy	Ratio: F(2007)/Fmsy	2.478E-01	----	----
Fmsy/F.	Ratio: Fmsy/F(2007)	4.036E+00	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2008	1.984E+07	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	1.604E+00	----	----
Ye.	Equilibrium yield available in 2008	7.862E+06	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	6.356E-01	----	----

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

fmsy(1)	Combined Index (1950-2006), Total Ldgs	1.635E+07	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	1950	0.079	2.277E+08	2.234E+08	1.770E+07	1.770E+07	9.494E+06	9.658E-01	1.510E+00
2	1951	0.077	2.195E+08	2.161E+08	1.666E+07	1.666E+07	1.005E+07	9.398E-01	1.455E+00
3	1952	0.081	2.128E+08	2.096E+08	1.691E+07	1.691E+07	1.049E+07	9.834E-01	1.412E+00
4	1953	0.089	2.064E+08	2.028E+08	1.806E+07	1.806E+07	1.090E+07	1.086E+00	1.369E+00
5	1954	0.088	1.993E+08	1.962E+08	1.733E+07	1.733E+07	1.125E+07	1.077E+00	1.322E+00
6	1955	0.098	1.932E+08	1.896E+08	1.850E+07	1.850E+07	1.155E+07	1.189E+00	1.281E+00
7	1956	0.101	1.862E+08	1.829E+08	1.839E+07	1.839E+07	1.181E+07	1.226E+00	1.235E+00
8	1957	0.117	1.796E+08	1.753E+08	2.052E+07	2.052E+07	1.204E+07	1.427E+00	1.191E+00
9	1958	0.106	1.712E+08	1.682E+08	1.792E+07	1.792E+07	1.220E+07	1.298E+00	1.135E+00
10	1959	0.101	1.655E+08	1.633E+08	1.650E+07	1.650E+07	1.228E+07	1.231E+00	1.097E+00
11	1960	0.116	1.612E+08	1.582E+08	1.837E+07	1.837E+07	1.234E+07	1.416E+00	1.069E+00
12	1961	0.100	1.552E+08	1.537E+08	1.532E+07	1.532E+07	1.236E+07	1.215E+00	1.029E+00
13	1962	0.113	1.522E+08	1.500E+08	1.687E+07	1.687E+07	1.237E+07	1.372E+00	1.010E+00
14	1963	0.101	1.477E+08	1.465E+08	1.473E+07	1.473E+07	1.236E+07	1.225E+00	9.798E-01
15	1964	0.106	1.454E+08	1.439E+08	1.521E+07	1.521E+07	1.234E+07	1.288E+00	9.641E-01
16	1965	0.125	1.425E+08	1.398E+08	1.753E+07	1.753E+07	1.230E+07	1.528E+00	9.451E-01
17	1966	0.105	1.373E+08	1.362E+08	1.430E+07	1.430E+07	1.225E+07	1.279E+00	9.105E-01
18	1967	0.108	1.352E+08	1.341E+08	1.448E+07	1.448E+07	1.222E+07	1.317E+00	8.969E-01
19	1968	0.115	1.330E+08	1.315E+08	1.514E+07	1.514E+07	1.217E+07	1.404E+00	8.819E-01
20	1969	0.119	1.300E+08	1.284E+08	1.523E+07	1.523E+07	1.210E+07	1.446E+00	8.622E-01
21	1970	0.095	1.269E+08	1.269E+08	1.207E+07	1.207E+07	1.206E+07	1.160E+00	8.414E-01
22	1971	0.118	1.269E+08	1.255E+08	1.478E+07	1.478E+07	1.202E+07	1.436E+00	8.413E-01
23	1972	0.103	1.241E+08	1.237E+08	1.269E+07	1.269E+07	1.197E+07	1.251E+00	8.230E-01
24	1973	0.091	1.234E+08	1.238E+08	1.121E+07	1.121E+07	1.197E+07	1.104E+00	8.182E-01
25	1974	0.102	1.241E+08	1.238E+08	1.257E+07	1.257E+07	1.197E+07	1.238E+00	8.232E-01
26	1975	0.122	1.235E+08	1.220E+08	1.492E+07	1.492E+07	1.192E+07	1.490E+00	8.192E-01
27	1976	0.158	1.205E+08	1.171E+08	1.851E+07	1.851E+07	1.175E+07	1.928E+00	7.994E-01
28	1977	0.097	1.138E+08	1.140E+08	1.109E+07	1.109E+07	1.164E+07	1.186E+00	7.545E-01
29	1978	0.085	1.143E+08	1.152E+08	9.833E+06	9.833E+06	1.168E+07	1.040E+00	7.581E-01
30	1979	0.081	1.162E+08	1.173E+08	9.466E+06	9.466E+06	1.176E+07	9.836E-01	7.704E-01
31	1980	0.087	1.185E+08	1.192E+08	1.032E+07	1.032E+07	1.183E+07	1.055E+00	7.856E-01
32	1981	0.037	1.200E+08	1.237E+08	4.553E+06	4.553E+06	1.197E+07	4.488E-01	7.956E-01
33	1982	0.084	1.274E+08	1.280E+08	1.078E+07	1.078E+07	1.209E+07	1.026E+00	8.447E-01

34	1983	0.047	1.287E+08	1.317E+08	6.247E+06	6.247E+06	1.217E+07	5.784E-01	8.534E-01
35	1984	0.039	1.346E+08	1.380E+08	5.442E+06	5.442E+06	1.228E+07	4.806E-01	8.927E-01
36	1985	0.048	1.414E+08	1.441E+08	6.983E+06	6.983E+06	1.234E+07	5.905E-01	9.380E-01
37	1986	0.037	1.468E+08	1.502E+08	5.630E+06	5.630E+06	1.237E+07	4.569E-01	9.736E-01
38	1987	0.039	1.535E+08	1.566E+08	6.178E+06	6.178E+06	1.235E+07	4.808E-01	1.018E+00
39	1988	0.052	1.597E+08	1.617E+08	8.376E+06	8.376E+06	1.230E+07	6.315E-01	1.059E+00
40	1989	0.054	1.636E+08	1.653E+08	8.995E+06	8.995E+06	1.225E+07	6.634E-01	1.085E+00
41	1990	0.053	1.669E+08	1.686E+08	8.896E+06	8.896E+06	1.220E+07	6.433E-01	1.107E+00
42	1991	0.062	1.702E+08	1.710E+08	1.057E+07	1.057E+07	1.215E+07	7.535E-01	1.129E+00
43	1992	0.047	1.718E+08	1.738E+08	8.154E+06	8.154E+06	1.208E+07	5.720E-01	1.139E+00
44	1993	0.040	1.757E+08	1.781E+08	7.166E+06	7.166E+06	1.196E+07	4.904E-01	1.165E+00
45	1994	0.039	1.805E+08	1.829E+08	7.101E+06	7.101E+06	1.181E+07	4.733E-01	1.197E+00
46	1995	0.030	1.852E+08	1.882E+08	5.632E+06	5.632E+06	1.161E+07	3.647E-01	1.228E+00
47	1996	0.020	1.912E+08	1.949E+08	3.962E+06	3.962E+06	1.131E+07	2.478E-01	1.268E+00
48	1997	0.028	1.985E+08	2.012E+08	5.693E+06	5.693E+06	1.099E+07	3.449E-01	1.317E+00
49	1998	0.021	2.038E+08	2.070E+08	4.434E+06	4.434E+06	1.065E+07	2.611E-01	1.352E+00
50	1999	0.028	2.100E+08	2.122E+08	5.996E+06	5.996E+06	1.031E+07	3.444E-01	1.393E+00
51	2000	0.034	2.144E+08	2.158E+08	7.290E+06	7.290E+06	1.007E+07	4.118E-01	1.422E+00
52	2001	0.026	2.171E+08	2.192E+08	5.711E+06	5.711E+06	9.820E+06	3.175E-01	1.440E+00
53	2002	0.022	2.212E+08	2.235E+08	5.025E+06	5.025E+06	9.491E+06	2.740E-01	1.467E+00
54	2003	0.026	2.257E+08	2.274E+08	5.912E+06	5.912E+06	9.178E+06	3.170E-01	1.497E+00
55	2004	0.021	2.290E+08	2.310E+08	4.864E+06	4.864E+06	8.867E+06	2.567E-01	1.519E+00
56	2005	0.024	2.330E+08	2.344E+08	5.735E+06	5.735E+06	8.563E+06	2.982E-01	1.545E+00
57	2006	0.023	2.358E+08	2.373E+08	5.428E+06	5.428E+06	8.300E+06	2.788E-01	1.564E+00
58	2007	0.020	2.387E+08	2.403E+08	4.884E+06	4.884E+06	8.012E+06	2.478E-01	1.583E+00
59	2008		2.418E+08						1.604E+00

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

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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 scale	Statist weight
1	1950	*	1.121E+00	0.0792	1.770E+07	1.770E+07	0.00000	1.000E+00
2	1951	*	1.084E+00	0.0771	1.666E+07	1.666E+07	0.00000	1.000E+00
3	1952	*	1.051E+00	0.0807	1.691E+07	1.691E+07	0.00000	1.000E+00
4	1953	*	1.017E+00	0.0891	1.806E+07	1.806E+07	0.00000	1.000E+00
5	1954	*	9.842E-01	0.0884	1.733E+07	1.733E+07	0.00000	1.000E+00
6	1955	*	9.514E-01	0.0975	1.850E+07	1.850E+07	0.00000	1.000E+00
7	1956	*	9.175E-01	0.1006	1.839E+07	1.839E+07	0.00000	1.000E+00
8	1957	*	8.796E-01	0.1171	2.052E+07	2.052E+07	0.00000	1.000E+00
9	1958	*	8.442E-01	0.1065	1.792E+07	1.792E+07	0.00000	1.000E+00
10	1959	*	8.193E-01	0.1010	1.650E+07	1.650E+07	0.00000	1.000E+00
11	1960	*	7.935E-01	0.1162	1.837E+07	1.837E+07	0.00000	1.000E+00
12	1961	*	7.712E-01	0.0997	1.532E+07	1.532E+07	0.00000	1.000E+00
13	1962	*	7.524E-01	0.1125	1.687E+07	1.687E+07	0.00000	1.000E+00
14	1963	*	7.352E-01	0.1005	1.473E+07	1.473E+07	0.00000	1.000E+00
15	1964	*	7.221E-01	0.1057	1.521E+07	1.521E+07	0.00000	1.000E+00
16	1965	*	7.016E-01	0.1254	1.753E+07	1.753E+07	0.00000	1.000E+00
17	1966	*	6.836E-01	0.1049	1.430E+07	1.430E+07	0.00000	1.000E+00
18	1967	*	6.728E-01	0.1080	1.448E+07	1.448E+07	0.00000	1.000E+00
19	1968	*	6.596E-01	0.1152	1.514E+07	1.514E+07	0.00000	1.000E+00
20	1969	*	6.443E-01	0.1186	1.523E+07	1.523E+07	0.00000	1.000E+00
21	1970	*	6.365E-01	0.0951	1.207E+07	1.207E+07	0.00000	1.000E+00
22	1971	*	6.294E-01	0.1178	1.478E+07	1.478E+07	0.00000	1.000E+00
23	1972	*	6.208E-01	0.1026	1.269E+07	1.269E+07	0.00000	1.000E+00
24	1973	*	6.209E-01	0.0906	1.121E+07	1.121E+07	0.00000	1.000E+00
25	1974	*	6.213E-01	0.1015	1.257E+07	1.257E+07	0.00000	1.000E+00

26	1975	*	6.121E-01	0.1223	1.492E+07	1.492E+07	0.00000	1.000E+00
27	1976	*	5.874E-01	0.1581	1.851E+07	1.851E+07	0.00000	1.000E+00
28	1977	*	5.722E-01	0.0973	1.109E+07	1.109E+07	0.00000	1.000E+00
29	1978	*	5.782E-01	0.0853	9.833E+06	9.833E+06	0.00000	1.000E+00
30	1979	*	5.886E-01	0.0807	9.466E+06	9.466E+06	0.00000	1.000E+00
31	1980	*	5.981E-01	0.0866	1.032E+07	1.032E+07	0.00000	1.000E+00
32	1981	*	6.205E-01	0.0368	4.553E+06	4.553E+06	0.00000	1.000E+00
33	1982	*	6.424E-01	0.0842	1.078E+07	1.078E+07	0.00000	1.000E+00
34	1983	*	6.606E-01	0.0474	6.247E+06	6.247E+06	0.00000	1.000E+00
35	1984	*	6.926E-01	0.0394	5.442E+06	5.442E+06	0.00000	1.000E+00
36	1985	5.633E-01	7.232E-01	0.0484	6.983E+06	6.983E+06	0.24982	1.000E+00
37	1986	7.536E-01	7.536E-01	0.0375	5.630E+06	5.630E+06	0.00000	1.000E+00
38	1987	9.047E-01	7.860E-01	0.0394	6.178E+06	6.178E+06	-0.14074	1.000E+00
39	1988	1.078E+00	8.113E-01	0.0518	8.376E+06	8.376E+06	-0.28469	1.000E+00
40	1989	1.063E+00	8.293E-01	0.0544	8.995E+06	8.995E+06	-0.24851	1.000E+00
41	1990	9.688E-01	8.458E-01	0.0528	8.896E+06	8.896E+06	-0.13586	1.000E+00
42	1991	7.965E-01	8.580E-01	0.0618	1.057E+07	1.057E+07	0.07430	1.000E+00
43	1992	8.176E-01	8.718E-01	0.0469	8.154E+06	8.154E+06	0.06427	1.000E+00
44	1993	8.302E-01	8.937E-01	0.0402	7.166E+06	7.166E+06	0.07373	1.000E+00
45	1994	9.799E-01	9.176E-01	0.0388	7.101E+06	7.101E+06	-0.06572	1.000E+00
46	1995	8.715E-01	9.444E-01	0.0299	5.632E+06	5.632E+06	0.08036	1.000E+00
47	1996	9.814E-01	9.778E-01	0.0203	3.962E+06	3.962E+06	-0.00358	1.000E+00
48	1997	9.284E-01	1.010E+00	0.0283	5.693E+06	5.693E+06	0.08378	1.000E+00
49	1998	1.016E+00	1.038E+00	0.0214	4.434E+06	4.434E+06	0.02177	1.000E+00
50	1999	1.065E+00	1.065E+00	0.0283	5.996E+06	5.996E+06	0.00000	1.000E+00
51	2000	1.080E+00	1.083E+00	0.0338	7.290E+06	7.290E+06	0.00241	1.000E+00
52	2001	1.218E+00	1.100E+00	0.0260	5.711E+06	5.711E+06	-0.10158	1.000E+00
53	2002	1.250E+00	1.121E+00	0.0225	5.025E+06	5.025E+06	-0.10823	1.000E+00
54	2003	1.322E+00	1.141E+00	0.0260	5.912E+06	5.912E+06	-0.14721	1.000E+00
55	2004	1.206E+00	1.159E+00	0.0211	4.864E+06	4.864E+06	-0.03994	1.000E+00
56	2005	1.176E+00	1.176E+00	0.0245	5.735E+06	5.735E+06	0.00000	1.000E+00
57	2006	1.088E+00	1.190E+00	0.0229	5.428E+06	5.428E+06	0.09003	1.000E+00
58	2007	1.042E+00	1.206E+00	0.0203	4.884E+06	4.884E+06	0.14553	1.000E+00

* Asterisk indicates missing value(s).

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	7.549E-01	-1.770E-02	-2.34%	6.089E-01	9.339E-01	7.097E-01	8.167E-01	1.070E-01	0.142
K	3.016E+08	1.331E+07	4.41%	1.830E+08	4.423E+08	2.451E+08	3.553E+08	1.101E+08	0.365
q(1)	5.017E-09	1.110E-09	22.12%	2.220E-09	5.749E-09	2.882E-09	5.020E-09	2.138E-09	0.426
MSY	1.237E+07	1.748E+05	1.41%	1.063E+07	1.418E+07	1.137E+07	1.319E+07	1.819E+06	0.147
Ye(2008)	7.862E+06	4.981E+05	6.34%	5.606E+06	1.071E+07	6.226E+06	9.573E+06	3.346E+06	0.426
Y.@Fmsy	1.984E+07	-1.055E+06	-5.32%	1.104E+07	2.517E+07	1.539E+07	2.282E+07	7.436E+06	0.375
Bmsy	1.508E+08	6.655E+06	4.41%	9.148E+07	2.211E+08	1.226E+08	1.776E+08	5.507E+07	0.365
Fmsy	8.204E-02	1.123E-02	13.69%	5.310E-02	1.573E-01	6.668E-02	1.127E-01	4.603E-02	0.561
fmsy(1)	1.635E+07	-8.999E+05	-5.50%	8.563E+06	2.254E+07	1.268E+07	1.995E+07	7.269E+06	0.445
B./Bmsy	1.604E+00	-1.292E-01	-8.06%	1.034E+00	1.773E+00	1.365E+00	1.725E+00	3.601E-01	0.225
F./Fmsy	2.478E-01	4.416E-02	17.82%	1.940E-01	4.478E-01	2.145E-01	3.195E-01	1.050E-01	0.424
Ye./MSY	6.356E-01	4.964E-02	7.81%	4.026E-01	9.813E-01	4.744E-01	8.632E-01	3.888E-01	0.612

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INFORMATION FOR REPAST (Prager, Porch, Shertzer, & Caddy. 2003. NAJFM 23: 349-361)
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Unitless limit reference point in F (Fmsy/F.):             4.036
CV of above (from bootstrap distribution):                0.2734


NOTES ON BOOTSTRAPPED ESTIMATES:
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- 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 MSY out of bounds:               15
Trials replaced for q out-of-bounds:          0
Trials replaced for K out-of-bounds:          8          Residual-adjustment factor:                      1.1002

Elapsed time: 0 hours, 10 minutes, 49 seconds.
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