Age-Based Analyses of the Gulf of Mexico Gray Triggerfish (*Balistes capriscus*) Stock

by

Joshua Sladek Nowlis

NOAA Fisheries
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, FL 33149

Sustainable Fisheries Division Contribution No. SFD-2005-033

30 November 2005, *revised* 15 December 2005

EXECUTIVE SUMMARY

Analyses were performed on inferred catch-at-age data from the Gulf of Mexico gray triggerfish (*Balistes capriscus*) stock. The inference of age-structure in this stock was not previously possible due to data gaps. Catch curve analyses were performed to estimate fishing mortality rates from catch at size distributions spanning 1990 to 2004. A state space age-structured production model (SSASPM) was also developed. The base model and most sensitivity runs indicated that the Gulf of Mexico gray triggerfish stock is overfished and experiencing overfishing, whether based on current SPR reference points or typical MSY based ones. Given the consistency across the range of sensitivity analyses, the status of gray trigger appears robust, at least to non-structural assumptions. Since a simple, non-age-structured surplus production model also indicated an overfished stock experiencing overfishing, the conclusion also appears robust to at least some structural assumptions. It is recommended that the base SSASPM model presented here serve as the base model for the current assessment of the Gulf of Mexico gray triggerfish stock and serve as the basis of future management actions.

INTRODUCTION

Two analytic exercises were conducted using the age structure inferred from catches of Gulf of Mexico gray triggerfish (*Balistes capriscus*). First, total mortality rates were estimated from catch curve analyses, which used the decay in numbers of gray triggerfish with increasing age. A state space age-structured production model (SSASPM) was also constructed for the Gulf of Mexico gray triggerfish stock. This model relied on parameters describing basic life history traits (e.g., natural mortality, stock-recruitment relationship) and properties of the fishery (e.g., effort, catchability, selectivity pattern). These parameters were sometimes treated as invariant (e.g., natural mortality) while others varied from year to year (e.g., recruitment deviations), fleet to fleet (e.g., effort) or age-class to age-class (e.g., selectivity). The model estimated specific parameters using data in the form of catches, indices of abundance, and age composition, typically categorized by fleet and year. One important feature of SSASPM is the way it estimates the starting point for the population. It uses an historic period during which the stock is fished down from virgin condition modeled as a linear increase in effort.

METHODS

Catch Curve Analysis

Data for the catch curve analysis came from the Trip Interview Program. Interviews included the direct measurement of catches from both commercial and recreational fishers in the eastern and western Gulf (split as close to the Mississippi River as the data allowed). The resulting size distributions were converted to ages using age-length relationships developed in the SEDAR9 Data Workshop (SEDAR9-DW- Report).

Instead of directly assigning an age to each fish based on its size, a probabilistic approach was used (Saul and Ingram, SEDAR9-AW06). Fish were sorted into 25 mm length bins and a multinomial model was used to estimate the probability of a fish of a particular length class occurring in a particular age class. The probability distributions for each fish were stacked to produce an overall distribution for strata defined by year, region (eastern and western Gulf), and sector (commercial or recreational).

In all cases, logistic selectivity patterns were assumed and a natural mortality rate of 0.27 was applied. However, these patterns depended on how shrimp bycatch was treated. In some runs, bycatch was split so that 30 percent was applied to the eastern Gulf and 70 percent to the western Gulf. In other runs, shrimp bycatch was ignored so that the estimated fishing mortality rates and selectivity patterns represented only directed fleets.

SSASPM Overview

Several decisions were made about the basic structure of the SSASPM model when used to describe gray triggerfish. These decisions were primarily based on conclusions made at the SEDAR9 Data Workshop (SEDAR9-DW-Report). Structural and data choices for the base model are presented in Appendices 1 and 2 to this document and described below.

Stock Structure

The Data Workshop concluded that although multiple Gulf stocks of gray trigger were possible, the evidence did not support a split. Nonetheless, examination of the age or size composition from the eastern and western Gulf indicated that younger fish are generally caught in the eastern Gulf (Saul and Ingram SEDAR9-AW06), presumably as a result of differential fishing pressure. Consequently, we modeled directed fleets separately as eastern and western components, with the split occurring at the Mississippi River.

Age structure

Gray triggerfish are caught as bycatch in shrimp trawls during their first year of life. However, modeling age-0 fish presents a number of difficulties, including the technical problem that SSASPM is not yet designed to accommodate age-0 fish. Moreover, it is very likely that age-0 fish experience much heavier natural mortality than older fish and this mortality may have density-dependent relationships which could differ from the patterns of density-dependence during reproduction. We can get around some of these problems by using a model that starts with age-1 fish, but this approach also raises the issue of how to account for fishing mortality on the youngest fish (in this case, from the shrimp fleet). This issue is addressed below. Gray triggers can live to at least 16 years of age. However, they become uncommon after age 10. Consequently, we modeled the stock in age classes starting at 1 and ending at 10+ years old.

Stock-recruitment

SSASPM allows one to model recruitment as a Beverton-Holt or Ricker curve. We chose a Beverton-Holt curve as it is believed to fit most stocks better, excepting those that experience especially strong, population-wide density-dependent competition. For initial exploration of the model, a prior distribution of the α parameter was used. It relied on a meta-analysis by Myers and colleagues (1999), which was modified to address various life history strategies by Rose and co-authors (2001). Gray triggerfish fit Rose and colleagues' definition of a periodic life history species. The distribution of α parameters for periodic species had a median value of 12.6, a mean of 17.6, and a lognormally distributed standard deviation of 0.98. These values closely correspond with the data workshop's advice to examine a range of steepness values centered around 0.8 ($\alpha = 16$) (SEDAR9-DW-Report).

Time Period

The quantity and quality of data streams for gray triggerfish improved dramatically in 1981 and again in 1986. From 1963 to 1980, only commercial catches were recorded. Starting in 1981, catch and catch-at-size information were recorded from the recreational fishery. In 1986, recreational sampling improved markedly, and by 1993 all current data streams were online. Although 1993 was the first year when virtually all sources were operational, the information in 1981 was deemed adequate to inform the model directly. The historic phase of the model stretches from 1963, when commercial catches were first reported, to 1980. Given the low level of catches in 1963, it may be reasonable to consider the stock virgin at that time. However, shrimp bycatch may have reduced it even at that early date.

Data Sources

Catches

Catch information was derived from several fleets (SEDAR9-DW-Report). Based on age-structure of the catches, these were pooled into four directed fleet categories: recreational east, recreational west, commercial east, and commercial west, with the east-west split occurring at the Mississippi River. Shrimp bycatch was derived for the Gulf as a whole (Table 1, Fig. 1). Bycatch from other fleets was ignored because of the extremely low release mortality of gray triggers (SEDAR9-DW-Report).

All directed catches were converted into weights even though SSASPM is capable of taking catches in numbers. Recreational catches were reported in numbers and converted using size distributions. This conversion provided consistency with the non-age-structured surplus production model but could be explored further. Commercial catches were reported in weight and so required no conversions. Shrimp bycatch were reported in numbers.

Shrimp trawls catch both 0- and 1-year old fish, which can be difficult to distinguish without direct aging. However, we chose a model structure that started with 1-year olds for reasons described above. Using unconverted numbers would imply many more 1-year old fish were killed than was the case, while ignoring age-0 fish entirely would under represent bycatch by the shrimp fishery. Instead, a catch series was produced for age-1 equivalents. To do so, the total shrimp bycatch estimates were separated into age-0 and age-1 portions using an estimated total mortality for this age class of $Z = 2$. Specifically, the number of age-1 fish for a given year was calculated from the number of age-0 fish estimated to have been caught in the previous year, as reduced by estimated total mortality. Finally, when calculating the age-1 equivalency of bycatch for any year, the number of age-1 fish was added to the number of age-0 fish that would have survived from the previous year.

The resulting catch series are shown in Table 1 and Fig. 1.

Indices of Abundance

Eight indices of abundance were used for the SSASPM model. Five fishery-dependent indices were based on MRFSS data from the eastern Gulf (western Gulf data were inadequate), headboat data from the eastern and western Gulf, and commercial logbook reports for handline gear from the eastern and western Gulf. These indices are discussed in greater detail elsewhere (Sladek Nowlis, SEDAR9-AW07) and are presented in Table 2 and Fig. 2a.

Three fishery-independent indices were also used, all Gulfwide since selectivity differences should not be a concern for scientific surveys. These included neuston net surveys, which sample pelagic larvae, assumed to represent spawning biomass; bottom trawl surveys, which sample young fish; and video surveys, which sample adults on hard bottom habitat using a baited video camera.

These indices are presented in Table 2 and Fig. 2b.

Age Composition

Catch at age data were derived from size distributions and probabilistic assignment of age, as described above in the Catch Curve Analysis section.

Base Model Configuration

The base model is presented in Appendices 1 and 2. Specific aspects of it are described below.

Fixed Parameters

Life History

A number of life history parameters were treated as fixed and taken from the Data Workshop report (SEDAR9-DW-Report). These included:

Maturity = 87.5% of 1-year olds and 100% of other age classes assumed to be mature.

Fecundity = $170289e^{0.3159x}$, where x = age.

M = 0.27 for all modeled age classes.

FL (mm) = $423.4\ (1-e^{-0.4269(x+0.6292)})$, where x = age.

Weight (lbs) = $4.4858 \times 10^{-8}\ \mathrm{FL\ (mm)}^{3.0203}$

Parameters Estimated

Several parameters were estimated, or at least explored over a range of values. These included:

The unfished recruitment levels;

Catchability for each fleet and index; and

Fleet selectivities.

In tuning the Gulf of Mexico gray triggerfish SSASPM model, three elements proved to have strong influence on the results. The first element was the α parameter from the stock-recruitment relationship. The second was a variance scalar applied to recruitment deviations. The third was a similar variance scalar applied to the shrimp fleet fishing effort.

α

When run using the prior distribution of α values from the meta-analysis of periodic life history strategists, the SSASPM model estimated a very high parameter value (70.9, corresponding to a steepness of 0.95). Alternatively, several runs were conducted using highly constrained estimates of α, ranging from 6 to 36 (runs with fixed values had the disconcerting property that they usually produced non-positive-definite Hessian matrices, suggesting instability). A reasonable base model might be the one that used a constrained $\alpha = 12$, which estimated $\alpha = 13.5$ (steepness = 0.77), just above the median of the meta-analytic distribution.

Recruitment Deviations

Initially, the model was constructed with a variance scalar applied to recruitment deviations that was on par with those applied to index observation errors (i.e., 2). Configured like this, the model predicted unrealistically high recruitment throughout the course of the model (Fig. 3a). Note that from the early 1980s until almost the present, this model set recruitment values above virgin levels. To avoid this unrealistic behavior, the variance scalar was set to 0.05, below even the value applied to effort deviations for most fleets (0.223). When constructed this way, the model predicted recruitment patterns (Fig. 3b) much more in line with dynamics of the population as indicated by abundance indices.

Shrimp Effort Deviations

Initially, the model was constructed with variance scalars applied to effort deviations of all fleets at values that corresponded with CVs of 50% (0.223). For most fleets, we don't have independent measures of effort and there is real potential for big fluctuations, especially given the less preferred nature of gray triggerfish. However, we do have independent estimates of shrimp fleet effort dynamics, derived for the recent Gulf of Mexico red snapper assessment (REF). The effort series for eastern and western Gulf fleets are shown in Fig. 4a. When the variance scalar for shrimp effort was set at the same level as other fleets, the model estimated large fluctuations in shrimp effort, which did not agree well with the independent estimates (Fig. 4b). When this variance scalar was set lower (0.0392, equivalent to a 20% CV), the modeled effort fluctuations were more on par with those estimated in the red snapper assessment (Fig. 4b).

Uncertainty and Measures of Precision

A number of sensitivity analyses were performed. These runs explored the degree to which the conclusions from the base model were sensitive to potential inaccuracies in the specification of various model parameters. The sensitivity runs included:

Runs described above, which explored a range of α, recruitment deviations, and shrimp effort deviations values.

Beginning the burning-in period in 1950 instead of 1963.

Using natural mortality values of M = 0.25 or M = 0.3.

RESULTS

Catch Curve Analysis

Catch curve analyses produced a series of estimated fishing mortality rates (Table 3). When shrimp bycatch was included, fishing mortality rates were moderate in the eastern Gulf (median = 0.355) and quite high in the western Gulf (median = 12.8), with "full" selectivity, defined as

75% of the maximum F, occurring by 1 or 2 years old. These fishing mortality estimates were quite variable in both places.

When only directed fleets were examined, the eastern Gulf had similar fishing mortality rates (median = 0.38). However, these estimates were much more consistent and applied primarily to slightly older fish (age 3+). These two analyses suggest that shrimp bycatch is less of a factor in the eastern Gulf and that the directed fleets target relatively young fish.

In the western Gulf, the directed fleets showed a substantially different picture than data that included shrimp bycatch. The western directed fleets had much lower, but still high, fishing mortality rates (median = 0.888) and these estimates were far more consistent across years. Most strikingly, full selectivity did not occur until ages 7 or 8. These analyses suggest that shrimp bycatch is a significant factor in the western Gulf, and that it and the directed fishery have substantial impact but on a limited number of age classes.

SSASPM Overall Model Fit

The base model generally performed well compared to sensitivity runs, according to AIC scores (Tables 4 and 5). There were some exceptions, though. Fits were best with very high α values, and so runs with values constrained higher than the base or estimated were more parsimonious with the data than the base run. Additionally, the model fit the data slightly better when natural mortality were set at M = 0.3.

The trajectory of fishing mortality rates were compared to those calculated through catch curve analysis (Table 3). The SSASPM Gulf wide results fell between catch curve patterns observed in the eastern and western Gulf. SSASPM-estimated fishing mortality rates fell very close to the mean from east and west, tending to be slightly lower (closer to the eastern values). Full selectivity (75% of maximum age-specific F) fell closer to the western Gulf, though.

SSASPM Catch Fits

Catches fits were mediocre for the base model (Fig. 5), although they did not improve markedly in any sensitivity analyses. Directed commercial catches showed the best fit, while shrimp bycatch was too flat (see discussion, above, of effort deviations) and recreational catches only captured some of the patterns of the underlying data.

SSASPM Index Fits

Indices fit better. They generally captured the broad pattern of the underlying data but missed most spikes (Fig. 6). Since the spikes may represent data issues rather than true population fluctuations, this result may be desirable.

Stock Status

Although the base model's behavior was not ideal, it may have been adequate. Greater confidence is gained by examining the key management benchmarks across a wide range of sensitivity analyses (Tables 4 and 5). Current status as a function of SPR- and MSY-based management benchmarks was quite stable.

Using SPR benchmarks, the base run and most sensitivity analyses indicated that the Gulf of Mexico gray triggerfish stock was overfished and experiencing overfishing (Tables 4 and 5, Fig. 7). Exceptions included the $\alpha \sim 6$, M = 0.3, no or large recruitment deviations, and equal shrimp effort deviations runs, which estimated the stock was not overfished (but in most cases was close to it). All runs indicated overfishing was occurring relative to a 30% SPR benchmark.

Using MSY benchmarks, the base run and most sensitivity analyses also indicated that the Gulf of Mexico gray triggerfish stock was overfished and experiencing overfishing (Tables 4 and 5, Fig. 8). The only exceptions here were the two highest a runs, which indicated the stock was above SSB_{MSY} and not experiencing overfishing; the M = 0.3 run, which indicated the stock was nearly but not quite overfished but still experiencing overfishing; the large recruitment deviations run which indicated the stock was just above SSB_{MSY} levels but still experiencing overfishing.

According to the base run, the stock dropped below MSY levels in the late 1970s, recovered briefly in the late 1980s and has steadily declined since 1990 (Fig. 9a). The model indicates that stock abundance reflects overfishing, which began in the 1970s and has continued to the present day (Fig. 9b).

REFERENCES

Myers, RM, KG Bowen, NJ Barrowman. 1999. Maximum reproductive rate of fish at low population sizes. Can. J. Fish. Aquat. Sci. 56: 2404-2419.

Rose, KA, JH Cowan Jr, KO Winemiller, RA Myers, R Hilborn. 2001. Compensatory density dependence in fishing populations: importance, controversy, understanding and prognosis. Fish Fish. 2: 293-327.

TABLE 1—Gulf of Mexico Gray Triggerfish Catches
Directed catches are reported in pounds, while shrimp bycatch is reported in age-1 equivalent fish (described in text).

YEAR	Recreational EAST	Recreational WEST	Commercial EAST	Commercial WEST	Shrimp Age-1 Equivalent
1963			3100	4200	
1964			15700	4300	
1965			17400	4300	
1966			8600	5200	
1967			12200	5200	
1968			8600	3900	
1969			14600	7700	
1970			16000	8200	
1971			30500	9900	
1972			47400	15200	
1973			40000	13200	112278
1974			40000	13100	342365
1975			62000	16000	380204
1976			69700	14800	220050
1977			50096	9290	189051
1978			48518	10197	460315
1979			65670	35733	1771057
1980			65422	31001	606638
1981	748779	179617	64498	25362	1467734
1982	2032601	362711	62959	33714	1206518
1983	397614	387301	49588	23831	1462755
1984	120970	844623	37445	32749	304994
1985	280865	479950	54840	37786	855586
1986	898096	79077	72858	22771	279374
1987	1135998	199066	89313	34290	1044555
1988	1638073	158328	137978	57084	1364168
1989	1765965	212002	230361	87271	906437
1990	2313261	184941	359686	99351	1286703
1991	1688392	399955	341319	103211	523154
1992	1434485	688825	338119	112076	3100516
1993	1317044	309425	381279	177448	432660
1994	1152103	186425	251578	153141	1951471
1995	1139967	329441	207212	130664	1065855
1996	618125	226006	142185	125332	1498133
1997	664794	100211	107780	76909	1751775
1998	560509	93309	106153	70571	1004208
1999	445430	43997	116194	102826	242741
2000	337241	109209	63042	95095	1656166
2001	487622	152571	108464	67718	490376
2002	721872	77016	148600	86963	5115407
2003	856626	58622	166425	85385	854441
2004	951559	78092	141411	77122	167162

TABLE 2—Gulf of Mexico Gray Triggerfish Relative Abundance Indices.
Fishery-dependent and independent indices were transformed separately, in such a manner that each index averaged 1 over the years where all indices of that category were available (1993-2004 for FD; 1992-97 and 2001-02 for FI).

Year	MRFSS EAST	Headboat EAST	Headboat WEST	Commercial Handline EAST	Commercial Handline WEST	Neuston FI Survey	Trawl FI Survey	Video FI Survey
1981	1.6548							
1982	1.4133							
1983	0.9873							
1984	5.9438							
1985	0.2173							
1986	3.641	0.7848	0.8973			0.8122		
1987	1.1654	0.5169	0.8861			0.5985	0.5298	
1988	2.0648	0.6791	1.2201			0.4037	0.4556	
1989	3.3945	1.5569	1.1254			0.2314	0.8096	
1990	7.1257	2.4939	1.5849			0.399	0.1866	
1991	2.9727	1.9669	1.8749			0.805	3.0919	
1992	2.6319	2.2737	1.6657			2.6547	0.1815	1.8348
1993	1.6326	1.7824	1.6771	1.7512	1.0824	0.9001	1.5339	1.0009
1994	1.4808	1.3821	1.6302	1.6507	1.3808	1.0343	1.4693	0.9002
1995	2.2807	1.2025	1.4973	1.7105	1.5589	1.0305	0.616	0.8518
1996	1.3233	0.8525	1.527	0.753	0.9714	0.6992	0.5421	0.7937
1997	0.742	0.9032	1.3769	0.6298	0.7733	0.7347	0.37	1.6738
1998	0.5624	0.7762	0.9371	0.5943	1.0118		0.0351	
1999	0.5828	0.8224	0.4182	0.5719	1.3704	0.2326	0.8293	
2000	0.4573	0.5781	0.4236	0.4171	1.0247	2.4034	1.4431	
2001	0.7023	0.6481	0.5009	0.6182	0.7079	0.3967	2.6692	0.143
2002	0.7272	0.9847	0.5528	1.1006	0.7565	0.5497	0.618	0.8018
2003	0.7016	0.9971	0.6782	1.2278	0.6793		0.524	
2004	0.8071	1.0708	0.7807	0.975	0.6826		0.6266	

TABLE 3—Catch Curve Analyses. Full sel. is age at which F is at least 75% of full F. Logistic selectivity functions.

Years	30-70 East-West Split				No Shrimp Bycatch				SSASPM Base Mode	
	East	Full sel.	West	Full sel.	East	Full sel.	West	Full sel.	Gulfwide	Full sel.
1981-90	0.256	2	15.24	2	0.319	2	0.947	7	0.535	6
1982-91	0.165	2	1.84	1	0.353	3	0.629	7	0.545	6
1983-92	0.654	1	9.22	2	0.354	3	1.07	8	0.534	6
1984-93	0.2	2	1.62	1	0.37	3	0.692	7	0.55	6
1985-94	0.522	1	47	2	0.334	2	0.941	8	0.551	6
1986-95	0.298	1	3.84	2	0.38	2	0.761	7	0.555	6
1987-96	0.737	1	12.8	2	0.406	3	0.888	7	0.576	6
1988-97	0.887	1	129.26	2	0.351	3	1.05	8	0.593	6
1989-98	0.534	1	83.59	2	0.413	3	0.866	7	0.591	6
1990-99	0.239	2	2.74	1	0.427	3	0.806	7	0.583	6
1991-00	1.7	1	428.02	3	0.38	3	0.892	8	0.586	6
1992-01	0.287	1	3.67	2	0.392	3	0.914	7	0.583	6
1993-02	2.38	2	608.32	3	0.407	3	0.622	7	0.586	6
1994-03	0.283	1	38.45	2	0.402	3	0.918	7	0.578	6
1995-04	0.355	3	1.91	1	0.421	3	0.725	7	0.566	6
MEDIAN	0.355	1	12.8	2	0.38	3	0.888	7	0.576	6
CV	0.98		1.94		0.09		0.16		0.04	

TABLE 4—Stock Recruitment α Runs. 292 data points, 170 estimated parameters, base run described in Table 3.

	α ~ 6	α ~ 9.33	Base	α ~ 16	α ~ 36	Est α
FIT						
Estimated params	170	170	170	170	170	170
Objective function	383.8	373.6	369.9	367	362.8	364.6
AIC	1108	1087	1080	1074	1066	1069
BENCHMARKS						
Alpha	8	11	13.5	17.4	37.1	70.9
Steepness	0.67	0.73	0.77	0.81	0.9	0.95
Max recr (m)	3.462	3.081	2.911	2.758	2.504	2.409
SSB_{VIRGIN} (m)	12.118	10.782	10.188	9.652	8.764	8.433
SSB_{MSY} (m)	3.083	2.447	2.158	1.881	1.36	1.117
$SSB_{20\%tSPR}$ (m)	1.052	1.298	1.391	1.46	1.559	1.593
F_{MSY}	0.273	0.332	0.372	0.424	0.594	0.74
$F_{30\%SPR}$	0.331	0.327	0.325	0.324	0.321	0.32
MSY (m)	1.846	1.848	1.861	1.887	1.988	2.067
CURRENTLY						
SSB_{2004} (m)	1.208	1.287	1.326	1.362	1.426	1.45
SSB_{2004}/SSB_{MSY}	0.39	0.53	0.61	0.72	1.05	1.3
$SSB_{2004}/SSB_{20\%tSPR}$	1.15	0.99	0.95	0.93	0.91	0.91
F_{2004}	0.561	0.545	0.537	0.531	0.52	0.515
F_{2004}/F_{MSY}	2.05	1.64	1.44	1.25	0.87	0.7
$F_{2004}/F_{30\%SPR}$	1.69	1.67	1.65	1.64	1.62	1.61

TABLE 5—Sensitivity Runs. 292 data points, base run described in Table 3.

	Base	1950 start	M 0.25	M 0.3	No recr. devs	Lg recr devs	Eq effort devs
FIT							
Estimated params	170	170	170	170	146	170	170
Objective function	369.9	389.8	378.5	358.8	431.4	391.3	379.1
AIC	1080	1120	1097	1058	1155	1123	1098
BENCHMARKS							
Alpha	13.5	13.4	14	13.1	14.2	12.7	13.6
Steepness	0.77	0.77	0.78	0.77	0.78	0.76	0.77
Max recr (m)	2.911	3.061	2.867	3.03	3.366	1.798	2.969
SSB_{VIRGIN} (m)	10.188	10.713	11.784	8.481	11.782	6.293	10.393
SSB_{MSY} (m)	2.158	2.276	2.49	1.807	2.455	1.37	2.197
$SSB_{20\%tSPR}$ (m)	1.391	1.456	1.629	1.136	1.646	0.829	1.418
F_{MSY}	0.372	0.371	0.339	0.427	0.384	0.343	0.379
$F_{30\%SPR}$	0.325	0.326	0.294	0.378	0.327	0.313	0.33
MSY (m)	1.861	1.955	1.92	1.828	2.177	1.122	1.906
CURRENTLY							
SSB_{2004} (m)	1.326	1.359	1.257	1.436	1.779	1.486	1.437
SSB_{2004}/SSB_{MSY}	0.61	0.6	0.5	0.79	0.72	1.08	0.65
$SSB_{2004}/SSB_{20\%tSPR}$	0.95	0.93	0.77	1.26	1.08	1.79	1.01
F_{2004}	0.537	0.529	0.559	0.504	0.433	0.513	0.511
F_{2004}/F_{MSY}	1.44	1.43	1.65	1.18	1.13	1.5	1.35
$F_{2004}/F_{30\%SPR}$	1.65	1.62	1.9	1.33	1.32	1.64	1.55

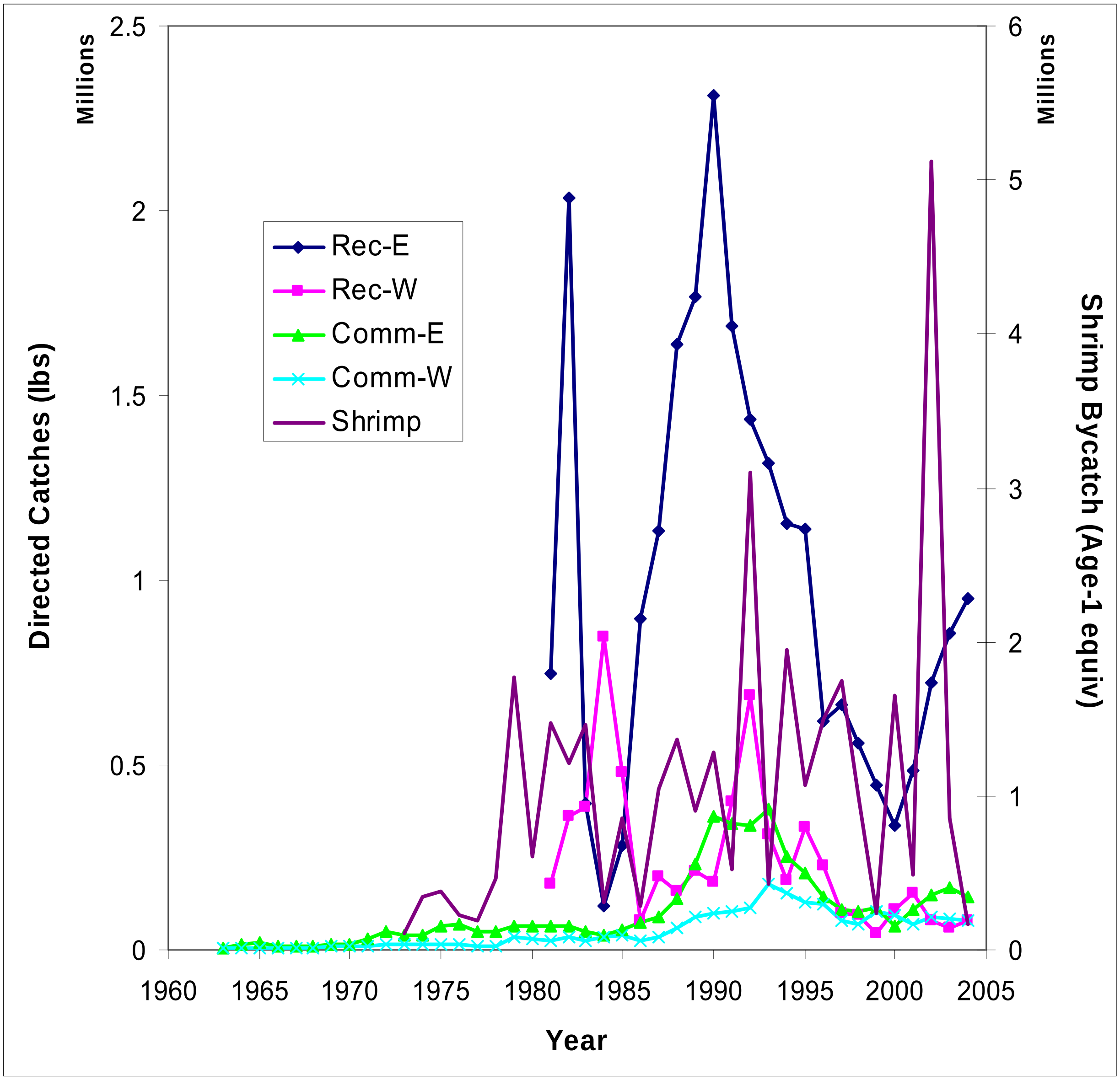


FIG. 1—Gulf of Mexico Gray Triggerfish Catches
Directed catches are reported in pounds, while shrimp bycatch is reported in age-1 equivalent fish (described in text).

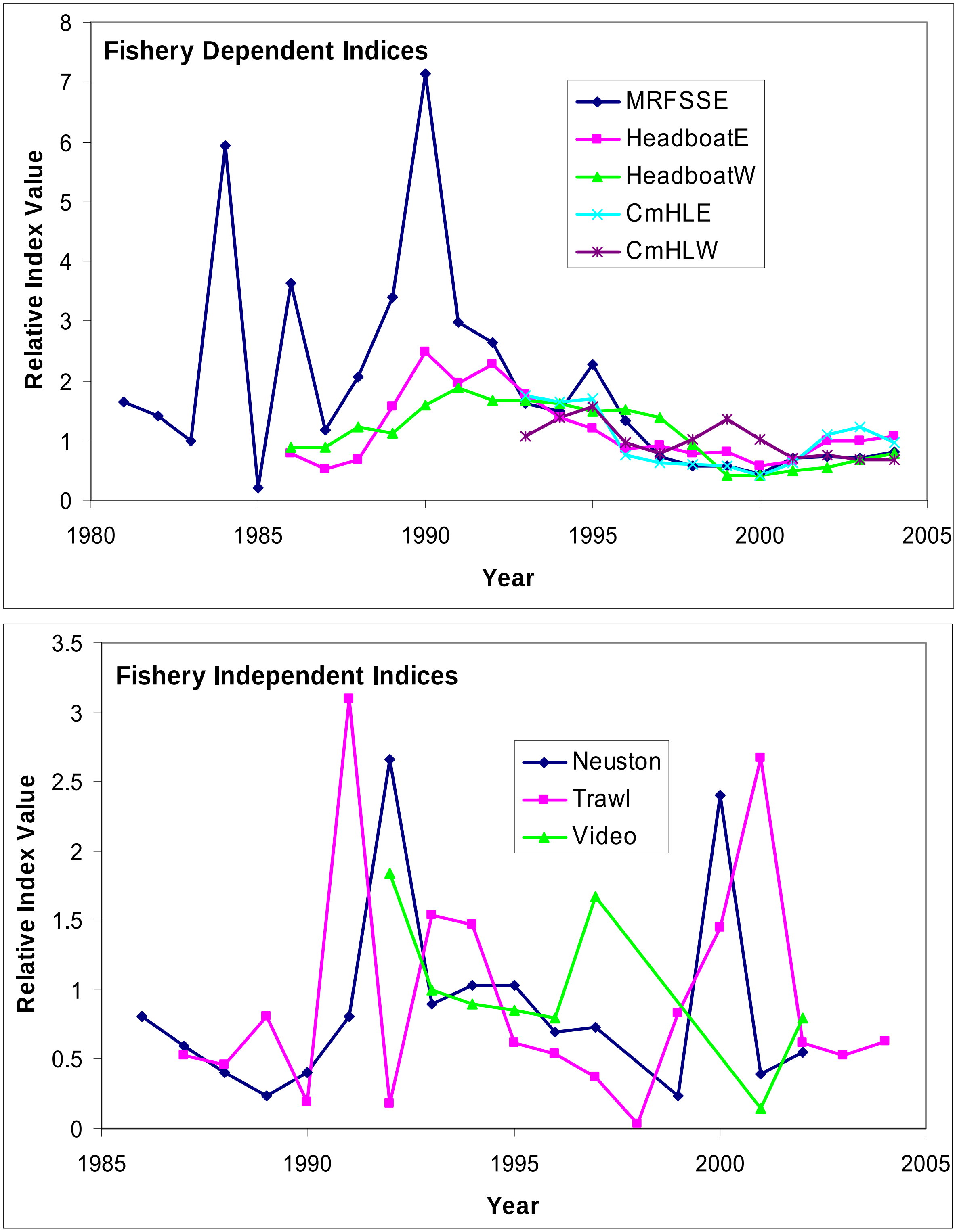
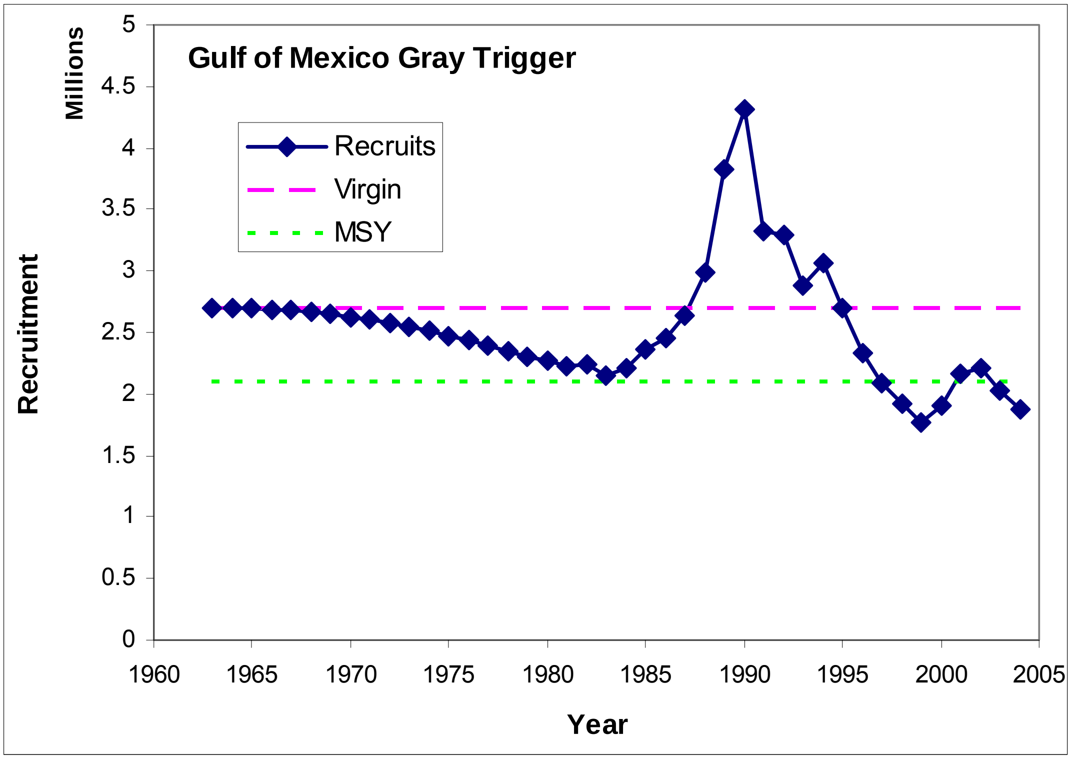


FIG. 2—Gulf of Mexico Gray Triggerfish Indices of Abundance
(a) Fishery-independent and (b) fishery-dependent indices of abundance. Normalized across the years where all indices were calculated (1992-97, 2001-02 for FI; 1993-2004 for FD).



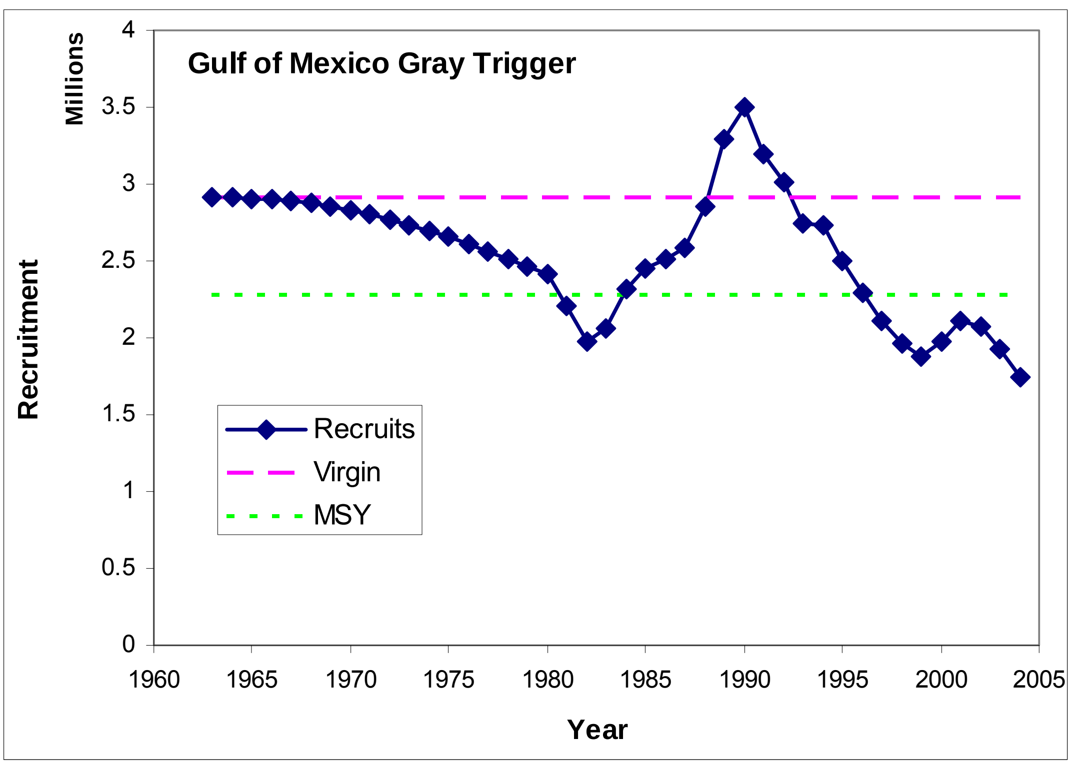
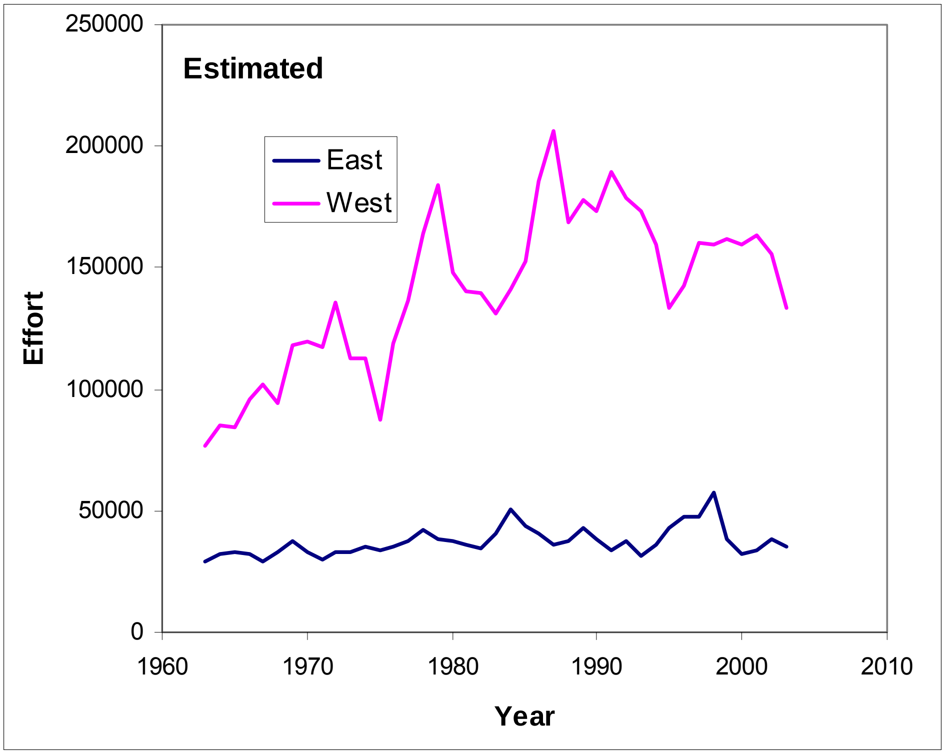


FIG. 3—Recruitment Trajectory
(a) Large Deviations (= 2), (b) Small Deviations (= 0.05).



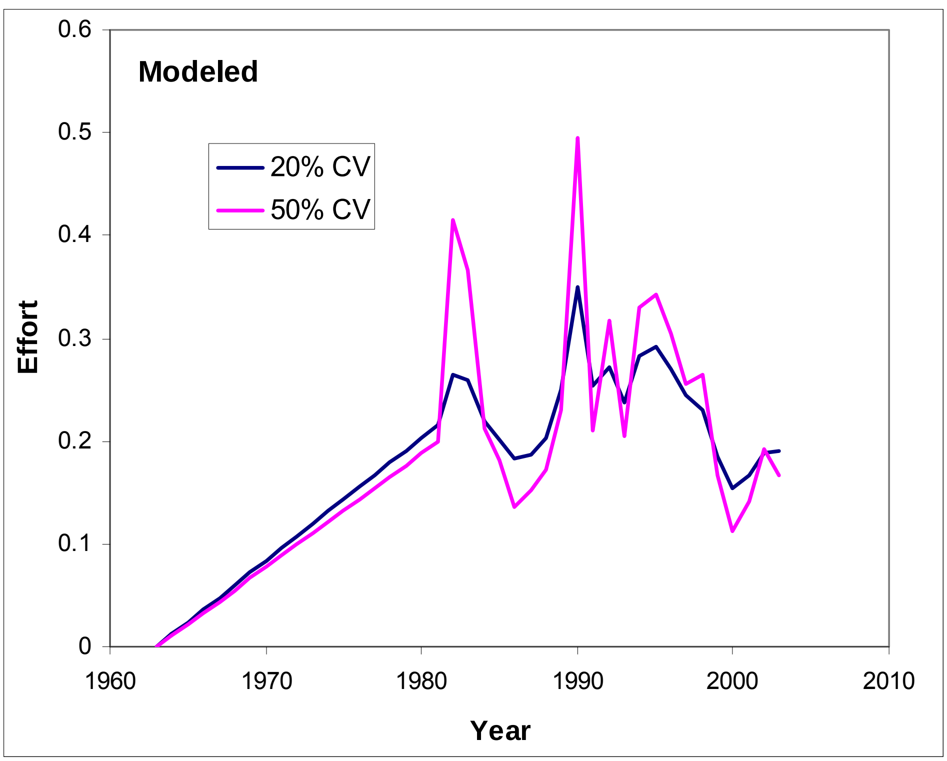


FIG. 4—Shrimp Effort Deviations
(a) Estimated values, (b) modeled values.

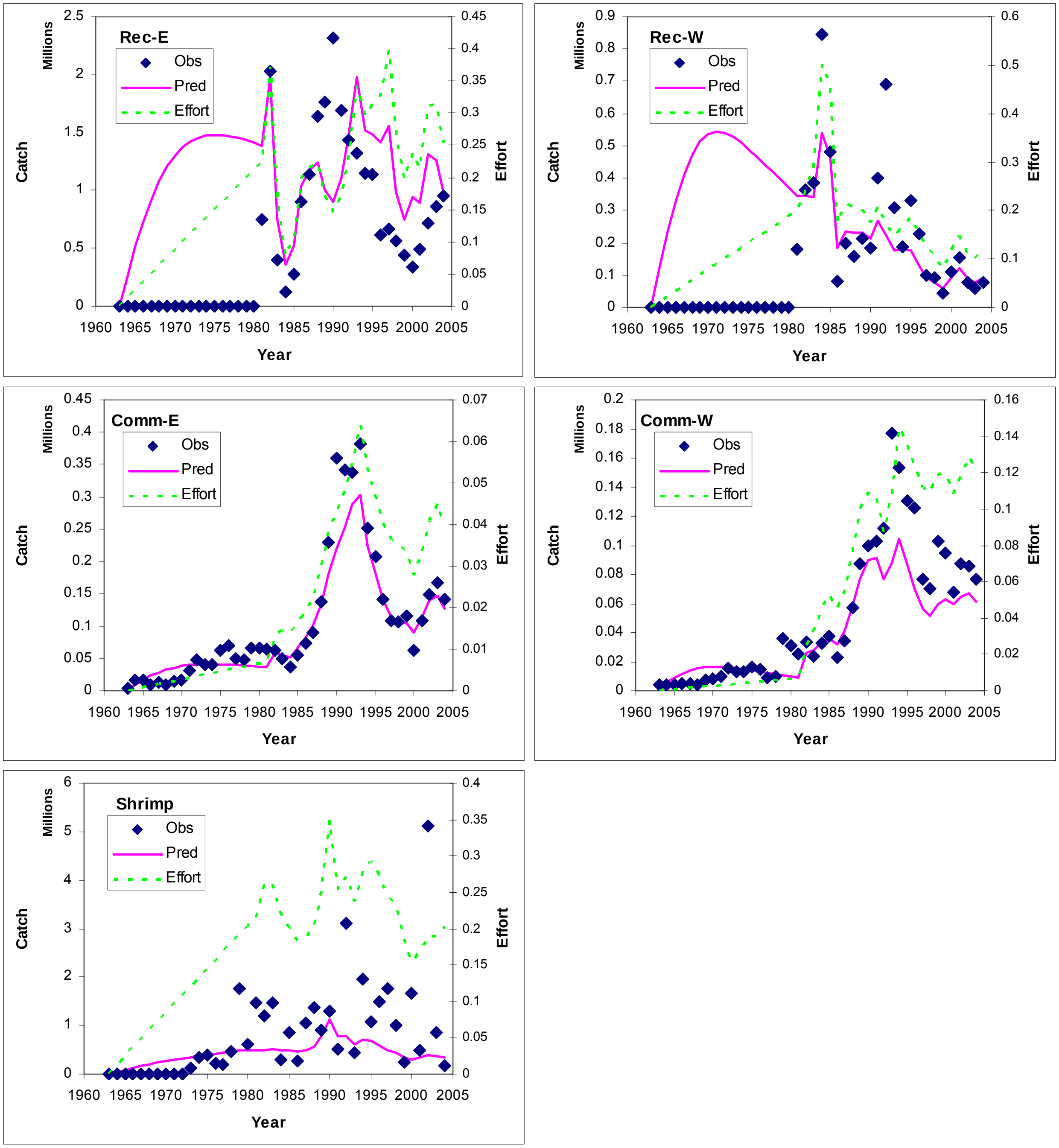


FIG. 5—Base Run Catch Fits

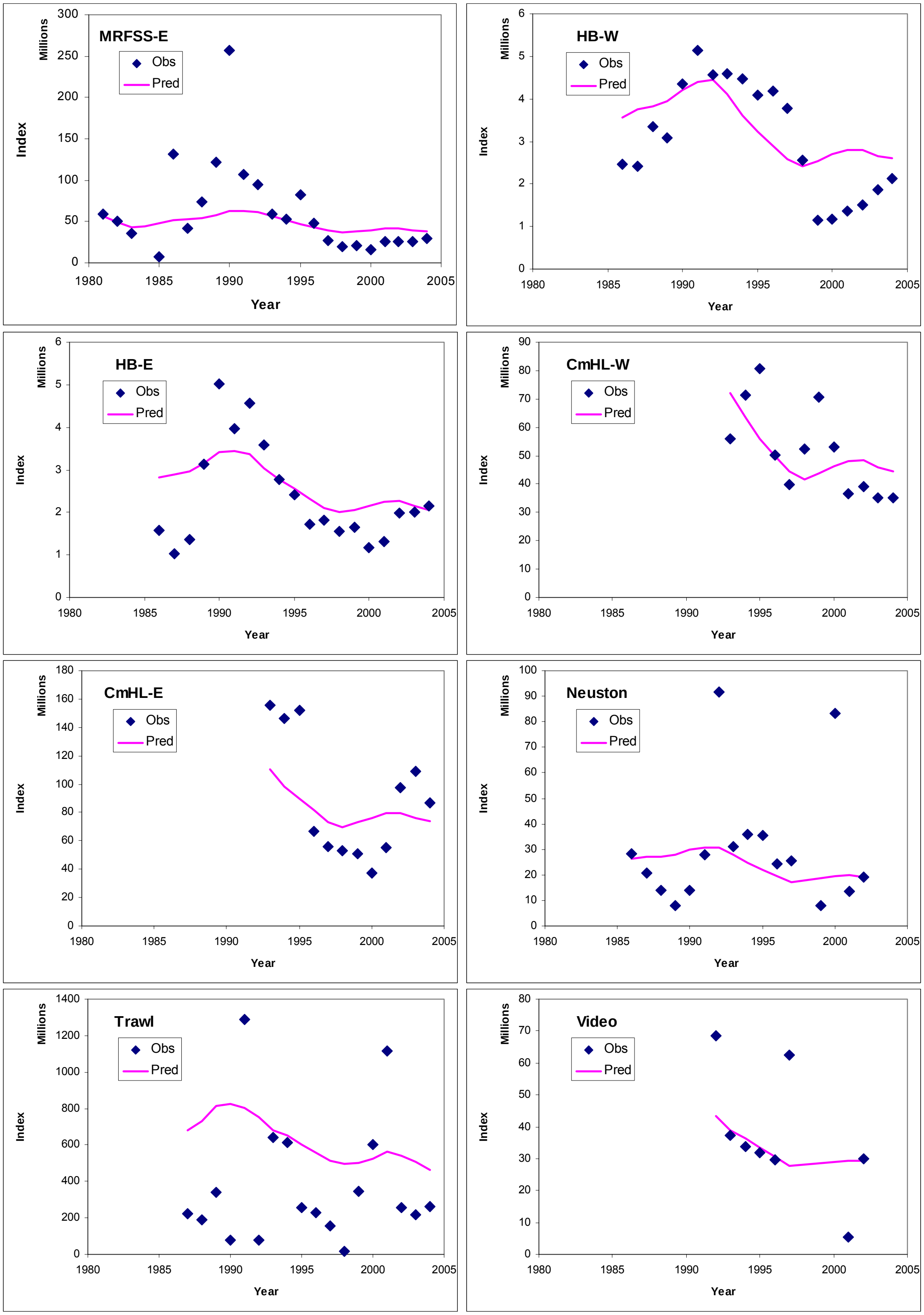
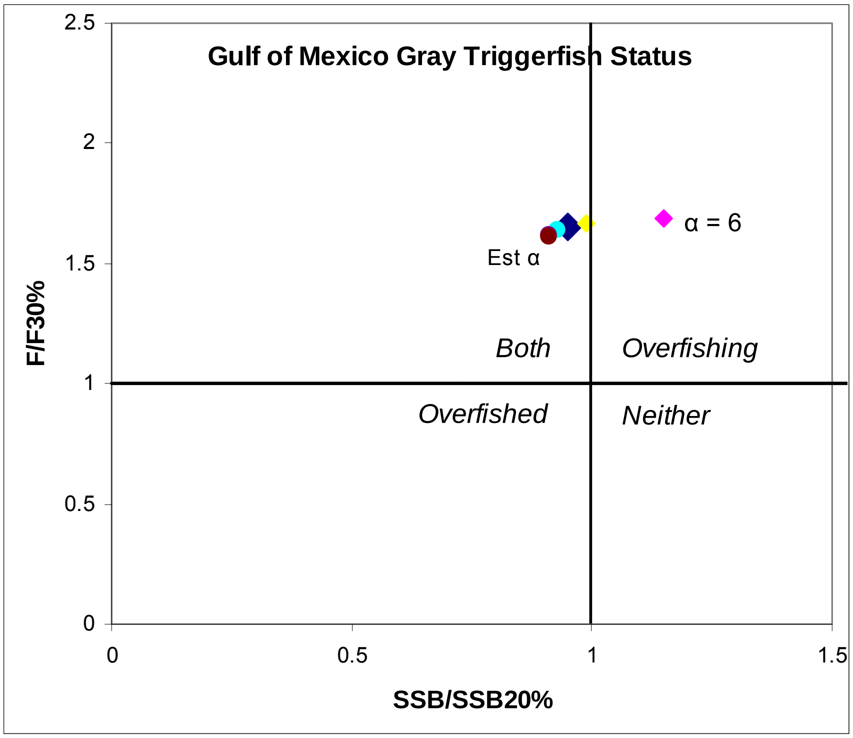


FIG. 6—Base Run Index Fits



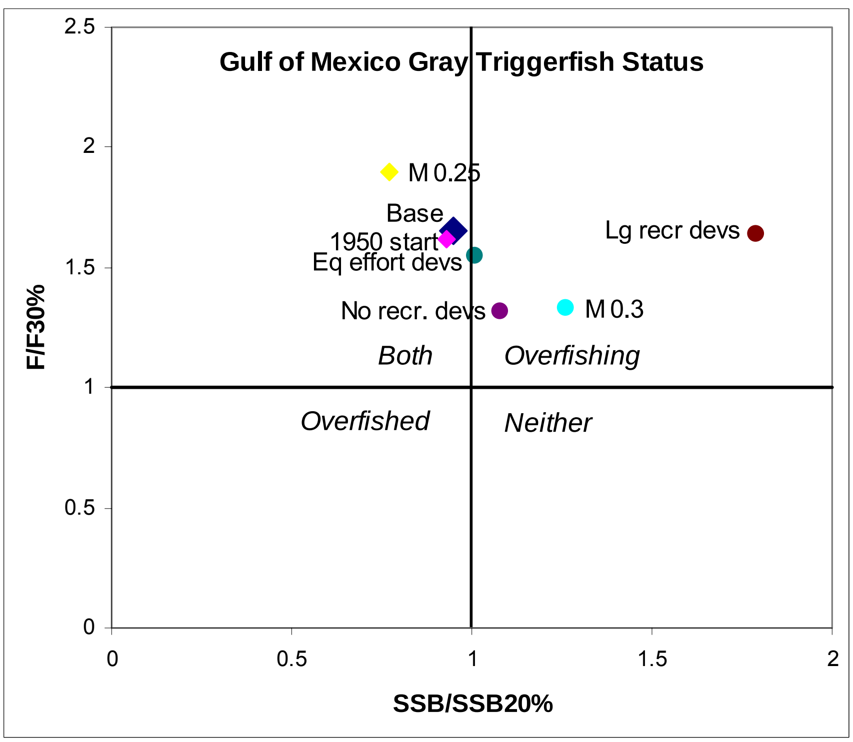


FIG. 7—Gray Triggerfish Status Relative to SPR
(a) Across steepness values; (b) across sensitivity trials.

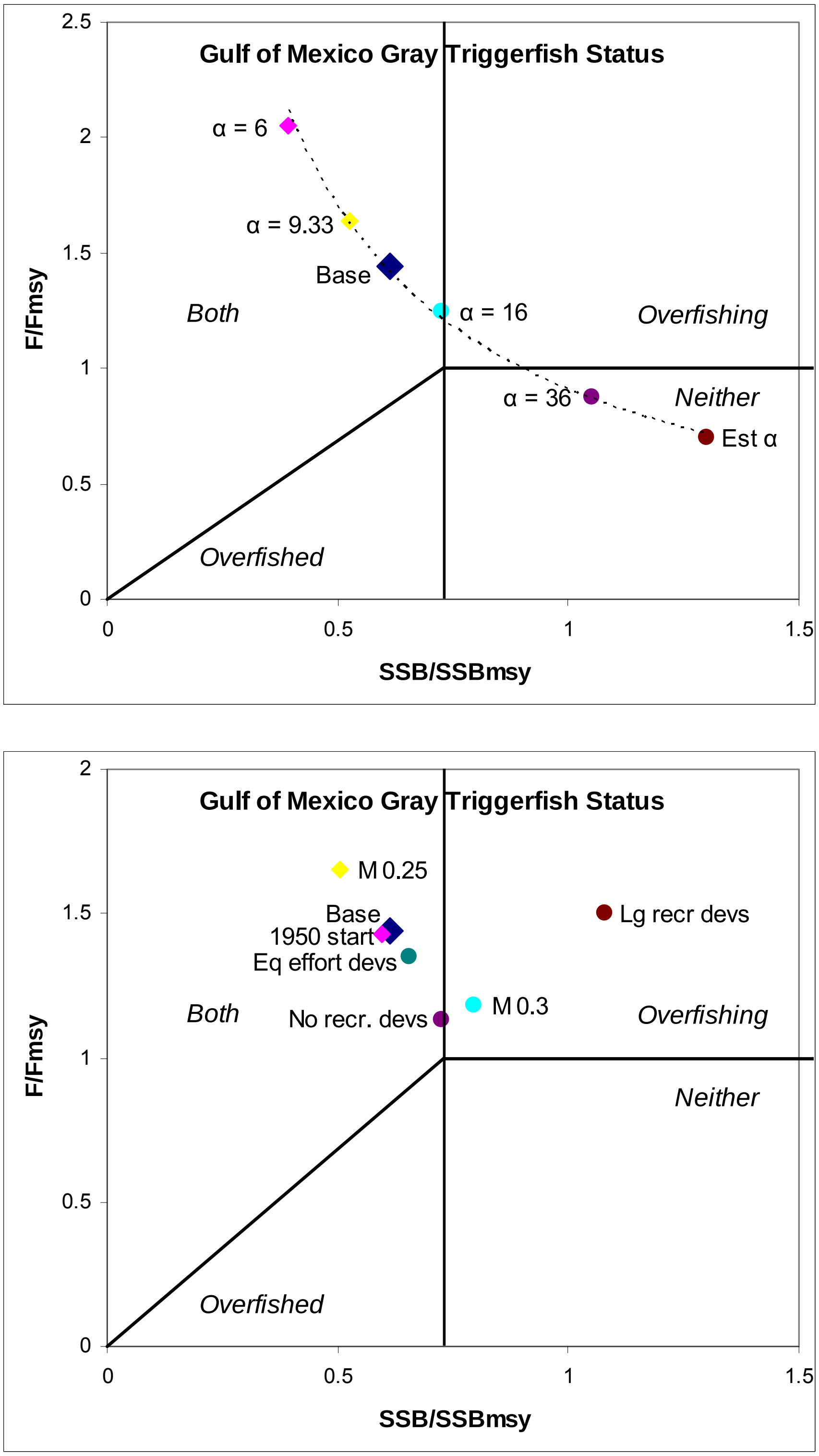
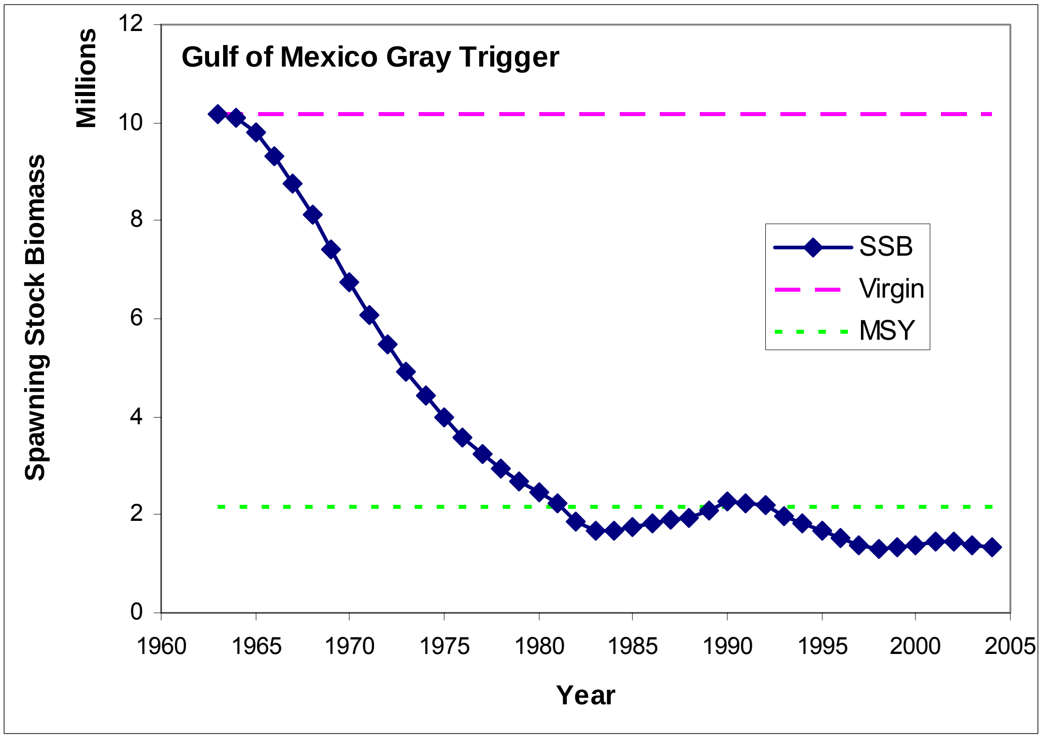


FIG. 8—Gray Triggerfish Status Relative to MSY
(a) Across steepness values; (b) across sensitivity trials.



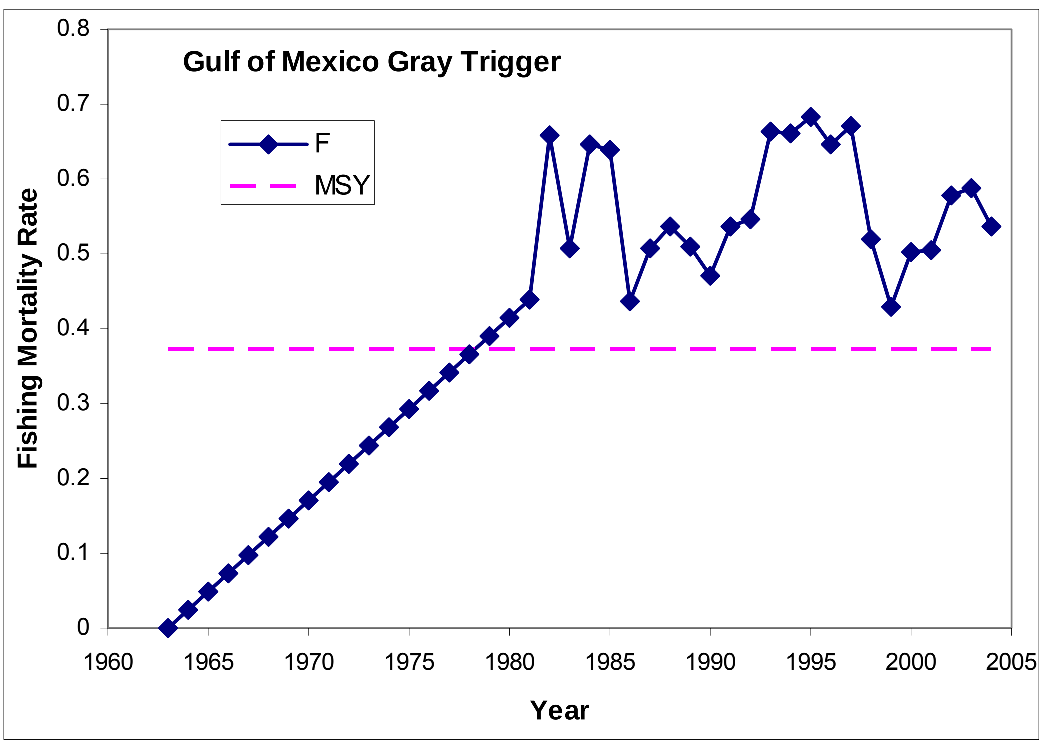


FIG. 9—Base Run Trajectories

```
#//////////////////////////////////////////////////////////////////////////////////////////////
#//////////////////////////////////////////////////////////////////////////////////////////////
#// 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
```

-1	-1	3100	4200	-1	1963
-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)

1	1	1	1	1	1963
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
1	1	1	1	1	1970
1	1	1	1	1	1971
1	1	1	1	1.254428	1972
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
-1	-1	-1	-1	-1	-1	-1	-1	1963
-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
-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
-1	-1	-1	-1	-1	-1	-1	-1	1976
-1	-1	-1	-1	-1	-1	-1	-1	1977
-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
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)

1	1	1	1	1	1	1	1	1963
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
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
1	1	1	1	1	1	1	1	1976
1	1	1	1	1	1	1	1	1977
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
```

```
        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