Rebuilding Projections for the Gulf of Mexico Gray Triggerfish (*Balistes capriscus*) Stock

by

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EXECUTIVE SUMMARY

The Gulf of Mexico gray triggerfish (*Balistes capriscus*) stock appears to be overfished and experiencing overfishing (SEDAR9-AW2-09). The base model for these conclusions was a state space age-structured production model (SSASPM). Using the results of this model, various projection scenarios were examined to identify potential rebuilding strategies. Assuming management action is taken in 2007, there is the potential to end overfishing that year and rebuild the stock as quickly as the end of 2008, although this scenario would require the elimination of all sources of catch and bycatch. The minimum fishing mortality rate required to rebuild the stock by the end of 2016 is almost exactly the $F_{30\%SPR}$ level, which is currently the proxy value for the fishing rate at maximum sustainable yield (F_{MSY}). Alternatively, the most common definition for the fishing rate at optimum yield ($F_{OY} = 0.75F_{MSY}$) would rebuild the stock by 2012 according to the base stock assessment model. These conclusions are based on MSY benchmarks, which are not yet enacted as policy for gray triggerfish. The Gulf of Mexico Fishery Management Council will have to revisit management benchmarks in the process of selecting a rebuilding plan for the gray triggerfish stock.

INTRODUCTION

The most recent effort at assessing the Gulf of Mexico gray triggerfish (*Balistes capriscus*) stock indicated that it is most likely overfished and experiencing overfishing (SEDAR9-AW2-09). The base model underlying those conclusions was a state space age-structured production model (SSASPM). It took advantage of a recent dissertation (Ingram 2001), which provided a significant improvement in our understanding of the life history of the gray triggerfish stock, particularly the age structure of the population. This improved understanding allowed us to pursue an assessment that incorporated substantially more information than was possible the last time this stock was assessed.

METHODS

Given the likely determination that Gulf of Mexico gray triggerfish are overfished and experiencing overfishing, rebuilding scenarios were explored to facilitate management action. Outputs were taken directly from the base SSASPM model and these were used to project the population forward in time under various scenarios. Given the relative ease with which the stock rebuilt, analyses were limited to simple projections that linked all fleets together. In other words, overall fishing mortality rates were manipulated but the selectivity-at-age patterns remained constant, which is the equivalent of assuming that all catch cuts were distributed proportionally across all directed and bycatch fleets. Moreover, it was assumed that the status determination will become official in early 2006 and that management action would take place in early 2007.

Additionally, various detailed tools for achieving rebuilding were not explored. Yet management choices will be simplified by the fact that gray triggerfish survive catch and release remarkably well, at least in directed fleets. As a result, size or trip limits can be used effectively for all but the shrimp fleet.

According to the proposed base assessment model, the gray triggerfish stock was at about 60% of MSY abundance levels and experiencing about 145% of MSY fishing mortality rates in 2004 (Fig. 1). Scenarios explored the rebuilding of this stock back to MSY abundance levels and used a maximum timeframe of 10 years.

RESULTS

Under a no fishing scenario, in which all directed and bycatch fisheries were eliminated, gray triggerfish were able to rebuild extremely quickly—less than 2 years after fishing were eliminated (Table 1; Fig. 2).

Without any management action, the stock does not fare so well. It is currently experiencing overfishing and, as a result, it fails to recover at all under current fishing mortality rates (Table 1; Fig. 3).

If fishing mortality rates were reduced by about 30%, to F_{MSY} levels, the stock would also fail to rebuild fully to MSY abundance levels but overfishing would be halted if using MSY as a benchmark (Table1; Fig. 4). If using 30%SPR, as is currently stated in the management plan, overfishing would still occur even with this reduction.

If fishing mortality rates were reduced by about 40%, to $F_{30\%SPR}$ levels, overfishing would end regardless of the benchmark used. And the stock would rebuild to nearly MSY levels by the end of 2016 (Table 1; Fig. 5). It would take only an extremely minor additional reduction of 2% to achieve rebuilding within this timeframe (Table 1; Fig. 6).

Finally, a scenario was explored using a common definition of optimum yield, noting that the current management plan has not identified this benchmark. Using 75% of the fishing mortality rate associated with MSY (i.e., $F_{OY} = 0.75F_{MSY}$) achieved rebuilding by 2012 but required cutting the fishing mortality rate nearly in half. The benefits of this strategy would primarily be in the future, noting that by 2016 catches under this lighter fishing pressure would nearly equal those under other, more aggressive fishing pressure scenarios (Table 1).

REFERENCES

Ingram, GW Jr. 2001. *Stock Structure of Gray Triggerfish,* Balistes capriscus*, on Multiple Spatial Scales in the Gulf of Mexico*. PhD Dissertation. Department of Marine Sciences, University of South Alabama. 229pp.

TABLE 1—Catches Under Various Rebuilding Scenarios
Lighter shading represents the ending of overfishing while darker shading represents the achievement of rebuilding.

Year	***No Fishing***			***Current F***			***MSY***		
	Catch	F/Fmsy	B/Bmsy	Catch (m)	F/Fmsy	B/Bmsy	Catch (m)	F/Fmsy	B/Bmsy
2004	1.34	1.44	0.6	1.34	1.44	0.6	1.34	1.44	0.6
2005	1.29	1.44	0.58	1.29	1.44	0.58	1.29	1.44	0.58
2006	1.27	1.44	0.57	1.27	1.44	0.57	1.27	1.44	0.57
2007	0	0	0.88	1.25	1.44	0.57	0.99	1	0.64
2008	0	0	1.12	1.24	1.44	0.56	1.06	1	0.69
2009	0	0	1.38	1.23	1.44	0.56	1.12	1	0.72
2010	0	0	1.67	1.22	1.44	0.55	1.17	1	0.75
2011	0	0	1.96	1.22	1.44	0.55	1.21	1	0.78
2012	0	0	2.25	1.22	1.44	0.55	1.24	1	0.8
2013	0	0	2.55	1.21	1.44	0.55	1.27	1	0.82
2014	0	0	2.84	1.21	1.44	0.55	1.29	1	0.83
2015	0	0	3.11	1.21	1.44	0.55	1.31	1	0.85
2016	0	0	3.34	1.21	1.44	0.55	1.32	1	0.85

Year	***30% SPR***			***Min F to Rebuild***			***OY***		
	Catch (m)	F/Fmsy	B/Bmsy	Catch (m)	F/Fmsy	B/Bmsy	Catch (m)	F/Fmsy	B/Bmsy
2004	1.34	1.44	0.6	1.34	1.44	0.6	1.34	1.44	0.6
2005	1.29	1.44	0.58	1.29	1.44	0.58	1.29	1.44	0.58
2006	1.27	1.44	0.57	1.27	1.44	0.57	1.27	1.44	0.57
2007	0.9	0.87	0.67	0.89	0.86	0.67	0.81	0.75	0.7
2008	0.98	0.87	0.73	0.97	0.86	0.73	0.9	0.75	0.77
2009	1.06	0.87	0.78	1.05	0.86	0.79	0.98	0.75	0.84
2010	1.12	0.87	0.83	1.12	0.86	0.84	1.06	0.75	0.91
2011	1.18	0.87	0.87	1.17	0.86	0.88	1.12	0.75	0.96
2012	1.22	0.87	0.9	1.22	0.86	0.91	1.18	0.75	1.01
2013	1.26	0.87	0.93	1.25	0.86	0.94	1.22	0.75	1.05
2014	1.29	0.87	0.95	1.28	0.86	0.96	1.26	0.75	1.08
2015	1.31	0.87	0.97	1.31	0.86	0.98	1.29	0.75	1.11
2016	1.33	0.87	0.98	1.33	0.86	1	1.31	0.75	1.13

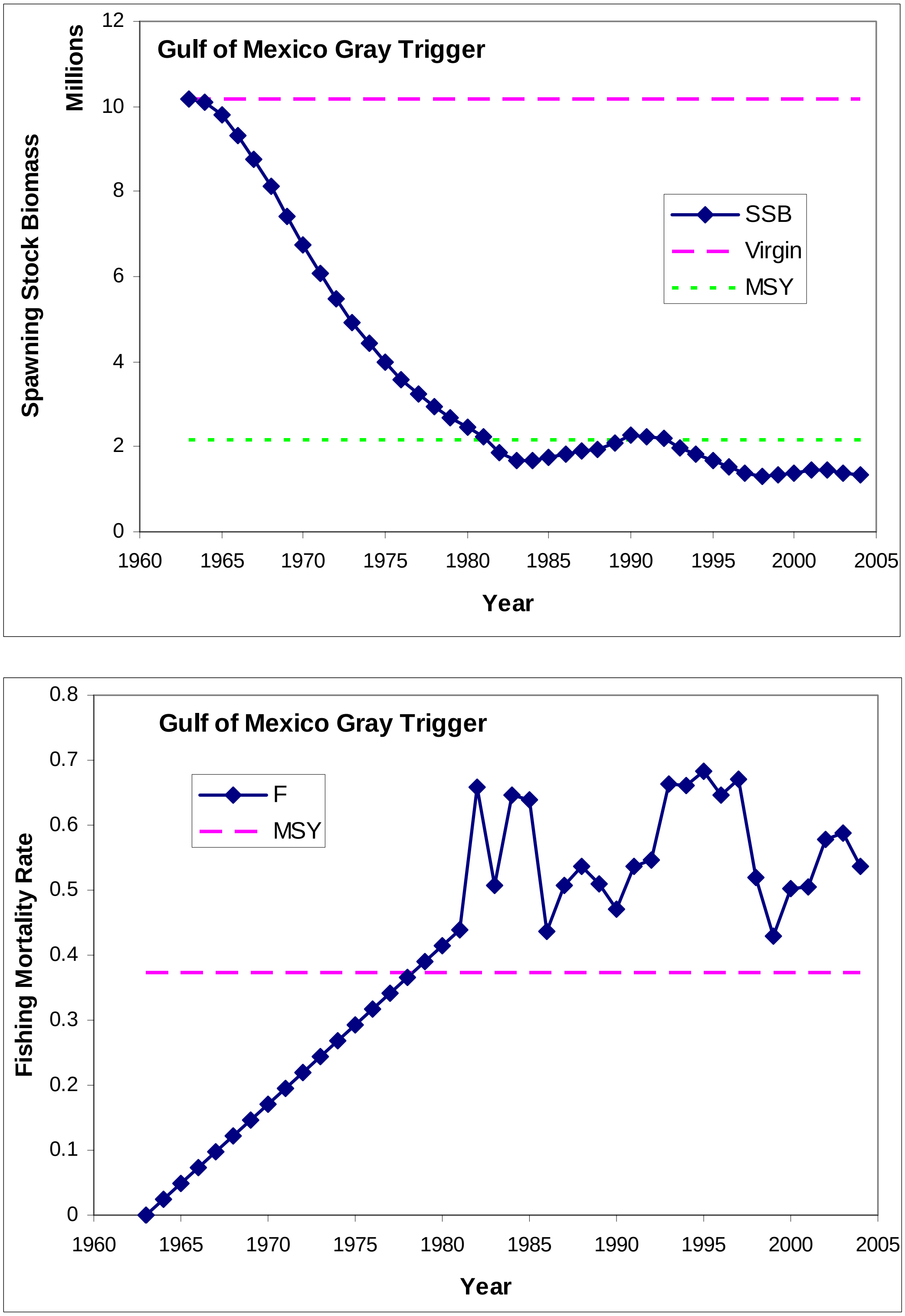

FIG. 1—Gray Triggerfish Status in 2004
(a) Spawning stock biomass (overfished); (b) Fishing mortality rate (overfishing).

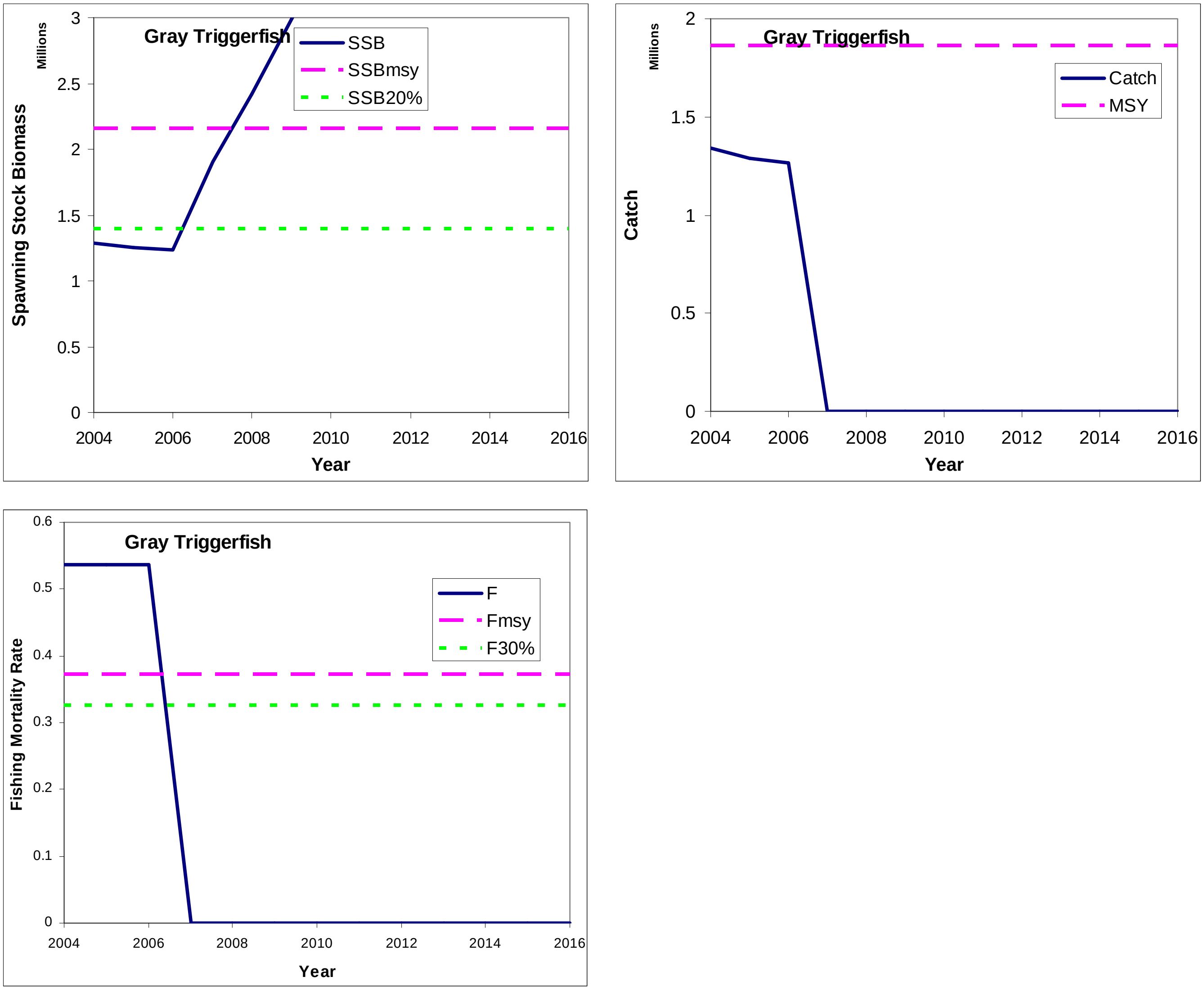

FIG. 2—Projections Under No Fishing
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

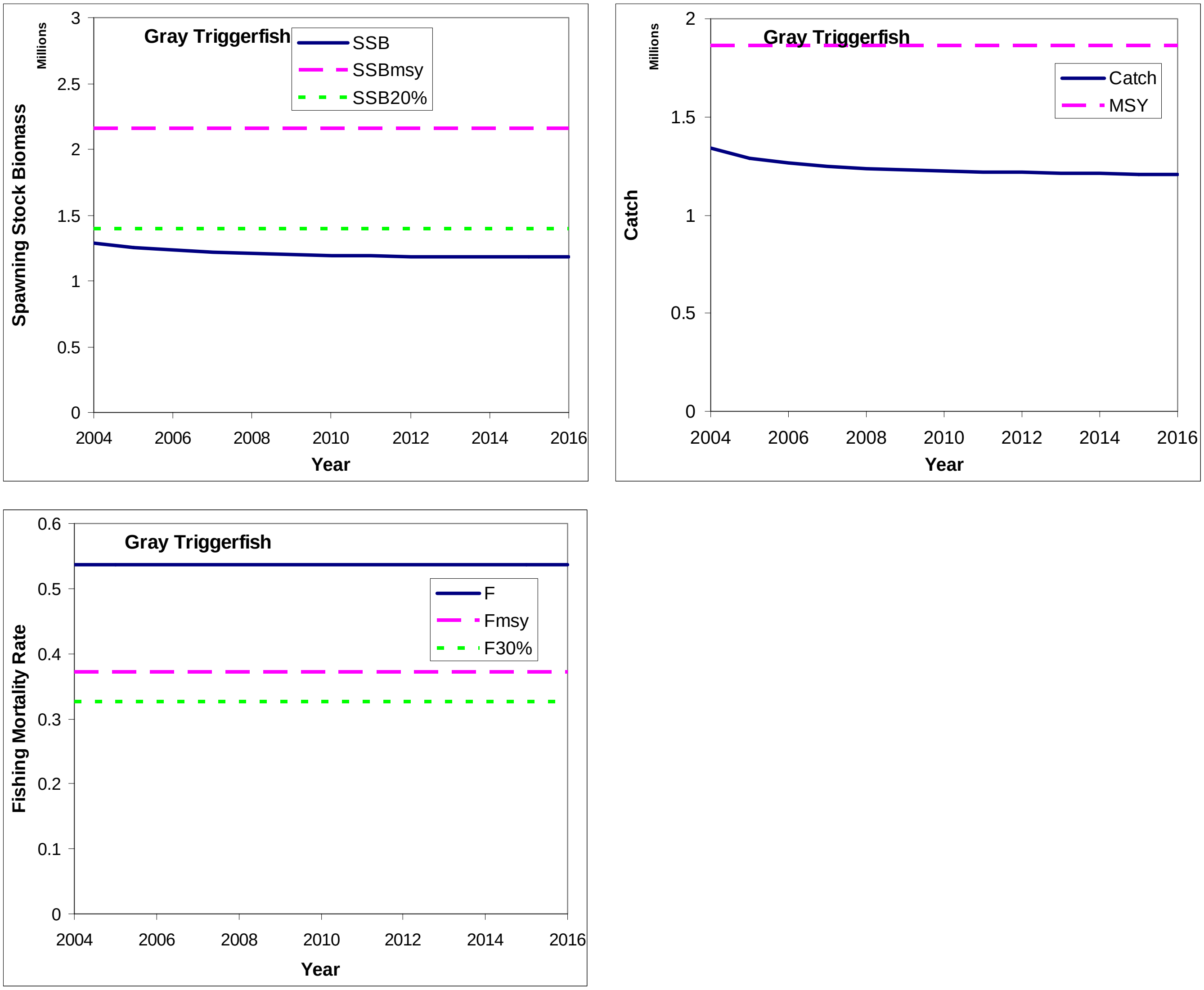

FIG. 3—Projections Under Current F (2004)
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

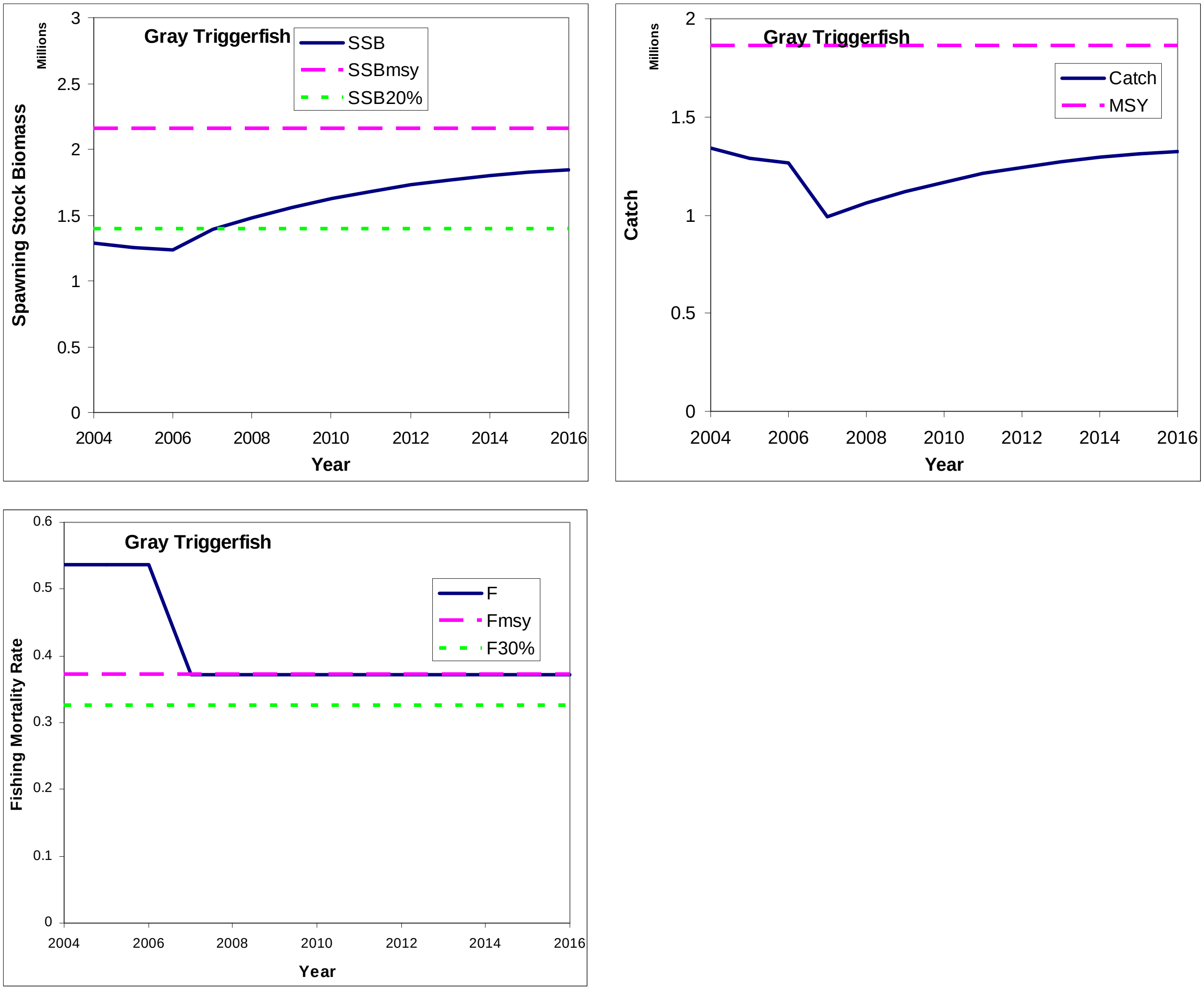

FIG. 4—Projections Under F_{MSY}
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

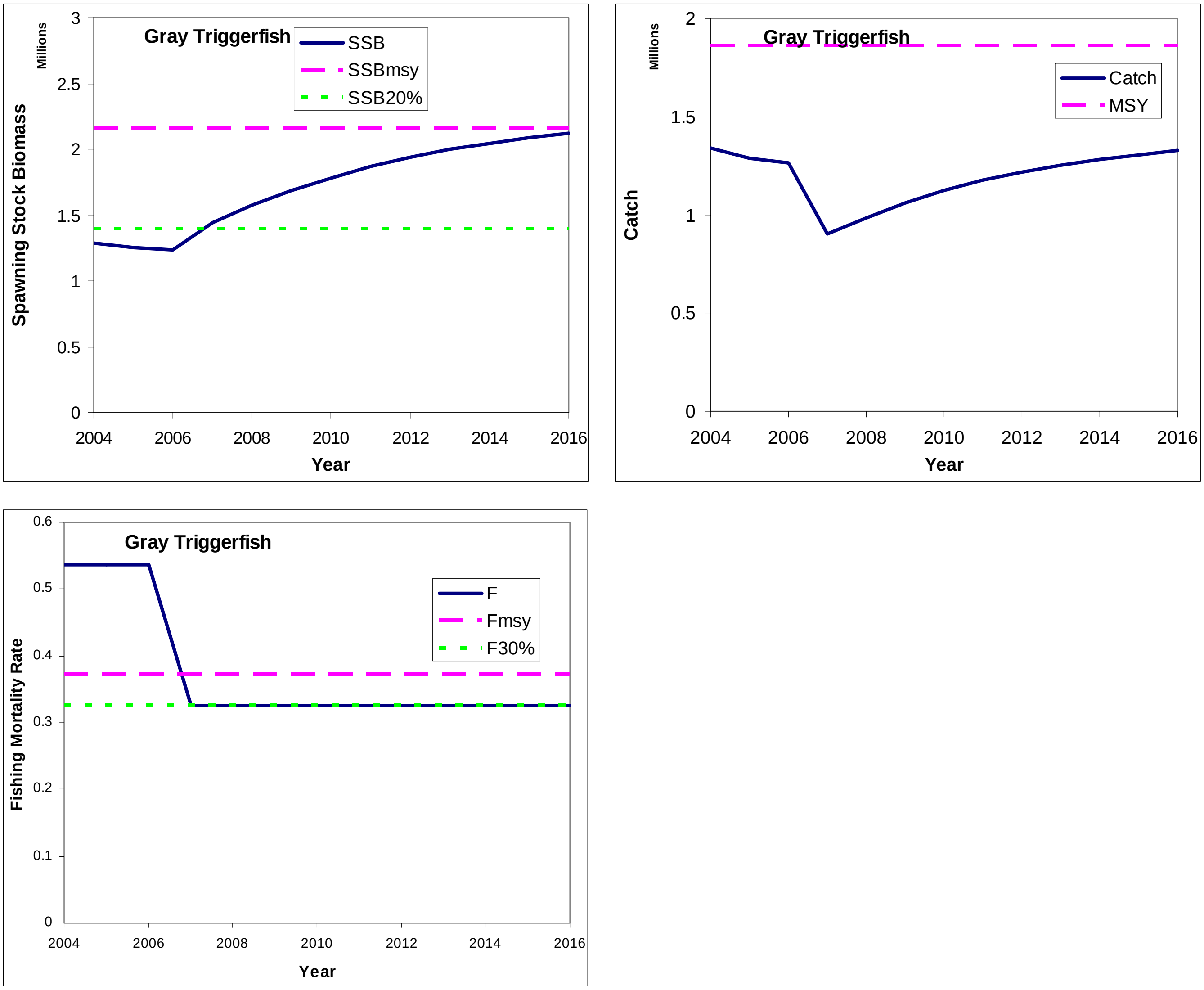

FIG. 5—Projections Under $F_{30\%SPR}$
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

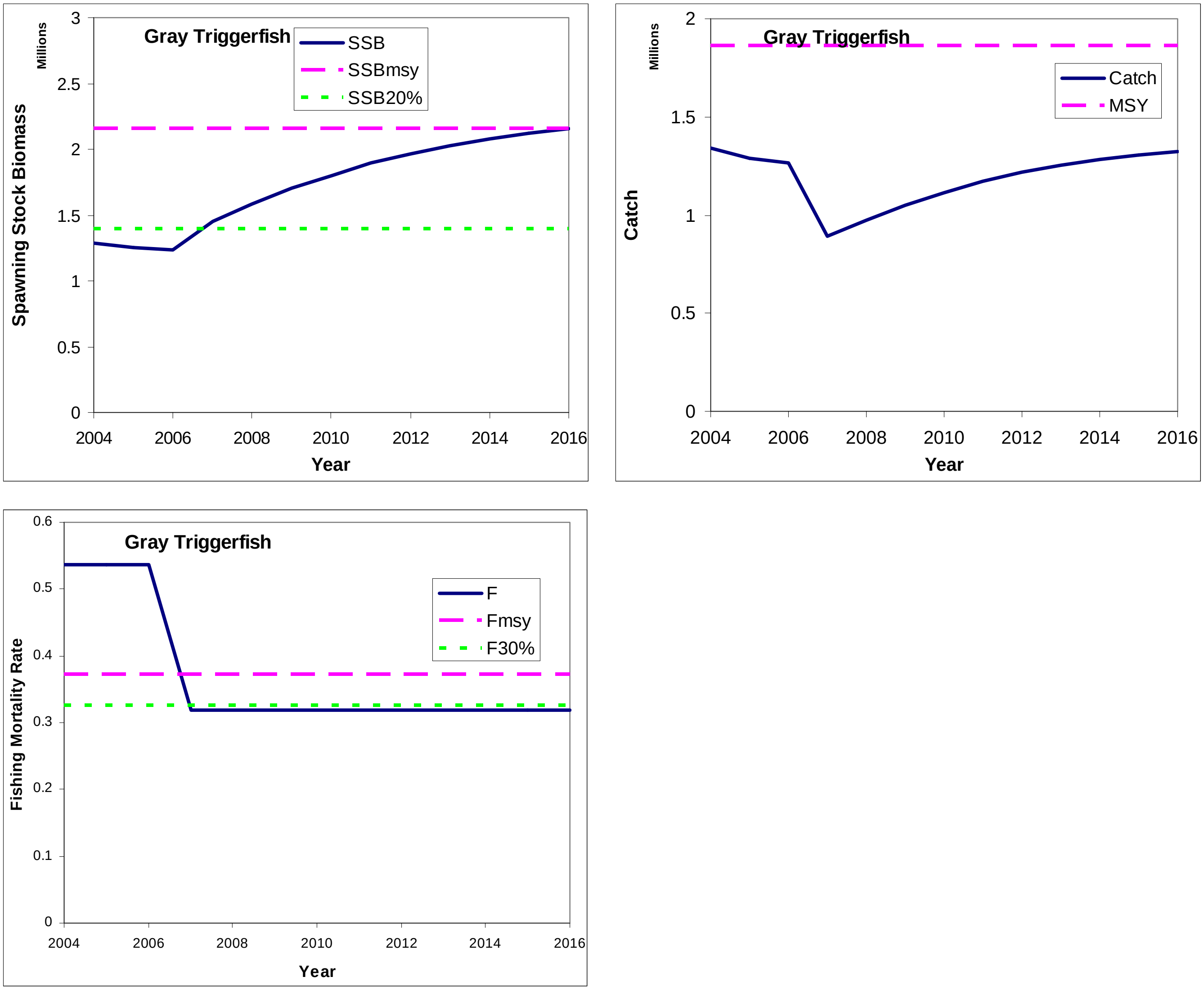

FIG. 6—Projections Under Minimum F Required to Rebuild by 2016
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

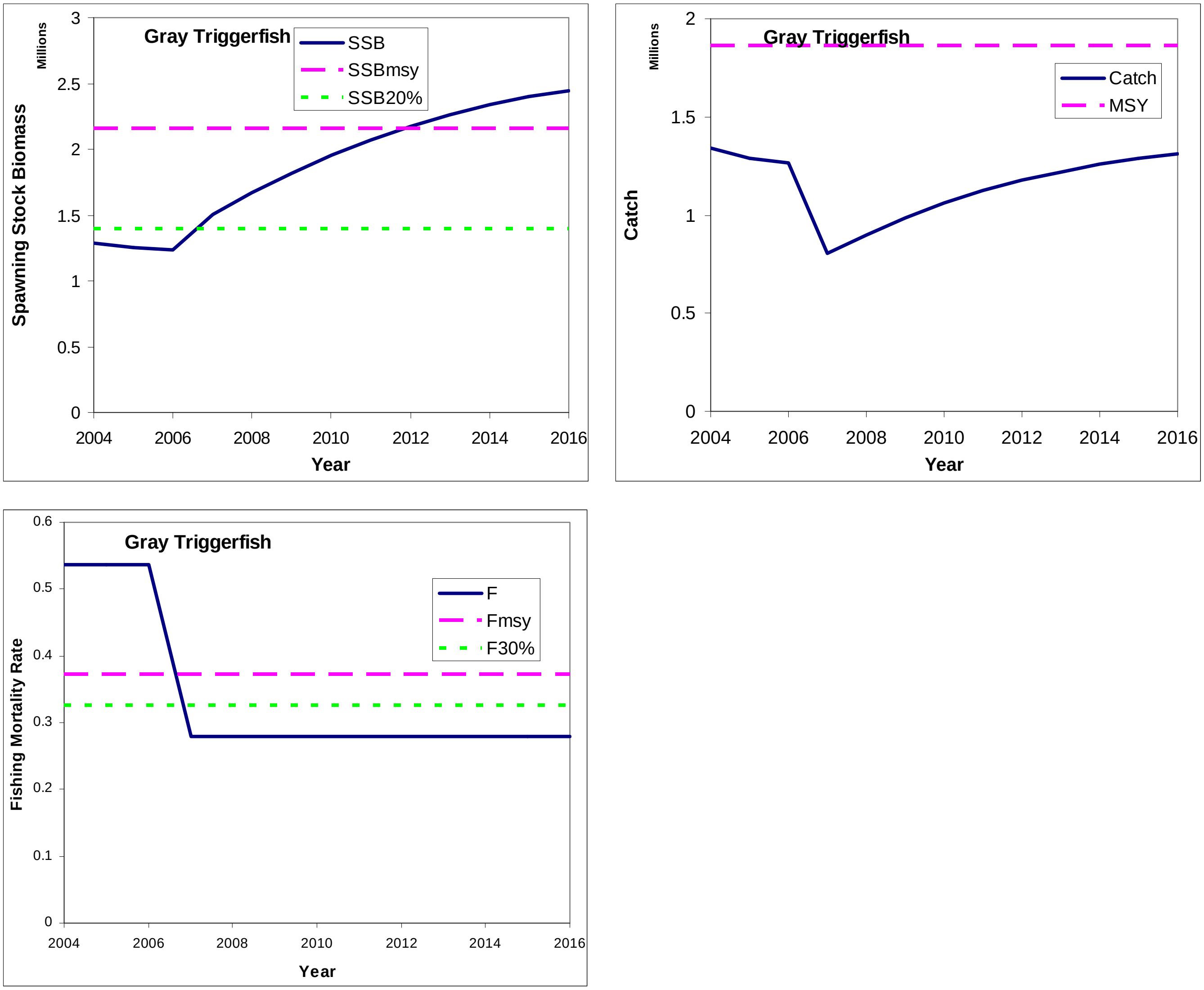

FIG. 7—Projections Under F_{OY}
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

```
#/////////////////////////////////////////////////////////////////////////////////////////////
#/////////////////////////////////////////////////////////////////////////////////////////////
#// INPUT DATA FILE FOR PROGRAM SSASPM
#//
#// Gulf of Mexico Gray Triggerfish
#// August 2005                    Modified    4-Oct-05
#//
#// Josh Sladek Nowlis
#// NOAA Fisheries
#// Southeast Fisheries Science Center
#// Miami, FL
#// (305) 361-4222
#// Joshua.Nowlis@noaa.gov
#//
#//
#// Select columns A-M, save as ssaspmlinear.dat
#//   Important notes:
#//    (1) Comments may be placed BEFORE or AFTER any line of data, however they MUST begin
#//        with a # symbol in the first column.
#//    (2) No comments of any kind may appear on the same line as the data (the #
#//        symbol will not save you here)
#//    (3) Blank lines without a # symbol are not allowed.
#//
#/////////////////////////////////////////////////////////////////////////////////////////////
#/////////////////////////////////////////////////////////////////////////////////////////////
#
###########################################################
# GENERAL INFORMATION
###########################################################
# first and last year of data
      1963      2004
# number of years of historical period
        18
# Historic effort (0 = exact match to effort data, 1 = estimated constant, 2 = estimated linear)
         2
# first and last age of data
         1        10
# number of seasons (months) per year
        12
# type of overall variance parameter (1 = log scale variance, 2 = observation scale variance, 0=force equal weighting)
         1
# spawning season (integer representing season/month of year when spawning occurs)
         7
# maturity schedue (fraction mof each age class that is sexually mature
     0.875         1         1         1         1         1         1         1         1         1
# fecundity schedule (index of per capita fecundity of each age class--batch fecundity in millions of eggs)
 0.2335502  0.320312  0.439306  0.602506  0.826332  1.133309  1.5543255  2.131747  2.923676  4.009801
###########################################################
# CATCH INFORMATION
###########################################################
# number of catch data series (if there are no series, there should be no entries after the next line below)
         5
# pdf of observation error for each series (1) lognormal, (2) normal
         1         1         1         1         1
# units (1=numbers, 2=weight)
         2         2         2         2         1
# season (month) when fishing begins for each series
         1         1         1         1         7
# season (month) when fishing ends for each series
        12        12        12        12        12
# set of catch variance parameters each series is linked to
         1         1         1         1         2
# set of q parameters each series is linked to
         1         2         3         4         5
# set of s parameters each series is linked to
         1         2         3         4         5
# set of e parameters each series is linked to
         1         2         3         4         5
# observed catches by set (no column for year allowed)
# Rec-E    Rec-W    Comm-E   Comm-W   Shrimp Age Year
```

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-1	-1	15700	4300	-1	1964
-1	-1	17400	4300	-1	1965
-1	-1	8600	5200	-1	1966
-1	-1	12200	5200	-1	1967
-1	-1	8600	3900	-1	1968
-1	-1	14600	7700	-1	1969
-1	-1	16000	8200	-1	1970
-1	-1	30500	9900	-1	1971
-1	-1	47400	15200	-1	1972
-1	-1	40000	13200	112277.6	1973
-1	-1	40000	13100	342364.6	1974
-1	-1	62000	16000	380204.4	1975
-1	-1	69700	14800	220049.9	1976
-1	-1	50095.91	9290.086	189051.1	1977
-1	-1	48518.03	10196.7	460314.5	1978
-1	-1	65670.02	35732.98	1771057	1979
-1	-1	65421.67	31001.23	606637.6	1980
748779.46	179616.8	64498	25362	1467734	1981
2032601.4	362711	62959	33714	1206518	1982
397613.53	387301.1	49588	23831	1462755	1983
120970.49	844622.8	37445	32749	304993.5	1984
280865.15	479950.2	54840	37786	855586	1985
898096.37	79076.84	72858	22771	279373.7	1986
1135997.7	199066.1	89313	34290	1044555	1987
1638073.3	158328.2	137978	57084	1364168	1988
1765965.4	212002	230361	87271	906437.2	1989
2313261.1	184940.6	359686.4	99351.17	1286703	1990
1688391.7	399955	341319.2	103211.2	523154.4	1991
1434485.1	688825	338118.9	112075.7	3100516	1992
1317044.1	309425.4	381279.2	177448.4	432659.9	1993
1152103	186425.4	251578.1	153141.4	1951471	1994
1139966.8	329440.7	207212.3	130664.3	1065855	1995
618124.69	226005.8	142184.6	125331.6	1498133	1996
664793.77	100211.2	107779.8	76909.41	1751775	1997
560509.32	93309.19	106152.6	70570.89	1004208	1998
445429.52	43997.12	116194.3	102826.1	242741.5	1999
337240.63	109208.6	63041.56	95094.95	1656166	2000
487621.94	152571.5	108463.6	67718.28	490376.2	2001
721871.85	77016.21	148600.1	86962.79	5115407	2002
856626.38	58622.49	166424.7	85385.05	854441.3	2003
951559.09	78092.38	141411.1	77121.77	167161.8	2004

annual scaling factors for observation variance (relative annual CVs)

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1	1	1	1	1	1964
1	1	1	1	1	1965
1	1	1	1	1	1966
1	1	1	1	1	1967
1	1	1	1	1	1968
1	1	1	1	1	1969
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1	1	1	1	1	1971
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1	1	1	1	0.911815	1973
1	1	1	1	0.99788	1974
1	1	1	1	1.047959	1975
1	1	1	1	0.563759	1976
1	1	1	1	0.56537	1977
1	1	1	1	0.604555	1978
1	1	1	1	1.259889	1979
1	1	1	1	0.442638	1980
1	1	1	1	0.776054	1981
1	1	1	1	0.936054	1982
1	1	1	1	1.073982	1983
1	1	1	1	1.065109	1984
1	1	1	1	1.061948	1985
1	1	1	1	1.135625	1986
1	1	1	1	1.177493	1987
1	1	1	1	1.155266	1988
1	1	1	1	1.109468	1989

1	1	1	1	1.139841	1990
1	1	1	1	1.144917	1991
1	1	1	1	0.477896	1992
1	1	1	1	0.443595	1993
1	1	1	1	0.935097	1994
1	1	1	1	1.088391	1995
1	1	1	1	1.143002	1996
1	1	1	1	1.120295	1997
1	1	1	1	1.127864	1998
1	1	1	1	1.074978	1999
1	1	1	1	1.184296	2000
1	1	1	1	1.187074	2001
1	1	1	1	1.173661	2002
1	1	1	1	1.219074	2003
1	1	1	1	1.400728	2004

###

INDICES OF ABUNDANCE (e.g., CPUE) If there are no series, there should be no entries between the comment lines.

###

number of index data series

8

pdf of observation error for each series (1) lognormal, (2) normal

1 1 1 1 1 1 1 1

units (1=numbers, 2=weight)

1 1 1 2 2 1 1 1

season (month) when index begins for each series

1 1 1 1 1 10 9 5

season (month) when index ends for each series

12 12 12 12 12 11 11 8

option to (1) scale or (0) not to scale index observations

0 0 0 0 0 0 0 0

set of index variance parameters each series is linked to

1 1 1 1 1 1 1 1

set of q parameters each series is linked to

6 7 8 9 10 11 12 13

set of s parameters each series is linked to

1 1 2 3 4 6 7 8

observed indices by series x 10^8 (no column for year allowed)

# MRFSSE	HBE	HBW	CmHLE	CmHLW	LarvalGW-	TrawlGW	VideoGW	Year
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-1	-1	-1	-1	-1	-1	-1	-1	1965
-1	-1	-1	-1	-1	-1	-1	-1	1966
-1	-1	-1	-1	-1	-1	-1	-1	1967
-1	-1	-1	-1	-1	-1	-1	-1	1968
-1	-1	-1	-1	-1	-1	-1	-1	1969
-1	-1	-1	-1	-1	-1	-1	-1	1970
-1	-1	-1	-1	-1	-1	-1	-1	1971
-1	-1	-1	-1	-1	-1	-1	-1	1972
-1	-1	-1	-1	-1	-1	-1	-1	1973
-1	-1	-1	-1	-1	-1	-1	-1	1974
-1	-1	-1	-1	-1	-1	-1	-1	1975
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-1	-1	-1	-1	-1	-1	-1	-1	1978
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59559378	-1	-1	-1	-1	-1	-1	-1	1981
50868542	-1	-1	-1	-1	-1	-1	-1	1982
35535094	-1	-1	-1	-1	-1	-1	-1	1983
213935444	-1	-1	-1	-1	-1	-1	-1	1984
7822068.2	-1	-1	-1	-1	-1	-1	-1	1985
131048572	1578860	2456749	-1	-1	28090000	-1	-1	1986
41944300	1039815	2426165	-1	-1	20700000	221222766	-1	1987
74319582	1366135	3340596	-1	-1	13960000	190217886	-1	1988
122178177	3132138	3081381	-1	-1	8002000	338042013	-1	1989
256472874	5017220	4339279	-1	-1	13800000	77926820	-1	1990
106996949	3957055	5133360	-1	-1	27840000	1.291E+09	-1	1991
94729530	4574219	4560725	-1	-1	91810000	75775134	68549000	1992
58760545	3585924	4591890	1.56E+08	55916617	31130000	640449444	37395000	1993
53296524	2780550	4463384	1.47E+08	71327783	35770000	613493817	33632000	1994

82087588	2419154	4099585	1.52E+08	80526939	35640000	257204165	31823000	1995
47628834	1715052	4180940	66896638	50180949	24180000	226347219	29654000	1996
26705984	1816977	3769818	55949368	39948460	25410000	154496306	62533000	1997
20243170	1561531	2565767	52796109	52268125	-1	14675364	-1	1998
20977824	1654448	1144995	50808752	70790644	8045000	346253161	-1	1999
16458045	1162980	1159826	37050498	52932912	83120000	602549721	-1	2000
25277308	1303939	1371411	54917389	36569329	13720000	1.115E+09	5343000	2001
26175442	1981108	1513616	97778962	39080538	19010000	258028537	29957000	2002
25252012	2005931	1856765	1.09E+08	35090550	-1	218780772	-1	2003
29049705	2154191	2137627	86613049	35260095	-1	261614013	-1	2004

annual scaling factors for observation variance (relative annual CVs)

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1	1	1	1	1	1	1	1	1964
1	1	1	1	1	1	1	1	1965
1	1	1	1	1	1	1	1	1966
1	1	1	1	1	1	1	1	1967
1	1	1	1	1	1	1	1	1968
1	1	1	1	1	1	1	1	1969
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1	1	1	1	1	1	1	1	1971
1	1	1	1	1	1	1	1	1972
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1	1	1	1	1	1	1	1	1974
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1	1	1	1	1	1	1	1	1978
1	1	1	1	1	1	1	1	1979
1	1	1	1	1	1	1	1	1980
2.3481011	1	1	1	1	1	1	1	1981
2.070742	1	1	1	1	1	1	1	1982
2.761414	1	1	1	1	1	1	1	1983
6.9512632	1	1	1	1	1	1	1	1984
7.2024144	1	1	1	1	1	1	1	1985
0.9399457	1.371901	0.951521	1	1	1	1	1	1986
1.2098526	1.832588	0.853511	1	1	0.934014	1.0551807	1	1987
1.1323095	1.285721	0.715741	1	1	1.090213	1.1171951	1	1988
1.1524367	0.684331	0.810134	1	1	1.158219	0.5279337	1	1989
1.0877329	0.446229	0.605246	1	1	0.868347	3.6978365	1	1990
1.0518819	0.549589	0.520694	1	1	0.834705	0.2072022	1	1991
0.8458045	0.480808	0.56144	1	1	0.900859	3.274347	0.865553	1992
1.0022765	0.566484	0.557139	1.060936	1.018465	1.132716	0.3129469	0.914865	1993
1.0913614	0.714003	0.528381	0.966938	0.999512	0.841992	0.3307473	0.878982	1994
1.174345	0.850946	0.563249	1.077523	1.01527	0.812304	0.7384777	0.974878	1995
1.2204588	1.053125	0.569626	1.006893	1.005816	0.970142	0.8194269	0.866941	1996
1.0742782	1.021767	0.661811	1.07055	1.006119	0.928487	1.7887012	1.060699	1997
1.041824	1.113295	0.873661	1.107454	0.996958	1.177347	0.7444719	1	1998
0.9039276	1.036357	1.727267	0.947706	0.985043	0.860483	0.5112333	1	1999
0.9771672	1.37544	1.643842	1.071766	0.992177	1.183722	0.3145877	1	2000
0.8978562	1.334974	1.392549	1.015394	1.003783	1.031773	0.2086763	1.395689	2001
0.8906162	1.023834	1.39093	0.906473	0.993139	0.820741	0.7019244	1.042393	2002
0.9040351	1.004179	1.088876	0.852938	0.991271	1.436616	0.8752888	1	2003
0.8218537	0.905594	1.002669	0.915428	0.992447	1.017321	0.7738224	1	2004

##
EFFORT OBSERVATIONS If there are no series, there should be no entries between the comment lines.
##
number of effort data series
0
##
AGE COMPOSITION OBSERVATIONS If there are no series, there should be no entries between the comment lines.
##
number of age-composition series (If there are no series,there should be no more entries in this section)
5
first year in age-composition series
1981
probability densities used for age-comp. series (0 = ignore, 3 = multinomial, 8 = robustified normal)
3 3 3 3 0
units (only 1=numbers, no other options at this time)
1 1 1 1 1
season (month) when age collections begin for each series

1 1 1 1 7

season (month) when age collections end for each series

12 12 12 12 12

age composition data for all years in the modern period

# series	year	sample siz	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10+
1	1981	49	6.683833	14.55645	12.9313	7.567416	3.479636	1.86342	0.940379	0.330072	0.289612	0.357806
1	1982	92	12.85183	25.20349	24.64398	15.073289	7.110661	3.663385	1.909051	0.78574	0.472655	0.285686
1	1983	70	7.990986	20.09468	19.24166	11.4367	5.114646	3.066469	1.520591	0.673263	0.395281	0.465488
1	1984	24	3.781056	8.243904	5.741553	2.7614778	1.589708	0.953419	0.424684	0.258591	0.068488	0.177131
1	1985	27	2.700271	6.048892	6.216951	5.2300015	3.051017	1.439593	1.254609	0.325129	0.32401	0.409568
1	1986	274	28.21374	70.70483	71.30153	47.530052	25.87361	14.52127	8.029534	3.354134	2.084648	2.386021
1	1987	578	77.85847	155.1662	139.2159	93.993625	54.70624	29.33744	14.72234	6.233203	3.829021	2.93678
1	1988	696	88.74984	199.2801	177.8355	112.98372	57.91839	30.61759	16.32679	5.815902	3.698644	2.772721
1	1989	1114	199.2858	328.4621	251.3632	158.14253	91.6563	47.31169	21.74484	6.898737	5.589603	3.54586
1	1990	1579	279.2999	513.461	367.1782	203.73874	112.1557	60.73686	25.98431	7.854036	5.91847	2.674526
1	1991	1499	204.1712	429.8621	380.9281	240.65181	125.4167	62.43495	31.82659	11.70053	6.905953	5.099961
1	1992	2200	299.4172	649.6174	557.9516	343.99012	175.938	91.81638	46.84962	16.35747	10.17757	7.882939
1	1993	970	136.4747	297.766	246.7135	143.60209	73.76489	38.88499	19.11463	6.714899	4.328258	2.635491
1	1994	1116	183.1159	350.1557	267.5916	155.36889	82.61143	42.67374	20.02459	6.420062	4.929604	3.109059
1	1995	1034	160.9987	340.6296	255.2023	137.58128	71.90313	38.45555	17.59014	5.710101	3.93704	1.992712
1	1996	788	116.6681	257.0968	200.7716	108.20571	54.18175	28.8908	13.41826	4.2366	2.812408	1.717871
1	1997	1190	170.5544	370.4786	295.6585	173.42588	92.33329	47.65315	23.86941	7.484731	5.364065	3.17802
1	1998	2094	292.6357	690.8389	540.5222	286.97132	142.7198	79.01015	37.66422	11.9715	7.591233	4.074114
1	1999	2379	324.4544	783.6046	623.2016	330.54404	160.4864	87.17141	42.04689	13.71274	8.469533	5.307429
1	2000	2426	304.7471	727.429	635.6375	382.59334	193.4004	97.14375	50.6322	17.15259	10.91044	6.351283
1	2001	2756	381.862	893.3115	704.6439	388.95179	198.6706	105.1803	50.56173	16.96656	10.31893	5.531969
1	2002	2935	377.7485	940.5624	773.9294	421.04542	211.4095	114.5846	57.40986	19.16064	11.54815	7.598442
1	2003	2655	353.2094	850.1884	691.0708	385.17401	191.5441	101.3534	50.3486	16.11704	10.23873	5.75467
1	2004	2884	368.1259	918.0599	769.2028	423.83612	204.467	109.6062	54.97446	18.06407	10.85488	6.806222
2	1981	10	0	0.02439	0.22147	1.38688	2.40068	2.49219	1.964	0.8144	0.37098	0.32506
2	1982	7	0.1	0.78328	0.82376	1.21632	1.84668	1.259	0.97096	0	0	0
2	1983	3	0	0	0.05506	0.27679	0.33185	0.45536	0.42411	0.28274	0.05506	0.11905
2	1984	29	0	0.02439	0.85605	1.75242	3.97362	5.38987	10.2954	3.87882	1.17946	1.65014
2	1985	1	0	0.02439	0.02439	0.14634	0.39024	0.21951	0.19512	0	0	0
2	1986	217	5.591276	19.81634	21.39219	36.251755	43.17054	42.44633	30.95531	8.980596	3.388802	4.007188
2	1987	235	4.983782	16.3795	18.42267	39.556984	52.39132	49.35746	35.28577	9.594876	3.031628	5.99618
2	1988	167	2.582747	15.16451	15.19125	30.095936	36.39325	32.59676	22.6764	6.318001	1.705891	4.275362
2	1989	274	2.260948	17.06062	20.2946	47.757383	64.05226	64.58842	38.17077	10.98458	3.011971	5.818565
2	1990	352	2.62216	17.66238	23.04167	59.816901	80.84969	83.91376	52.33052	17.59651	4.795701	9.370779
2	1991	313	1.107287	10.73989	16.57688	50.80844	72.12251	73.15469	51.76513	19.5431	5.201813	10.98091
2	1992	743	9.33545	47.53322	54.58139	126.46244	169.0177	165.7886	108.88	33.36381	9.402623	17.63554
2	1993	427	1.47559	12.00779	21.49249	62.411733	96.49948	101.2756	78.60541	29.74856	9.93158	12.52676
2	1994	676	3.325708	32.10039	45.05173	105.50355	155.0755	154.479	114.62	35.88974	11.63157	16.32305
2	1995	566	1.817169	19.09081	28.97476	89.68223	137.9308	138.6886	94.52591	30.80543	9.820216	14.66412
2	1996	488	2.338714	18.38168	27.43717	80.172516	121.5692	120.4059	77.01096	22.42297	6.666286	11.59475
2	1997	185	1.005982	8.613619	12.12966	28.707928	38.76528	43.95521	31.70517	12.18747	3.051064	4.8787
2	1998	332	1.40533	14.12528	20.35309	51.766045	79.09085	78.06189	56.20971	17.2914	6.112707	7.583795
2	1999	135	0.399998	4.56866	6.943022	21.573414	32.16997	32.84531	20.35465	6.793916	2.146123	3.205029
2	2000	56	0	1.533119	3.191339	7.0636873	13.14988	11.8594	11.89793	3.459279	1.418	1.42757
2	2001	111	0.302969	3.511307	5.182332	18.268734	28.32873	29.09136	17.28685	5.235766	1.331844	2.460155
2	2002	154	0.794001	2.824699	5.025956	24.522922	36.30256	39.41294	25.9285	10.08559	2.863372	5.23972
2	2003	182	0.611716	7.061209	10.78633	28.637659	40.70334	43.90187	31.34596	11.07285	2.816449	5.062833
2	2004	119	0.1	3.417449	6.372952	18.543997	28.95136	29.17832	20.22771	7.128822	1.929466	3.150161
3	1981	0	0	0	0	0	0	0	0	0	0	0
3	1982	0	0	0	0	0	0	0	0	0	0	0
3	1983	0	0	0	0	0	0	0	0	0	0	0
3	1984	0	0	0	0	0	0	0	0	0	0	0
3	1985	0	0	0	0	0	0	0	0	0	0	0
3	1986	0	0	0	0	0	0	0	0	0	0	0
3	1987	0	0	0	0	0	0	0	0	0	0	0
3	1988	0	0	0	0	0	0	0	0	0	0	0
3	1989	1	0.08717	0.401937	0.263922	0.1452803	0.053267	0.026638	0.012108	0.009687	0	0
3	1990	67	3.223407	9.623322	12.35797	11.236006	9.087983	8.766192	4.093127	3.342451	1.814501	3.454747
3	1991	36	0.927806	1.428554	2.411908	5.037953	5.961932	7.114225	3.314033	3.135205	2.005321	4.662976
3	1992	54	2.540079	7.25546	9.242561	9.5551401	8.409575	6.419864	3.518082	2.517056	1.457359	3.08471
3	1993	623	52.34089	146.1499	167.2291	115.84978	61.15442	36.30718	19.4739	10.53481	5.468831	8.48897
3	1994	980	93.8867	242.8888	253.3765	179.87201	97.70492	52.67382	29.59293	13.16928	8.164492	8.668242
3	1995	979	94.54778	256.4688	264.0245	177.27583	92.28004	46.03134	26.24207	10.57459	6.319682	5.233185
3	1996	907	92.30825	236.7039	244.5612	163.37036	81.63231	42.79206	23.94791	9.86463	5.960975	5.855954
3	1997	735	82.35543	195.5767	195.7529	132.18528	65.6331	31.99752	17.51549	6.860957	3.947595	3.17332

3	1998	635	75.84935	183.8084	161.3491	98.080283	52.03049	30.7372	15.78697	7.378001	4.090488	5.889145
3	1999	566	48.66077	134.9053	145.8223	103.79679	56.57937	33.67083	18.91222	10.08299	5.131431	8.436479
3	2000	359	30.45848	88.99176	96.32543	65.183714	34.06245	19.67907	11.51744	5.719862	2.659451	4.401294
3	2001	817	82.69642	216.3159	224.6094	143.27417	71.31313	38.49329	20.43596	8.898379	5.136658	5.824159
3	2002	525	57.53503	145.6692	134.4771	84.572832	45.46871	26.0167	14.22372	6.490751	4.172445	6.372406
3	2003	343	34.69652	81.44614	79.33191	57.920221	37.21914	23.10775	12.2144	7.239466	3.722304	6.10139
3	2004	186	12.79279	38.78265	46.5092	36.885832	22.33516	12.768	7.427791	3.727102	2.090014	2.680931
4	1981	0	0	0	0	0	0	0	0	0	0	0
4	1982	0	0	0	0	0	0	0	0	0	0	0
4	1983	0	0	0	0	0	0	0	0	0	0	0
4	1984	0	0	0	0	0	0	0	0	0	0	0
4	1985	0	0	0	0	0	0	0	0	0	0	0
4	1986	0	0	0	0	0	0	0	0	0	0	0
4	1987	0	0	0	0	0	0	0	0	0	0	0
4	1988	0	0	0	0	0	0	0	0	0	0	0
4	1989	0	0	0	0	0	0	0	0	0	0	0
4	1990	284	0.3	3.33243	9.28439	29.86115	50.66102	57.17613	68.93896	26.529	8.57147	11.34705
4	1991	660	1.4	13.77083	27.65188	82.34424	134.2891	143.8223	137.1464	52.49309	18.41527	21.67027
4	1992	1181	1.7	18.80012	44.07285	156.88276	258.6317	274.6359	239.1921	93.90986	34.31449	39.86634
4	1993	586	0.5	5.47739	20.07087	61.22433	109.0858	124.808	141.8139	58.74066	21.98465	21.29761
4	1994	870	1.8	14.49279	34.95952	88.9082	152.6647	173.3878	218.1225	83.99081	31.0788	34.60019
4	1995	381	0.6	5.7624	13.31641	44.3335	75.55197	82.39726	87.12224	33.63071	11.02511	13.26221
4	1996	248	0	1.50873	8.32633	27.21919	47.39304	51.31487	60.1971	25.68764	9.79453	10.56029
4	1997	249	0	0.60627	6.64874	25.3365	47.4027	53.94095	64.01243	25.37671	9.33828	10.33875
4	1998	115	0.664652	2.249573	4.84175	15.321409	26.78601	25.54883	23.64832	8.248703	3.970953	3.72041
4	1999	51	0	0.04878	1.41746	6.04058	10.00084	11.9494	11.63542	5.82904	2.06428	2.01454
4	2000	35	0	0.21603	1.02486	4.36068	7.56322	7.14625	8.50205	3.10815	1.32224	1.75677
4	2001	99	0.1	0.92962	3.54888	10.26101	19.50143	20.32304	25.21073	9.93736	4.14388	4.04461
4	2002	145	0.1	1.52893	5.41801	17.18919	30.95911	32.34375	33.10108	13.47699	5.64968	5.23408
4	2003	205	0.563019	1.791486	7.408921	24.81121	40.73053	47.11034	45.68147	20.2789	7.706452	7.916424
4	2004	78	0	1.31709	3.28814	11.01523	17.66183	16.45391	16.19646	5.51711	1.91302	3.63776
5	1981	1	1	0	0	0	0	0	0	0	0	0
5	1982	1	1	0	0	0	0	0	0	0	0	0
5	1983	1	1	0	0	0	0	0	0	0	0	0
5	1984	1	1	0	0	0	0	0	0	0	0	0
5	1985	1	1	0	0	0	0	0	0	0	0	0
5	1986	1	1	0	0	0	0	0	0	0	0	0
5	1987	1	1	0	0	0	0	0	0	0	0	0
5	1988	1	1	0	0	0	0	0	0	0	0	0
5	1989	1	1	0	0	0	0	0	0	0	0	0
5	1990	1	1	0	0	0	0	0	0	0	0	0
5	1991	1	1	0	0	0	0	0	0	0	0	0
5	1992	1	1	0	0	0	0	0	0	0	0	0
5	1993	1	1	0	0	0	0	0	0	0	0	0
5	1994	1	1	0	0	0	0	0	0	0	0	0
5	1995	1	1	0	0	0	0	0	0	0	0	0
5	1996	1	1	0	0	0	0	0	0	0	0	0
5	1997	1	1	0	0	0	0	0	0	0	0	0
5	1998	1	1	0	0	0	0	0	0	0	0	0
5	1999	1	1	0	0	0	0	0	0	0	0	0
5	2000	1	1	0	0	0	0	0	0	0	0	0
5	2001	1	1	0	0	0	0	0	0	0	0	0
5	2002	1	1	0	0	0	0	0	0	0	0	0
5	2003	1	1	0	0	0	0	0	0	0	0	0
5	2004	1	1	0	0	0	0	0	0	0	0	0

```
##########################################################################################
# PARAMETER INPUT FILE--Gray Triggerfish September 2005            Modified     18-Nov-05
##########################################################################################
#
#==========================================================================================
# Total number of process parameters (must match number of entries in 'Specifications 1' section)
#==========================================================================================
          58
#==========================================================================================
# Number of sets of each class of parameters (must be at least 1)
#==========================================================================================
#        q (catchability)
#           |           Effort
#           |           |           Vulnerability (selectivity)
#           |           |           |           catch observation variance scalar
#           |           |           |           |           index variance scalar
#           |           |           |           |           |     effort variance scalar
#           |           |           |           |           |           |
#----------------------------------------------------------------------------------------------------------------------
                       13          5          8          2          1          1
#==========================================================================================
# Specifications 1: process parameters and observation error parameters
#==========================================================================================
#        class (nature) of parameter (1=constant, 2-4 = polynomial of degree x)
#           |           best estimate (or central tendency of prior)
#           |           |           lower bound  upper bound
#           |           |           |           |           phase to estimate (-1 = don't estimate)
#           |           |           |           |           |     prior density (1= lognormal, 2=normal, 3=uniform)
#           |           |           |           |           |           |     prior variance
#           |           |           |           |           |           |           |
#----------------------------------------------------------------------------------------------------------------------
# Natural mortality rate
                        1       0.27       0.19        0.41         -3          1       0.25
# Recruitment (10=Beverton/Holt, 11=Ricker)
                       10   20000000    1000000  1000000000          1          3          1
                       10         12        1.1         100          2          1     0.0098
# Growth (type 8 = von Bertalanfy/Richards, Linf, K, t0, m, a, b (weight=al^b))
                        8      423.4     0.0001     1000000         -1          0          1
                        8     0.4269          0           2         -1          0          1
                        8    -0.6292         -5           5         -1          0          1
                        8          1          0          10         -1          0          1
                        8 4.4858E-08          0         100         -1          0          1
                        8     3.0203          0           5         -1          0          1
# catchability
                        1          1      1E-10          10         -1          0          1 # Rec-E
                        1          1      1E-10          10         -1          0          1 # Rec-W
                        1          1      1E-10          10         -1          0          1 # Comm-E
                        1          1      1E-10          10         -1          0          1 # Comm-W
                        1          1      1E-10          10         -1          0          1 # Shrimp
                        1        0.1      0.001        1000          1          0          1 # MRFSSE
                        1        0.1      0.001        1000          1          0          1 # HBE
                        1        0.1      0.001        1000          1          0          1 # HBW
                        1        0.1      0.001        1000          1          0          1 # CmHLE
                        1        0.1      0.001        1000          1          0          1 # CmHLW
                        1        0.1      0.001        1000          1          0          1 # Larval
```

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        1        0.1      0.001       1000        1        0        1 # Trawl
        1        0.1      0.001       1000        1        0        1 # Video
# effort for 'prehistoric' period when data is sparse (Fix at anything if linear estimation is used)
        1     0.0001     -1E-32        1.1       -4        0        1 # Rec-E
        1     0.0001     -1E-32        1.1       -4        0        1 # Rec-W
        1     0.0001   0.000001        1.1        4        0        1 # Comm-E
        1     0.0001   0.000001        1.1        4        0        1 # Comm-W
        1     0.0001     -1E-32        1.1       -4        0        1 # Shr
# effort for period with useful data
        1      0.001    0.00001        0.3        1        0        1 # Rec-E
        1      0.001    0.00001        0.3        1        0        1 # Rec-W
        1      0.001    0.00001        0.3        1        0        1 # Comm-E
        1      0.001    0.00001        0.3        1        0        1 # Comm-W
        1      0.001    0.00001        0.3        1        0        1 # Shr
# vulnerability (selectivity) (5=knife edge, 6=logistic, 7=gamma, 15 = double logistic)
        6        0.4          0          2        3        0        1 # Rec-E
        6       1.65        0.5         10        4        0   0.0625
        6        0.7          0          2        3        0        1 # Rec-W
        6        1.2        0.5         10        4        0   0.0625
        6        0.5          0          2        3        0        1 # Comm-E
        6        1.2        0.5         10        4        0   0.0625
        6        0.7          0          2        3        0        1 # Comm-W
        6        1.7        0.5         10        4        0   0.0625
       15          0         -1         10       -3        0   0.0625 #Shrimp
       15       0.01          0          2       -4        0        1
       15        2.1         -1         10       -3        0   0.0625
       15        0.2          0          2       -4        0        1
       15 0.99592986          0          1       -4        0        1
        6        0.7          0          2       -3        0   0.0625 #Larval
        6          8          0         10       -4        0        1
       15          0         -1         10       -3        0   0.0625 #Trawl
       15       0.01          0          2       -4        0        1
       15        2.1         -1         10       -3        0   0.0625
       15        0.2          0          2       -4        0        1
       15 0.99592986          0          1       -4        0        1
        6        0.5          0          2       -3        0        1 #Video
        6          1        0.5         10       -4        0   0.0625
# catch observation error variance scalar
        1          1       0.01          5       -1        0        1 # All others
        1          2       0.01          5       -1        0        1 # Shrimp
# index observation error variance scalar
        1          2        0.1          5       -1        0        1
# effort observation error variance scalar
        1          1        0.1          5       -1        0        1
#==============================================================================
# Specifications 2: process ERROR parameters
#==============================================================================
#       best estimate (or central tendency of prior)
#          |          lower bound  upper bound
#          |          |             phase to estimate (<0 = don't estimate)
#          |          |          |          |         prior density (1=lognormal, 2=normal, 3=uniform)
#          |          |          |          |         |    prior variance
#          |          |          |          |         |         |
#-------------------------------------------------------------------------------------------
# overall variance (negative value indicates a CV)
```

```
-0.2   -2   -0.01   3   0   1
# recruitment process variation parameters (allows year to year fluctuations)
#   correlation coefficient
0   -1E-32   0.99   -1   0   1
#   variance scalar (multiplied by overall variance)
0.05   0   1E+20   -1   0   1
#   annual deviation parameters (last entry is arbitrary for deviations)
0   -5   5   4   1   1
# catchability process variation parameters (allows year to year fluctuations)
#   correlation coefficients
0   -1E-32   0.99   -1   0   1   # Rec-E
0   -1E-32   0.99   -1   0   1   # Rec-W
0   -1E-32   0.99   -1   0   1   # Comm-E
0   -1E-32   0.99   -1   0   1   # Comm-W
0   -1E-32   0.99   -1   0   1   # Shrimp
0   -1E-32   0.99   -1   0   1   # MRFSSE
0   -1E-32   0.99   -1   0   1   # HBE
0   -1E-32   0.99   -1   0   1   # HBW
0   -1E-32   0.99   -1   0   1   # CmHLE
0   -1E-32   0.99   -1   0   1   # CmHLW
0   -1E-32   0.99   -1   0   1   # Larval
0   -1E-32   0.99   -1   0   1   # Trawl
0   -1E-32   0.99   -1   0   1   # Video
#   variance scalars (multiplied by overall variance)
0   -1E-32   1E+20   -1   0   1   # Rec-E
0   -1E-32   1E+20   -1   0   1   # Rec-W
0   -1E-32   1E+20   -1   0   1   # Comm-E
0   -1E-32   1E+20   -1   0   1   # Comm-W
0   -1E-32   1E+20   -1   0   1   # Shrimp
0   -1E-32   1E+20   -1   0   1   # MRFSSE
0   -1E-32   1E+20   -1   0   1   # HBE
0   -1E-32   1E+20   -1   0   1   # HBW
0   -1E-32   1E+20   -1   0   1   # CmHLE
0   -1E-32   1E+20   -1   0   1   # CmHLW
0   -1E-32   1E+20   -1   0   1   # Larval
0   -1E-32   1E+20   -1   0   1   # Trawl
0   -1E-32   1E+20   -1   0   1   # Video
#   annual deviation parameters (last entry is arbitrary for deviations)
0   -5   5   -1   0   1   # Rec-E
0   -5   5   -1   0   1   # Rec-W
0   -5   5   -1   0   1   # Comm-E
0   -5   5   -1   0   1   # Comm-W
0   -5   5   -1   0   1   # Shrimp
0   -5   5   -1   0   1   # MRFSSE
0   -5   5   -1   0   1   # HBE
0   -5   5   -1   0   1   # HBW
0   -5   5   -1   0   1   # CmHLE
0   -5   5   -1   0   1   # CmHLW
0   -5   5   -1   0   1   # Larval
0   -5   5   -1   0   1   # Trawl
0   -5   5   -1   0   1   # Video
# effort process variation parameters (allows year to year fluctuations)
#   correlation coefficients
0.5   0   0.99   -1   0   1   # Rec-E
0.5   0   0.99   -1   0   1   # Rec-W
```

	0.5	0	0.99	-1	0	1	# Comm-E
	0.5	0	0.99	-1	0	1	# Comm-W
	0.5	0	0.99	-1	0	1	# Shr
#	variance scalars (multiplied by overall variance)						
	0.223	0	1E+20	-1	0	1	# Rec-E
	0.223	0	1E+20	-1	0	1	# Rec-W
	0.223	0	1E+20	-1	0	1	# Comm-E
	0.223	0	1E+20	-1	0	1	# Comm-W
	0.0392	0	1E+20	-1	0	1	# Shr
#	annual deviation parameters (last entry is arbitrary for deviations)						
	0.0001	-5	5	2	1	1	# Rec-E
	0.0001	-5	5	2	1	1	# Rec-W
	0.0001	-5	5	2	1	1	# Comm-E
	0.0001	-5	5	2	1	1	# Comm-W
	0.0001	-5	5	2	1	1	# Shr