5. ASSESSMENT SUMMARY

The Summary Report provides a broad but concise view of the salient aspects of the stock assessment. It recapitulates: (a) the information available to and prepared by the Data Workshop; (b) the application of those data, development and execution of one or more assessment models, and identification of the most reliable model configuration as the base run by the Assessment Workshop (AW); and (c) the findings and advice determined during the Review Workshop.

Stock Status and Determination Criteria

The U.S. southeast stock of black grouper is not currently overfished, nor is it experiencing overfishing.

Table 1. Summary of stock status determination criteria.

Criteria	Recommended Values from SEDAR 19	
	Definition	Value
M (Instantaneous natural mortality; per year)	Average of Lorenzen M (if used)	0.136
F_{2008} (per year)	Fishing mortality in 2008	0.108
$F_{current}$ (per year)	Geometric mean of the directed fishing mortality rates on fully selected ages from 2006 - 2008	0.096
F_{MSY} proxy (per year; if used)	$F_{30\%SPR}$	0.216
SSB_{2008} (million pounds)	Spawning stock biomass in 2008	8.29
$SSB_{MSY\ (or\ proxy)}$ (million pounds)	$SSB_{F30\%SPR}$	5.92
MSST (million pounds)	(1-M)*$SSB_{F30\%SPR}$	5.12
MFMT (per year)	$F_{30\%SPR}$	0.216
MSY (million pounds)	Yield at 30%SPR	0.520
OY (million pounds in 2011)	Yield at F_{OY}	OY (65% $F_{30SPR)}$= 0.461 OY (75% $F_{30SPR)}$= 0.530 OY (85% $F_{30SPR)}$= 0.596
F_{OY} (per year)	F_{OY} = 65%,75%, 85% $F_{F30\%SPR}$	65% F_{30SPR}= 0.141 75% F_{30SPR}= 0.162 85% F_{30SPR}= 0.185
Biomass Status	$SSB_{2008}/SSB_{F30\%SPR}$	1.40
Exploitation Status	$F_{current}$/MFMT	0.50

***All weights are whole weight in pounds.

Stock Identification and Management Unit

The black grouper (*Mycteroperca bonaci*) fishery has been managed in the US as separate Atlantic and Gulf of Mexico stock units with the boundary essentially being U.S. Highway 1 in the Florida Keys west to the Dry Tortugas. The SEDAR19 Life History Data Working Group (LH WG) for the South Atlantic (SA) and Gulf of Mexico (GOM) reviewed the available stock structure information and concluded there is no evidence that suggests different stock management units need to be considered at this time. Also, given that black grouper in the southeastern U.S. appear to belong to a single population and that catches of black grouper in the southeastern U.S. are primarily in south Florida, particularly in the Florida Keys, the assessment should treat the stock as a single unit rather than provide separate assessments for each of the two management units.

Species Distribution

Black grouper (*M. bonaci*) in the southeastern United States (the northern most part of their range) are found chiefly in southern Florida and the Florida Keys, although specimens have been recorded from Massachusetts to Texas. The range of black grouper extends to southeastern Brazil and east to Bermuda. They are often found associated with rocky ledges and coral reefs from 10-100 m. In the northern hemisphere, black grouper are more often caught in the southeastern Gulf of Mexico, southern Gulf of Mexico, and the Caribbean, spawning aggregations off the coast of Belize. In the southeastern US, black grouper are caught more commonly in the Florida Keys along the reef tract, and are caught along high relief areas in deeper waters off of the west coast of Florida to the Florida Middle Grounds and off of the east coast of Florida. Generally, larger and older individuals are caught more often in deeper waters.

Stock Life History

- There are species identification issues between black grouper and gag
- Limited tagging data suggests black groupers only move short distances
- Natural mortality is thought to vary by age so an age-specific Lorenzen mortality curve was used, with an average M of 0.136 per year and that value was determined through the Hoenig method, using a maximum observed age of 33 years.
- The LH WG recommended using an overall von Bertalanffy growth curve with L_{∞} = 1334 (mm), $k = 0.1432 \cdot \text{year}^{-1}$, and $t_0 = -0.9028 \cdot \text{year}$ in the assessment model. These values were obtained using the most appropriate treatment of the data: all available age data with the Diaz et al. (2004) correction applied for fishery dependent samples.

- Black grouper are protogynous hermaphrodites and age and length of transition were determined.
- The peak spawning season of black grouper based on back-calculated hatching dates of post-larval fish from February through April

Assessment Methods

Three models were developed for black grouper ranging from catch curves to provide a reasonable scale for natural mortality, a non-equilibrium surplus production to investigate whether the landings and indices contained useful information, and the main (base) assessment model, a statistical catch-at-age model (ASAP2), to estimate population sizes, spawning biomass trends, benchmarks, stock status, and projections.

Assessment Data

The base run was configured with four fleets (headboat, general recreational (MRFSS), commercial hook-and-line which includes landings from traps and spears, and commercial longlines) and five indices of abundance (four fishery-dependent indices and the FWC Visual Survey Age-1 index) for the period of 1986 through 2008. Because of changes in minimum size limits, a separate selectivity block for each regulatory period (1986-1991, 1992-1998, and 1999-2009) was used to estimate the age composition for each fleet except for the longline fleet which did not have age samples from the first period (1986-1991). Discards were linked to their fleets.

Release Mortality

- The commercial workgroup recommended using 20% as the point estimate for hook and line release mortality for black grouper with a sensitivity range of 10-30% and a point estimate of 30% for long line release mortality for black grouper with a sensitivity range of 25-35%.
- The Recreational workgroup recommended a discard mortality of 20%, fishery-wide, with sensitivity analyses run for from 10-30%.
- The Assessment Workshop decided to support the point estimates and range of values recommended by the Data Workshop: 20% (range of 10-30%) for hook-and-line and 30% (range of 25-35%) for longline.
- The Review Panel was concerned with the lack of empirical data to support the discard mortality estimate of 20%. Sensitivity runs were performed that varied this estimate from 10 – 90%. These results support the high impact of this parameter. In the absence of any substantive empirical data the panel did not see a strong basis to change the value from 20%, however, attempts should be made to obtain a more accurate estimate of both acute and chronic discard mortality.

Catch Trends

Headboat and commercial longline catches remained relatively low and stable over the assessment period when compared to general recreational and commercial handline, which showed a steady decline over the time series. Commercial handline peaked in 1987 with 64,461 fish, and declined to similar landings as commercial longline and headboat from about 1998 onward.

Fishing Mortality Trends

- The instantaneous total catch rates (F-multipliers) for commercial hook-and-line and for MRFSS in the beginning of the time series were approximately 0.17 per year but then the commercial hook-and-line catch rate declined while the total catch rate for MRFSS was variable but remained at the higher level and the total catch rate in 2008 (0.28 per year) was the highest of the time series.
- Prior to 1991, the commercial hook-and-line fleet accounted for much of the directed fishing mortality with MRFSS being the next highest. However, the fishing mortality from the commercial hook-and-line fleet has declined since 1987 to a low of 0.010 per year in 2008 while the fishing mortality rate for MRFSS increased from 1990 to 1998 and then has declined from a peak in 1997 to a low in 2003. The directed fishing mortality on age-5 (fully selected) fish for MRFSS was 0.091 per year in 2008. The other fleets, headboats and longlines, accounted for only a small portion of the fishing mortality.
- The combined (directed and discards) fishing mortality rate on age-5 fish, the fully selected age, has declined from values exceeding 0.25 per year in the beginning of the time series to less than half that level in recent years even with the upturn in 2008. The combined fishing mortality rate in 2008 was 0.108 per year.

Stock Abundance and Biomass Trends

- The number of fish in the population decreased until 1990 and then increased until 2000 and has declined afterwards. Over the whole time series, the total number per year has increased.
- Recruitment, expressed as the number of age-1 fish, has been variable but decreased after 1994. Early in the time series, recruitment comprised approximately 30-35% of the stock by number but more recently, 2002-2008, the percentage has been lower at 23-27%. In numbers of fish, the plus group of age-20 and older fish was approximately 2% of the annual total number in the early part of the time series and then declined to 1.4% in 1994-1997 and has returned to 2%in 2008.

- The total biomass was stable at 6.0 million pounds until 1993 when it began to increase and has continued to increase such that the highest total biomass was in 2008 (11 million pounds). The spawning biomass, including both males and females, had a similar pattern and was stable at 3.5 million pounds until 1993 when it began to increase. In 2008, the spawning biomass was 8.3 million pounds. The plus group has decreased from 19% to 9% of the total biomass and was 10% in 2008.

Projections

Eight stochastic projections were run using F = 0, $F_{current}$, $F_{30\%SPR}$ (both councils' overfishing limit), $0.65*F_{30\%SPR}$, $0.75*F_{30\%SPR}$, $0.85*F_{30\%SPR}$, $F_{40\%SPR}$, and $F_{45\%SPR}$ (the SAFMC's optimum yield measure). The stochastic projections encompassed a wider range of fishing mortality rates and the projections include more variability than did the P* estimates because they used the number of fish in 2008 and the fishing mortality rates for 2006-2008 from the 2.5 million MCMC results to provide variability in the starting number of fish in the population in addition to the variability in the overfishing limit. The overfishing limit, $F_{30\%SPR}$ had the highest fishing mortality rate (0.217 per year on fully selected ages) followed by $0.85*F_{30\%SPR}$ (F= 0.185 per year on fully selected ages), $F_{40\%SPR}$ and $0.75*F_{30\%SPR}$ had similar rates (0.165 and 0.163 per year on fully selected ages respectively) and $0.65*F_{30\%SPR}$ and $F_{45\%SPR}$ also had similar rates at (F = 0.141 and 0.144 per year on fully selected ages, respectively). Recruitment was inverse to fishing mortality, i.e. the lowest fishing mortality rates, F = 0 or F = $F_{current}$, had higher recruitment. The spawning biomass increased with $F_{45\%SPR}$ or lower fishing mortality rates and declined under higher fishing mortality rates. Because we assume that the fishery for reef species will continue to operate on suitable bottom habitat, when the directed fishery closes, i.e., F = 0, the discards were projected to increase because the directed fishery was converted to discards and those were in addition to the existing level of discard of undersized fish.

Scientific Uncertainty

ASAP2 estimates uncertainty with a covariance matrix of the estimated parameters and through Markov Chain Monte Carlo (MCMC) simulations. The distributions of MCMC outcomes for the fishing mortality per year on fully selected ages in 2008 and the spawning biomass in 2008 can be found in the addendum. The profiles were similar to their normal approximations but the F_{2008} point estimate was higher than the mode of the MCMC estimates.

ASAP2 has retrospective analysis (Mohn 1999) as an option and we found little the retrospective bias in the black grouper estimates assessment model when using terminal years of 2004 through 2008.

To gain further understanding of the model and the data, the reviewers suggested additional sensitivity runs and we re-ran the original sensitivity runs identified at the Data workshop. The additional sensitivity runs requested by the reviewers were reinstating the longline age compositions, removing the years 1994-1997 from the NMFS-UM RVC indices, removing the years 2006-2008 from the longline index because of trip limits, weighting the longline index by 10, weighting all of the indices by 10, using a single hook-and-line selectivity block and a single longline selectivity block for all years, excluding the 1986-1990 from of the time series in the analysis, repeating these runs with the shortened time series, and a run with the FWC Visual Survey age-1index but excluding the RVC indices and FWC Visual Survey. This exercise led to making additional runs using just the RVC indices, the RVC multi-age index, the RVC age-1 index, the FWC VS indices, the FWC VS multi-age index, the FWC VS age-1 index, keeping the RVC and the FWC multi-age indices after removing the age-1 indices. The original sensitivity runs included two alternative natural mortality rates, 0.10 per year and 0.20 per year; alternative release mortality rates of 0.10, 0.20, 0.30, 0.50, 0.75, and 0.90 for hook-and-line fleets including the recreational fleets coupled to longline release mortality rates of 0.25, 0.30, 0.35, 0.50, 0.75, 0.90; and setting steepness values at 0.60 to 0.95 plus free in 0.05 increments and then running that range again but allowing the steepness to vary with CV=0.10 There were 75 sensitivity runs.

Significant Assessment Modifications

The methods for the Statistical Catch-at-Age model (ASAP2) did not change from what was done at the assessment workshop. However, additional runs were conducted to explore the influence of different data inputs such as indices or years to include in the analyses. These exploratory runs ultimately led the reviewers to select a new base run. The differences in configuration between the original base run and the new base run were 1) to reinstate the longline age compositions in the model which had been removed at the recommendation of the AW, 2) exclude the NMFS-UM Reef Census Survey (RVC) and the RVC age-1 index, and 3) exclude the FWC Visual Survey. In reviewing the data inputs for the final configuration after the review workshop, we found that the longline discard weight had been calculated with the average hook-and-line weight at age instead of the longline average weight-at-age (revised longline discard weights are provided in Table A2.1.2) and that the initial effective sample sizes used the lesser of the number of lengths in the fleet or the number of ages in the von Bertalanffy growth curve i.e. by period instead of the number of ages by year. Those additional corrections were incorporated into the new base run, sensitivity runs, and projections.

Sources of Information

All information was copied directly or generated from the information available in the final Stock Assessment Report for SEDAR 19: South Atlantic and Gulf of Mexico Black Grouper.

Tables

- Table 1: Summary of stock status and determination criteria (above)
- Table 2: Summary of life history parameters by age
- Table 3: Catch and discards by fishery sector
- Table 4: Fishing mortality estimates
- Table 5: Stock abundance and biomass
- Table 6: Spawning stock biomass and Recruitment

Figures

- Figure 1: Landings by fishery sector
- Figure 2: Discards by fishery sector
- Figure 3: Fishing Mortality
- Figure 4: Stock Biomass
- Figure 5: Abundance Indices
- Figure 6: Stock-Recruitment
- Figure 7: Yield per Recruit
- Figure 8: Stock Status and Control Rule
- Figure 9: Projections

Table 2: Summary of life history characteristics.

Age (year)	TL (mm) (mid-year)	M (y^{-1})	Proportion mature		Proportion	
			Female	Male	Female	Male
0	243	0.495	0.00	0.00	1.00	0.00
1	388	0.343	0.00	0.01	1.00	0.00
2	515	0.271	0.00	0.01	1.00	0.00
3	624	0.230	0.00	0.01	1.00	0.00
4	719	0.203	0.02	0.01	1.00	0.00
5	801	0.185	0.08	0.02	1.00	0.00
6	872	0.171	0.31	0.03	0.97	0.03
7	934	0.161	0.70	0.04	0.96	0.04
8	987	0.153	0.93	0.06	0.94	0.06
9	1033	0.147	0.99	0.08	0.92	0.08
10	1074	0.141	1.00	0.11	0.89	0.11
11	1108	0.137	1.00	0.15	0.85	0.15
12	1138	0.134	1.00	0.20	0.80	0.20
13	1165	0.131	1.00	0.26	0.74	0.26
14	1187	0.129	1.00	0.33	0.67	0.33
15	1207	0.127	1.00	0.41	0.59	0.41
16	1224	0.125	1.00	0.50	0.50	0.50
17	1239	0.124	1.00	0.58	0.42	0.58
18	1251	0.123	1.00	0.67	0.33	0.67
19	1262	0.122	1.00	0.74	0.26	0.74
20	1272	0.121	1.00	0.80	0.20	0.80
21	1280	0.120	1.00	0.85	0.15	0.85
22	1287	0.120	1.00	0.89	0.11	0.89
23	1294	0.119	1.00	0.92	0.08	0.92
24	1299	0.119	1.00	0.94	0.06	0.94
25	1304	0.118	1.00	0.96	0.04	0.96
26	1308	0.118	1.00	0.97	0.03	0.97
27	1311	0.118	1.00	0.98	0.02	0.98
28	1314	0.117	1.00	0.99	0.01	0.99
29	1317	0.117	1.00	0.99	0.01	0.99
30	1319	0.117	1.00	0.99	0.01	0.99
31	1321	0.117	1.00	0.99	0.01	0.99
32	1323	0.117	1.00	1.00	0.00	1.00
33	1325	0.117	1.00	1.00	0.00	1.00

Table 3: (Table A2.1.2.) Landings and discards in numbers and pounds by fleet and year.

	Landings (numbers)				Landings (pounds)				
Year	Headboat	MRFSS	Comm HL	Comm LL	Headboat	MRFSS	Comm HL	Comm LL	Total
1986	4,803	62,293	34,185	7,492	19,976	447,266	426,270	129,457	1,022,970
1987	3,231	55,769	64,461	11,337	39,603	382,021	567,539	125,101	1,114,264
1988	3,056	29,269	25,835	5,144	24,288	188,198	365,587	83,995	662,067
1989	2,084	28,002	35,478	4,998	19,806	181,452	384,267	82,395	667,920
1990	1,921	21,959	25,711	6,765	17,764	74,441	299,700	109,944	501,850
1991	1,703	32,959	13,817	2,594	15,378	398,475	163,451	53,681	630,985
1992	2,546	34,094	14,018	1,546	20,965	281,616	218,010	58,787	579,378
1993	2,128	26,831	12,070	982	25,129	140,596	165,666	35,670	367,061
1994	2,474	21,996	8,518	643	24,053	166,073	139,558	25,401	355,084
1995	4,525	25,993	7,546	571	31,760	236,796	115,303	24,975	408,834
1996	2,911	37,155	9,105	788	36,613	316,559	120,418	29,915	503,505
1997	3,763	43,409	6,215	828	48,274	450,156	89,464	34,644	622,538
1998	6,122	30,635	6,133	1,066	84,984	389,372	88,334	41,778	604,468
1999	1,873	15,280	3,625	1,418	25,267	169,613	79,719	51,646	326,245
2000	1,065	8,763	4,362	1,304	15,118	112,952	92,434	50,077	270,581
2001	2,073	10,350	4,731	1,390	31,013	136,623	100,951	55,020	323,607
2002	1,120	11,663	4,265	1,498	15,271	139,377	89,052	53,496	297,196
2003	1,270	16,914	6,135	1,856	11,940	262,670	97,394	77,142	449,147
2004	1,613	15,585	4,280	2,113	18,414	139,018	91,732	73,385	322,549
2005	2,000	12,943	3,358	1,563	25,733	135,772	73,266	45,734	280,505
2006	1,130	7,732	3,373	1,792	17,862	92,165	72,223	61,444	243,695
2007	1,282	14,614	2,431	1,300	17,828	156,224	54,849	43,457	272,357
2008	339	14,671	1,451	536	3,930	162,408	33,236	17,843	217,417

	Discards (numbers)				Discards (pounds)				
Year	Headboat	MRFSS	Comm HL	Comm LL	Headboat	MRFSS	Comm HL	Comm LL	Total
1986	5,018	6,694			8,014	10,691			18,705
1987	3,376	31,074			5,391	49,626			55,017
1988	3,193	3,192			5,099	5,097			10,196
1989	2,177	4,118			3,477	6,576			10,053
1990	2,007	3,509			3,205	5,604			8,809
1991	1,779	15,025			2,842	23,995			26,837
1992	2,660	17,345			13,767	83,614			97,380
1993	2,223	10,488	1,114	40	11,506	50,558	6,517	121	68,702
1994	2,585	15,158	1,357	49	13,377	73,074	7,934	147	94,532
1995	4,728	6,564	1,225	44	22,505	29,113	6,587	131	58,336
1996	3,041	17,646	1,330	46	14,478	78,264	7,152	120	100,014
1997	3,932	14,565	1,407	50	18,715	64,599	7,566	131	91,011
1998	6,396	11,943	1,301	48	30,448	52,970	6,995	124	90,538
1999	1,957	11,035	1,459	53	8,628	82,449	11,586	419	103,082
2000	1,113	8,805	1,443	49	4,906	65,786	11,457	384	82,533
2001	2,166	7,026	1,249	46	9,550	52,493	9,915	360	72,318
2002	1,170	9,173	1,315	42	3,788	63,012	8,339	297	75,436
2003	1,327	10,590	1,665	48	4,296	24,531	10,555	349	39,730
2004	1,685	10,592	940	44	7,273	79,234	7,483	276	94,266
2005	2,090	4,124	1,880	33	8,959	23,541	11,452	186	44,138
2006	1,181	6,315	231	39	3,362	36,501	1,424	216	41,502
2007	1,339	8,884	1,777	35	4,181	58,075	12,385	219	74,860
2008	354	10,686	259	31	1,514	82,197	2,123	217	86,051

Table 4: (Table A3.3.4.11.) Fishing mortality per year for directed (a), dead discards (b), and combined (c) for black grouper by year and age.

a. Directed fishing mortality per year.

	Ages																			
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	0.066	0.265	0.346	0.305	0.254	0.203	0.156	0.117	0.089	0.070	0.058	0.050	0.045	0.042	0.040	0.039	0.038	0.037	0.036	0.036
1987	0.015	0.268	0.403	0.354	0.293	0.232	0.175	0.128	0.094	0.071	0.057	0.048	0.042	0.039	0.036	0.035	0.034	0.033	0.032	0.032
1988	0.039	0.228	0.321	0.284	0.237	0.188	0.141	0.102	0.074	0.056	0.045	0.038	0.033	0.031	0.029	0.028	0.027	0.027	0.026	0.026
1989	0.009	0.206	0.281	0.249	0.209	0.166	0.124	0.090	0.066	0.050	0.040	0.034	0.030	0.028	0.027	0.026	0.025	0.024	0.024	0.024
1990	0.005	0.090	0.234	0.206	0.172	0.137	0.104	0.077	0.058	0.045	0.037	0.032	0.028	0.026	0.025	0.024	0.024	0.023	0.023	0.023
1991	0.005	0.145	0.248	0.215	0.177	0.140	0.106	0.079	0.059	0.045	0.036	0.030	0.026	0.023	0.021	0.020	0.019	0.018	0.018	0.017
1992	0.014	0.092	0.156	0.176	0.197	0.155	0.106	0.073	0.052	0.038	0.030	0.024	0.020	0.018	0.017	0.016	0.015	0.015	0.015	0.014
1993	0.016	0.059	0.122	0.154	0.165	0.134	0.091	0.062	0.043	0.032	0.024	0.019	0.016	0.014	0.013	0.012	0.012	0.011	0.011	0.011
1994	0.003	0.017	0.067	0.133	0.168	0.128	0.085	0.056	0.038	0.028	0.021	0.017	0.014	0.012	0.011	0.011	0.010	0.010	0.010	0.010
1995	0.017	0.044	0.093	0.134	0.152	0.112	0.074	0.049	0.033	0.024	0.018	0.015	0.012	0.011	0.010	0.010	0.009	0.009	0.009	0.009
1996	0.006	0.039	0.102	0.143	0.179	0.133	0.085	0.054	0.035	0.025	0.018	0.015	0.012	0.011	0.010	0.010	0.009	0.009	0.009	0.009
1997	0.000	0.038	0.102	0.175	0.198	0.141	0.088	0.055	0.035	0.024	0.018	0.015	0.012	0.011	0.010	0.010	0.010	0.009	0.009	0.009
1998	0.000	0.020	0.080	0.156	0.195	0.141	0.088	0.055	0.035	0.024	0.018	0.015	0.013	0.011	0.011	0.010	0.010	0.010	0.009	0.009
1999	0.004	0.022	0.042	0.074	0.120	0.097	0.067	0.048	0.035	0.027	0.021	0.018	0.015	0.014	0.012	0.012	0.011	0.010	0.010	0.010
2000	0.000	0.016	0.030	0.054	0.095	0.081	0.058	0.042	0.031	0.024	0.020	0.017	0.014	0.013	0.012	0.011	0.010	0.010	0.009	0.009
2001	0.001	0.015	0.036	0.064	0.094	0.076	0.054	0.040	0.030	0.023	0.019	0.016	0.014	0.013	0.011	0.011	0.010	0.010	0.009	0.009
2002	0.001	0.007	0.029	0.069	0.097	0.076	0.054	0.039	0.029	0.023	0.018	0.015	0.013	0.012	0.011	0.010	0.010	0.009	0.009	0.009
2003	0.000	0.002	0.018	0.058	0.084	0.065	0.048	0.036	0.027	0.022	0.018	0.016	0.014	0.012	0.011	0.011	0.010	0.010	0.009	0.009
2004	0.000	0.014	0.041	0.076	0.105	0.082	0.056	0.040	0.029	0.022	0.018	0.015	0.013	0.011	0.010	0.010	0.009	0.009	0.008	0.008
2005	0.000	0.002	0.023	0.071	0.086	0.063	0.045	0.032	0.024	0.019	0.015	0.013	0.011	0.010	0.009	0.008	0.008	0.008	0.007	0.007
2006	0.000	0.002	0.018	0.055	0.076	0.059	0.041	0.029	0.021	0.016	0.013	0.011	0.010	0.009	0.008	0.008	0.008	0.007	0.007	0.007
2007	0.000	0.003	0.028	0.071	0.096	0.071	0.048	0.032	0.023	0.017	0.013	0.011	0.009	0.008	0.007	0.007	0.006	0.006	0.006	0.006
2008	0.000	0.022	0.050	0.073	0.105	0.081	0.051	0.033	0.022	0.015	0.011	0.008	0.007	0.006	0.005	0.005	0.005	0.004	0.004	0.004

Table 4: (Table A3.3.4.11) (continued). Fishing mortality per year for directed (a), dead discards (b), and combined (c) for black grouper by year and age.

b. Dead discard fishing mortality per year.

	Ages																			
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	0.025	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.041	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.022	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.024	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.022	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.034	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.036	0.036	0.031	0.021	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.031	0.036	0.030	0.018	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.034	0.044	0.040	0.021	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.029	0.034	0.029	0.016	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.040	0.046	0.038	0.023	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.045	0.051	0.043	0.021	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.046	0.055	0.048	0.025	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.021	0.058	0.044	0.025	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.016	0.046	0.036	0.021	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.017	0.043	0.032	0.017	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.015	0.045	0.034	0.016	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.012	0.036	0.028	0.013	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.017	0.049	0.036	0.018	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.016	0.039	0.029	0.011	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2006	0.013	0.038	0.028	0.013	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.015	0.048	0.035	0.016	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2008	0.016	0.055	0.039	0.021	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 4: (Table A3.3.4.11) (continued). Fishing mortality per year for directed (a), dead discards (b), and combined (c) for black grouper by year and age.

c. Combined fishing mortality per year.

	Ages																			
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	0.091	0.274	0.346	0.305	0.254	0.203	0.156	0.117	0.089	0.070	0.058	0.050	0.045	0.042	0.040	0.039	0.038	0.037	0.036	0.036
1987	0.056	0.287	0.403	0.354	0.293	0.232	0.175	0.128	0.094	0.071	0.057	0.048	0.042	0.039	0.036	0.035	0.034	0.033	0.032	0.032
1988	0.061	0.237	0.321	0.284	0.237	0.188	0.141	0.102	0.074	0.056	0.045	0.038	0.033	0.031	0.029	0.028	0.027	0.027	0.026	0.026
1989	0.033	0.213	0.281	0.249	0.209	0.166	0.124	0.090	0.066	0.050	0.040	0.034	0.030	0.028	0.027	0.026	0.025	0.024	0.024	0.024
1990	0.028	0.113	0.234	0.206	0.172	0.137	0.104	0.077	0.058	0.045	0.037	0.032	0.028	0.026	0.025	0.024	0.024	0.023	0.023	0.023
1991	0.039	0.164	0.248	0.215	0.177	0.140	0.106	0.079	0.059	0.045	0.036	0.030	0.026	0.023	0.021	0.020	0.019	0.018	0.018	0.017
1992	0.050	0.128	0.186	0.197	0.201	0.155	0.106	0.073	0.052	0.038	0.030	0.024	0.020	0.018	0.017	0.016	0.015	0.015	0.015	0.014
1993	0.047	0.095	0.152	0.172	0.170	0.134	0.091	0.062	0.043	0.032	0.024	0.019	0.016	0.014	0.013	0.012	0.012	0.011	0.011	0.011
1994	0.037	0.062	0.107	0.154	0.171	0.128	0.085	0.056	0.038	0.028	0.021	0.017	0.014	0.012	0.011	0.011	0.010	0.010	0.010	0.010
1995	0.045	0.079	0.122	0.149	0.154	0.112	0.074	0.049	0.033	0.024	0.018	0.015	0.012	0.011	0.010	0.010	0.009	0.009	0.009	0.009
1996	0.045	0.084	0.140	0.166	0.182	0.133	0.085	0.054	0.035	0.025	0.018	0.015	0.012	0.011	0.010	0.010	0.009	0.009	0.009	0.009
1997	0.045	0.089	0.144	0.196	0.200	0.141	0.088	0.055	0.035	0.024	0.018	0.015	0.012	0.011	0.010	0.010	0.010	0.009	0.009	0.009
1998	0.046	0.076	0.128	0.181	0.198	0.141	0.088	0.055	0.035	0.024	0.018	0.015	0.013	0.011	0.011	0.010	0.010	0.010	0.009	0.009
1999	0.025	0.080	0.086	0.099	0.124	0.097	0.067	0.048	0.035	0.027	0.021	0.018	0.015	0.014	0.012	0.012	0.011	0.010	0.010	0.010
2000	0.016	0.061	0.066	0.075	0.099	0.081	0.058	0.042	0.031	0.024	0.020	0.017	0.014	0.013	0.012	0.011	0.010	0.010	0.009	0.009
2001	0.018	0.058	0.068	0.081	0.097	0.076	0.054	0.040	0.030	0.023	0.019	0.016	0.014	0.013	0.011	0.011	0.010	0.010	0.009	0.009
2002	0.016	0.052	0.063	0.085	0.099	0.076	0.054	0.039	0.029	0.023	0.018	0.015	0.013	0.012	0.011	0.010	0.010	0.009	0.009	0.009
2003	0.012	0.039	0.046	0.071	0.085	0.065	0.048	0.036	0.027	0.022	0.018	0.016	0.014	0.012	0.011	0.011	0.010	0.010	0.009	0.009
2004	0.017	0.063	0.076	0.094	0.108	0.082	0.056	0.040	0.029	0.022	0.018	0.015	0.013	0.011	0.010	0.010	0.009	0.009	0.008	0.008
2005	0.016	0.041	0.052	0.082	0.087	0.063	0.045	0.032	0.024	0.019	0.015	0.013	0.011	0.010	0.009	0.008	0.008	0.008	0.007	0.007
2006	0.013	0.040	0.046	0.068	0.078	0.059	0.041	0.029	0.021	0.016	0.013	0.011	0.010	0.009	0.008	0.008	0.008	0.007	0.007	0.007
2007	0.016	0.051	0.063	0.087	0.098	0.071	0.048	0.032	0.023	0.017	0.013	0.011	0.009	0.008	0.007	0.007	0.006	0.006	0.006	0.006
2008	0.016	0.077	0.089	0.095	0.108	0.081	0.051	0.033	0.022	0.015	0.011	0.008	0.007	0.006	0.005	0.005	0.005	0.004	0.004	0.004

Table 5: (Table A3.3.4.9.) Estimated annual population numbers-at-age (a) and stock biomass (lb, b) at the beginning of the year.

a. Population abundance.

	Ages																			
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	276,734	201,534	59,614	39,803	29,717	23,213	16,833	12,171	8,842	6,788	5,221	3,922	3,065	2,489	2,037	1,675	1,400	1,175	993	14,692
1987	230,281	170,049	113,811	33,049	23,746	19,060	15,919	12,237	9,282	6,986	5,498	4,297	3,266	2,572	2,099	1,726	1,424	1,192	1,003	13,467
1988	206,163	146,521	94,864	59,603	18,774	14,652	12,706	11,359	9,234	7,297	5,650	4,528	3,585	2,749	2,177	1,785	1,473	1,218	1,022	12,477
1989	184,453	130,538	85,906	53,943	36,295	12,250	10,205	9,379	8,796	7,404	5,994	4,712	3,818	3,045	2,345	1,865	1,533	1,267	1,051	11,707
1990	200,271	120,104	78,411	50,838	34,013	24,365	8,723	7,656	7,346	7,110	6,118	5,021	3,987	3,252	2,605	2,013	1,606	1,323	1,096	11,087
1991	210,105	131,083	79,716	48,640	33,456	23,674	17,847	6,677	6,076	5,987	5,905	5,142	4,259	3,403	2,787	2,239	1,736	1,386	1,145	10,599
1992	209,365	136,005	82,678	48,748	31,752	23,189	17,299	13,631	5,288	4,945	4,970	4,968	4,370	3,646	2,927	2,406	1,940	1,506	1,206	10,273
1993	230,107	134,038	88,882	53,759	32,393	21,466	16,682	13,220	10,866	4,336	4,134	4,208	4,246	3,760	3,150	2,537	2,092	1,689	1,315	10,072
1994	260,137	147,733	90,567	59,835	36,623	22,594	15,776	12,943	10,655	8,984	3,648	3,519	3,613	3,668	3,261	2,741	2,214	1,828	1,480	10,023
1995	245,559	168,746	103,200	63,771	41,485	25,525	16,709	12,316	10,491	8,852	7,590	3,116	3,030	3,129	3,188	2,843	2,396	1,938	1,604	10,140
1996	234,841	157,915	115,910	71,573	44,432	29,397	19,167	13,185	10,058	8,761	7,507	6,499	2,688	2,628	2,723	2,782	2,487	2,099	1,702	10,361
1997	233,863	151,058	107,838	78,963	49,024	30,616	21,622	14,960	10,711	8,381	7,423	6,426	5,607	2,331	2,287	2,376	2,434	2,179	1,843	10,641
1998	236,399	150,410	102,682	73,127	52,520	33,177	22,349	16,822	12,142	8,925	7,102	6,356	5,544	4,863	2,029	1,995	2,078	2,132	1,913	11,009
1999	235,117	151,885	103,626	70,793	49,367	35,627	24,217	17,391	13,655	10,118	7,564	6,081	5,483	4,808	4,230	1,770	1,745	1,820	1,871	11,392
2000	233,464	154,389	104,171	74,502	51,869	36,058	27,167	19,234	14,216	11,385	8,556	6,456	5,229	4,741	4,172	3,683	1,545	1,526	1,596	11,687
2001	210,197	154,639	107,913	76,429	55,930	38,866	27,943	21,790	15,815	11,895	9,649	7,314	5,559	4,526	4,118	3,636	3,219	1,352	1,339	11,715
2002	205,130	138,961	108,471	78,994	57,001	41,973	30,265	22,485	17,955	13,252	10,091	8,254	6,300	4,813	3,932	3,589	3,177	2,818	1,187	11,514
2003	192,852	135,893	97,985	79,821	58,687	42,676	32,677	24,364	18,541	15,057	11,252	8,639	7,116	5,459	4,184	3,429	3,138	2,783	2,473	11,208
2004	182,592	128,277	97,152	73,307	60,164	44,585	33,597	26,469	20,156	15,573	12,792	9,634	7,446	6,163	4,743	3,647	2,997	2,747	2,442	12,063
2005	181,721	120,790	89,462	70,523	53,999	44,681	34,529	26,978	21,807	16,902	13,227	10,958	8,310	6,455	5,361	4,139	3,190	2,626	2,413	12,802
2006	188,252	120,399	86,119	66,555	52,562	40,934	35,237	28,049	22,392	18,377	14,406	11,360	9,471	7,216	5,623	4,684	3,625	2,799	2,309	13,444
2007	188,386	125,012	85,958	64,416	50,326	40,202	32,437	28,748	23,366	18,928	15,702	12,396	9,833	8,234	6,292	4,916	4,105	3,182	2,462	13,921
2008	168,761	124,801	88,242	63,229	47,782	37,733	31,458	26,274	23,861	19,719	16,165	13,515	10,738	8,558	7,188	5,508	4,315	3,607	2,803	14,500

Table 5: (Table A3.3.4.9) (continued). Estimated annual population numbers-at-age (a) and stock biomass (lb, b) at the beginning of the year.

b. Stock biomass.

	Ages																			
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	247,677	558,652	344,094	387,404	428,253	453,776	419,358	368,918	314,780	276,038	237,226	195,592	165,338	143,487	124,303	107,278	93,421	81,223	70,741	1,172,459
1987	206,101	471,376	656,917	321,663	342,199	372,593	396,598	370,925	330,445	284,081	249,799	214,290	176,164	148,305	128,090	110,496	95,019	82,419	71,487	1,074,717
1988	184,516	406,156	547,554	580,115	270,551	286,408	316,545	344,317	328,719	296,734	256,729	225,838	193,422	158,482	132,846	114,289	98,255	84,169	72,841	995,682
1989	165,085	361,851	495,848	525,029	523,053	239,455	254,245	284,284	313,128	301,089	272,346	235,009	205,963	175,558	143,081	119,382	102,306	87,586	74,841	934,234
1990	179,243	332,928	452,588	494,805	490,156	476,291	217,315	232,077	261,516	289,126	277,958	250,416	215,100	187,517	158,934	128,906	107,122	91,409	78,054	884,781
1991	188,044	363,362	460,118	473,413	482,127	462,779	444,630	202,384	216,314	243,473	268,311	256,461	229,766	196,207	170,026	143,386	115,814	95,825	81,554	845,837
1992	187,382	377,006	477,216	474,468	457,571	453,293	430,963	413,192	188,243	201,082	225,839	247,751	235,770	210,197	178,563	154,049	129,429	104,120	85,941	819,798
1993	205,946	371,553	513,026	523,234	466,820	419,608	415,606	400,725	386,829	176,301	187,827	209,849	229,050	216,786	192,174	162,458	139,586	116,771	93,690	803,726
1994	232,823	409,516	522,752	582,373	527,775	441,658	393,037	392,340	379,304	365,310	165,762	175,474	194,912	211,482	198,956	175,474	147,718	126,362	105,425	799,816
1995	219,775	467,764	595,670	620,680	597,843	498,961	416,264	373,332	373,473	359,952	344,867	155,380	163,440	180,395	194,502	182,019	159,841	133,954	114,274	809,200
1996	210,183	437,740	669,033	696,617	640,305	574,651	477,498	399,664	358,037	356,270	341,066	324,131	145,012	151,500	166,116	178,130	165,956	145,070	121,236	826,805
1997	209,307	418,733	622,441	768,546	706,486	598,472	538,676	453,477	381,315	340,786	337,288	320,471	302,490	134,422	139,513	152,138	162,412	150,620	131,295	849,181
1998	211,577	416,937	592,681	711,746	756,860	648,544	556,791	509,915	432,232	362,927	322,699	316,982	299,097	280,385	123,768	127,745	138,674	147,357	136,271	878,508
1999	210,430	421,025	598,129	689,023	711,424	696,427	603,321	527,144	486,104	411,426	343,669	303,252	295,805	277,196	258,114	113,303	116,414	125,791	133,287	909,064
2000	208,950	427,966	601,275	725,131	747,481	704,860	676,804	583,009	506,065	462,939	388,733	321,960	282,107	273,372	254,569	235,833	103,097	105,475	113,682	932,662
2001	188,126	428,659	622,874	743,883	806,006	759,747	696,151	660,483	563,012	483,690	438,415	364,754	299,865	260,963	251,268	232,775	214,746	93,477	95,389	934,841
2002	183,591	385,200	626,095	768,844	821,434	820,482	753,992	681,550	639,162	538,863	458,499	411,648	339,890	277,495	239,935	229,813	212,005	194,742	84,550	918,872
2003	172,603	376,695	565,567	776,901	845,734	834,230	814,070	738,509	660,055	612,282	511,241	430,850	383,860	314,732	255,276	219,555	209,399	192,333	176,211	894,405
2004	163,420	355,584	560,762	713,501	867,025	871,548	837,002	802,337	717,533	633,252	581,222	480,438	401,683	355,328	289,415	233,492	199,964	189,885	173,955	962,652
2005	162,640	334,830	516,372	686,398	778,184	873,426	860,209	817,742	776,300	687,299	601,000	546,466	448,281	372,184	327,075	264,988	212,871	181,507	171,906	1,021,585
2006	168,486	333,746	497,077	647,783	757,467	800,174	877,864	850,212	797,140	747,290	654,565	566,525	510,937	416,074	343,109	299,880	241,893	193,457	164,513	1,072,818
2007	168,605	346,533	496,151	626,958	725,242	785,865	808,100	871,412	831,817	769,668	713,432	618,206	530,487	474,777	383,906	314,787	273,877	219,910	175,388	1,110,956
2008	151,041	345,948	509,331	615,405	688,592	737,603	783,721	796,430	849,410	801,841	734,487	674,007	579,304	493,433	438,580	352,664	287,876	249,333	199,654	1,157,105

Table 6: (Table A3.3.4.10.) Spawning biomass offset to the spawning season (mid-March) and recruitment of age-1 fish by year.

Year	Spawning biomass (lb)	Recruitment Number of age-1 fish
1986	3,706,670	276,734
1987	3,644,680	230,281
1988	3,541,110	206,163
1989	3,457,730	184,453
1990	3,424,660	200,271
1991	3,486,200	210,105
1992	3,587,180	209,365
1993	3,691,590	230,107
1994	3,811,990	260,137
1995	3,961,100	245,559
1996	4,160,390	234,841
1997	4,385,590	233,863
1998	4,630,100	236,399
1999	4,896,800	235,117
2000	5,213,420	233,464
2001	5,570,170	210,197
2002	5,958,520	205,130
2003	6,371,550	192,852
2004	6,809,070	182,592
2005	7,225,420	181,721
2006	7,636,630	188,252
2007	8,000,670	188,386
2008	8,291,540	168,761

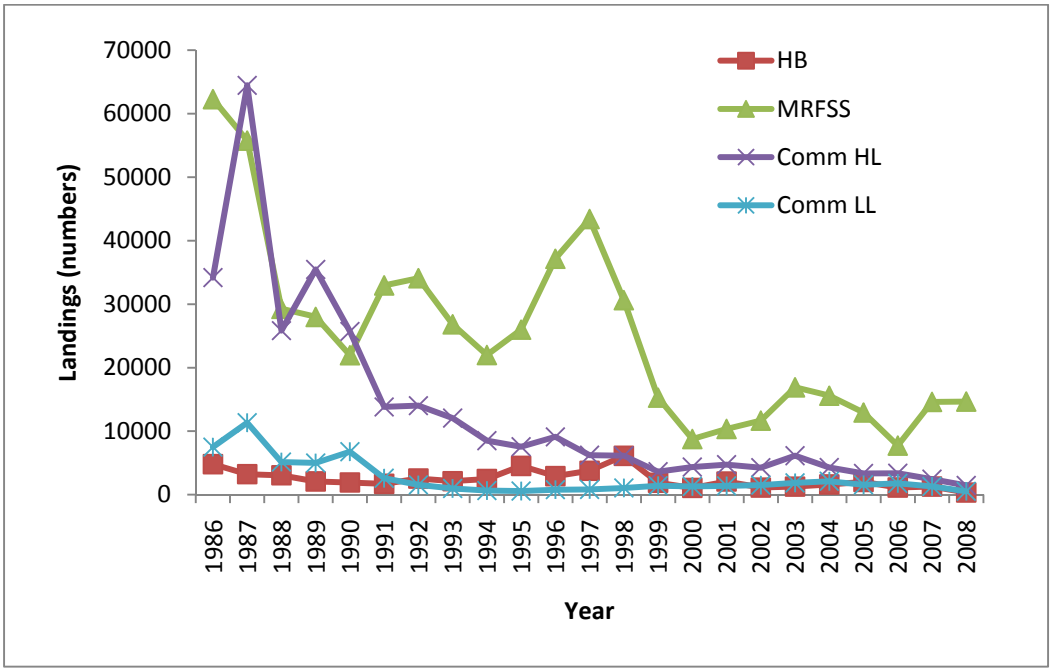


Figure 1: Landings (in numbers) by fleet.

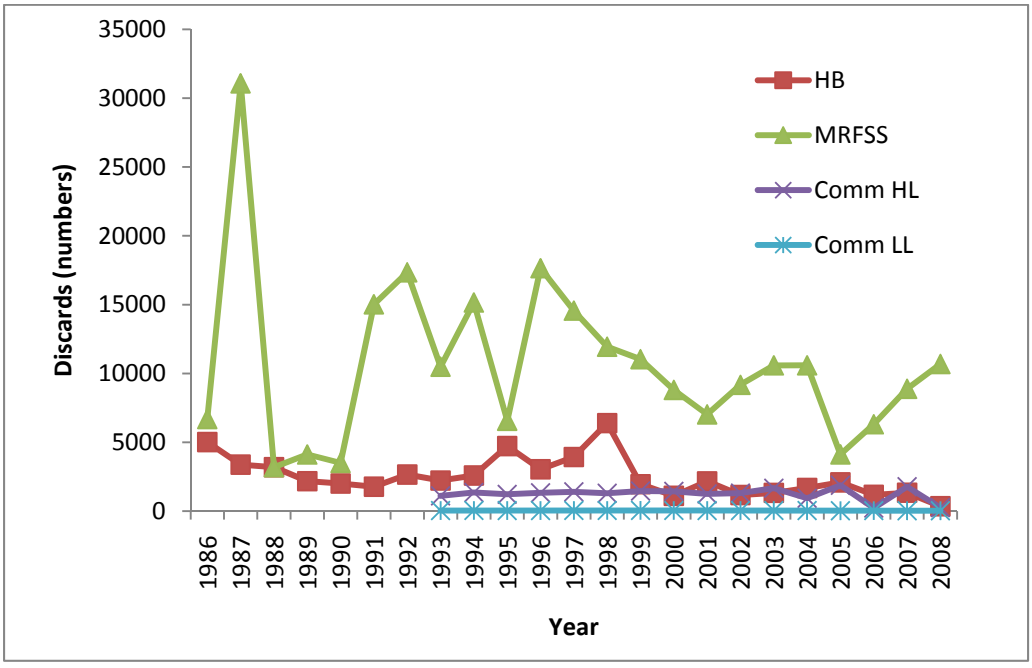
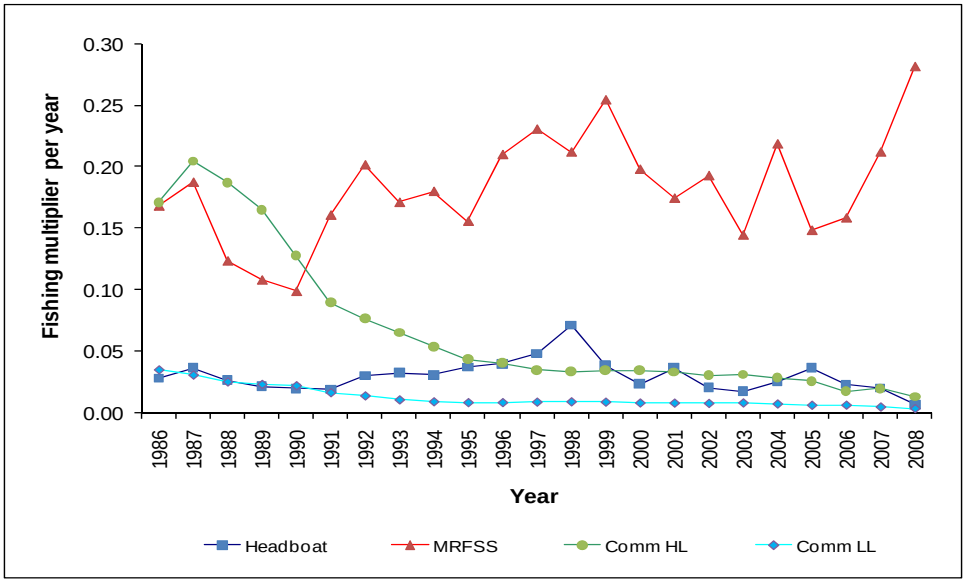


Figure 2: Discards (in numbers) by fleet.

a.



b.

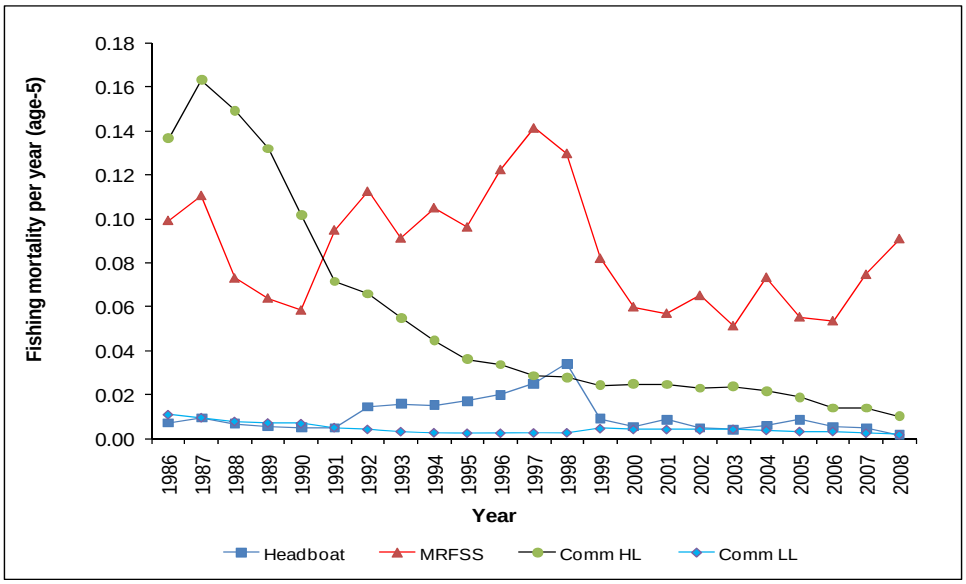


Figure 3: (Figure A3.3.5.10.) Fishing multiplier (directed and discards, a) and the directed fishing mortality rate (b) by fleet and year.

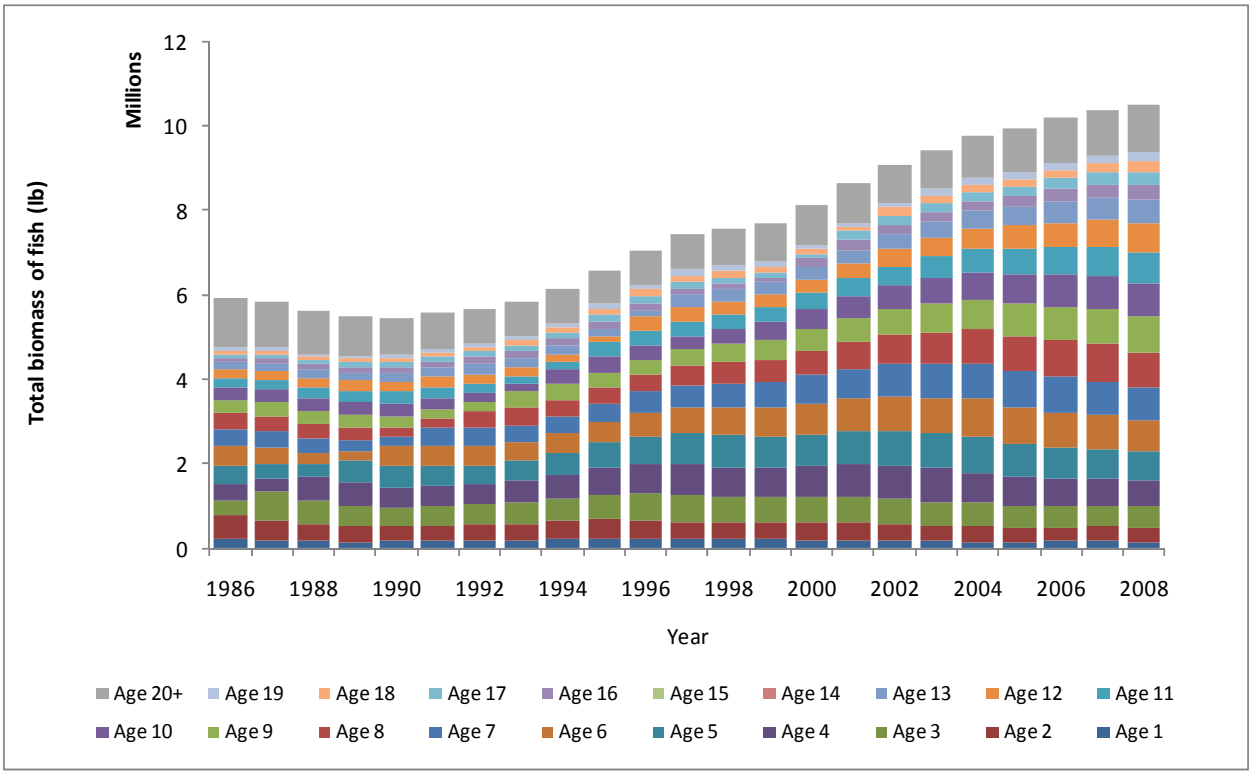


Figure 4: (Figure A3.3.5.8.) Total biomass in pounds by year and age.

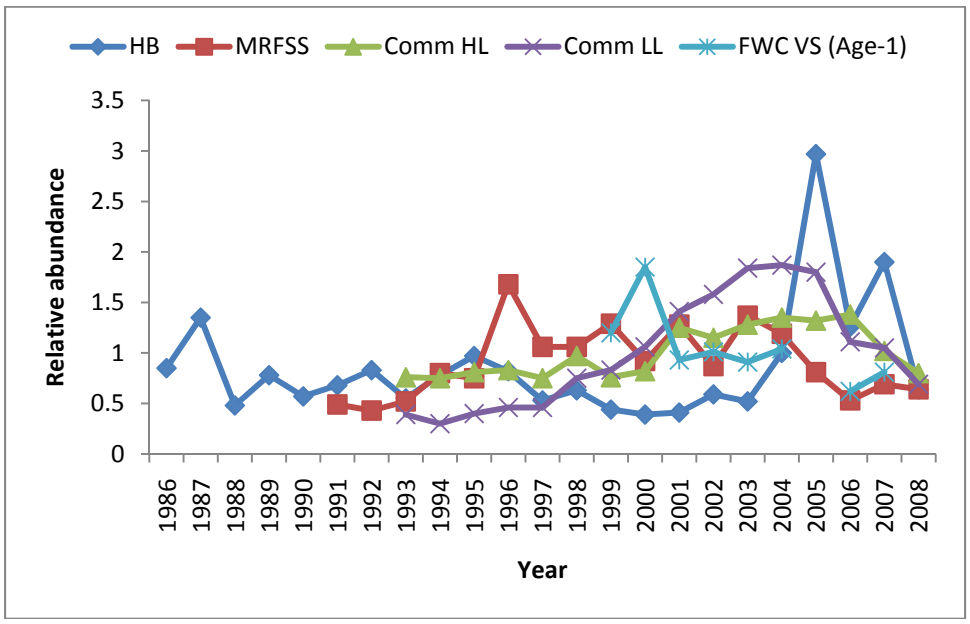


Figure 5. Indices of abundance included in final base model.

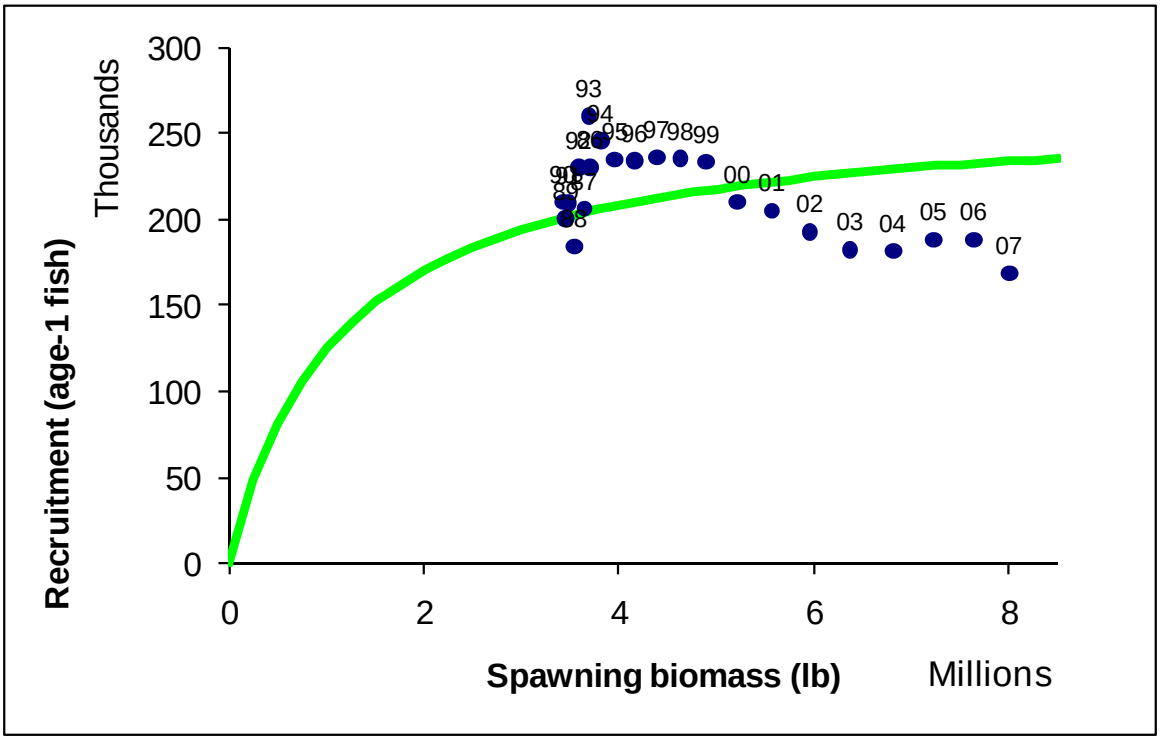


Figure 6: (Figure A3.3.5.14.) The estimated Beverton-Holt stock-recruitment relationship for black grouper. The point estimate for steepness was 0.84 and 22.4 million lb for the spawning biomass at F= 0. The equivalent figure in the original report was Figure 3.3.5.13.

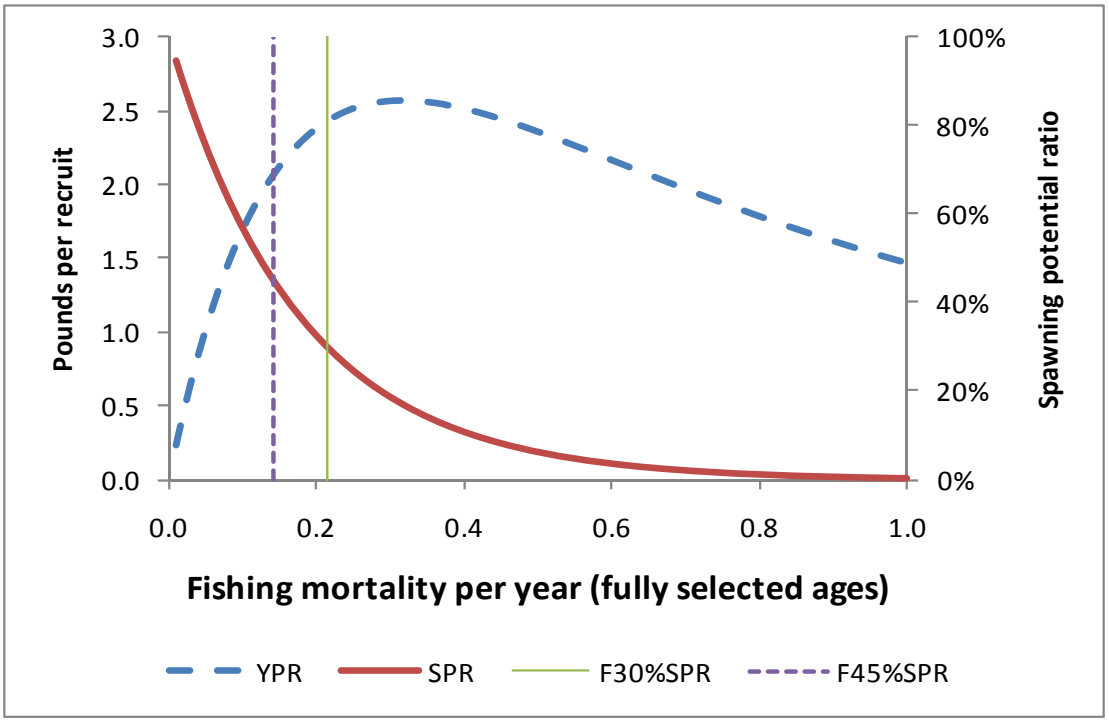


Figure 7: **(Figure A3.3.5.12.)** Yield-per-recruit and static spawning potential ratio for black grouper.

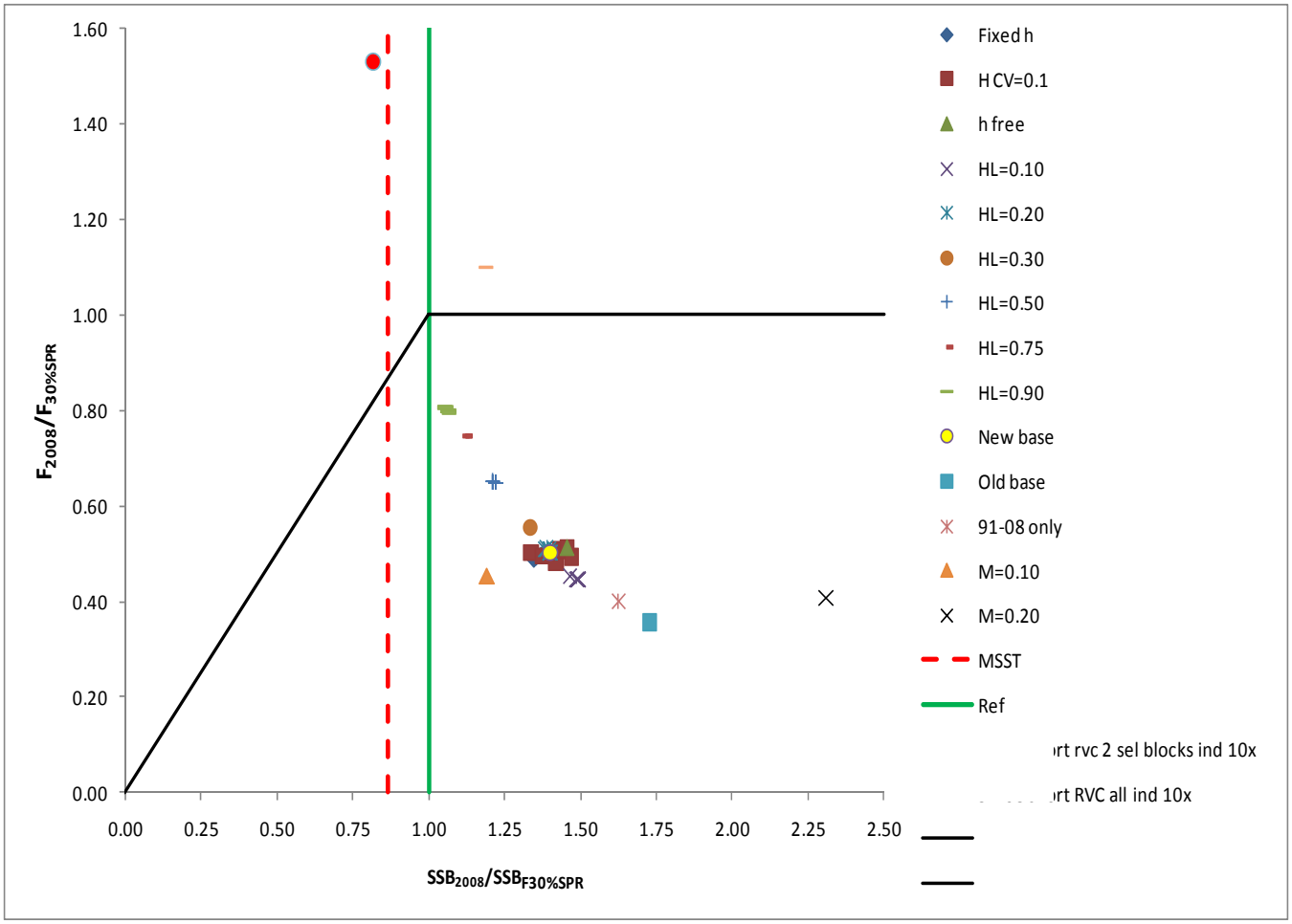
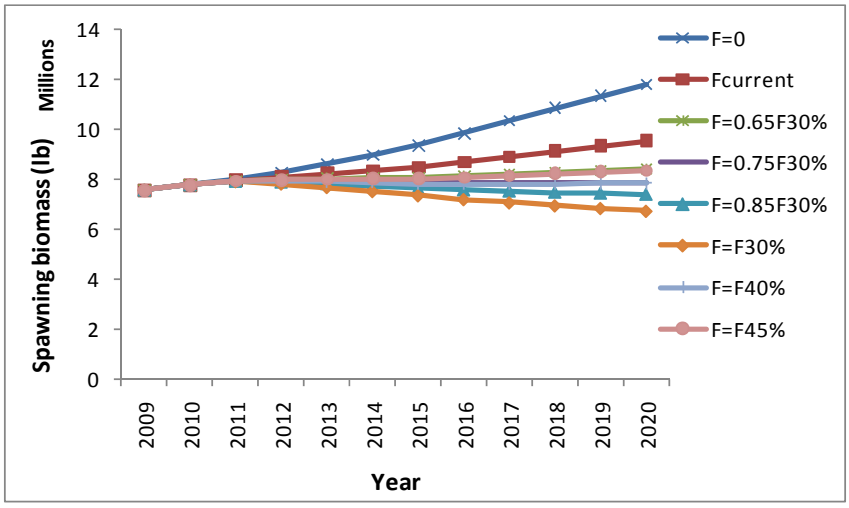
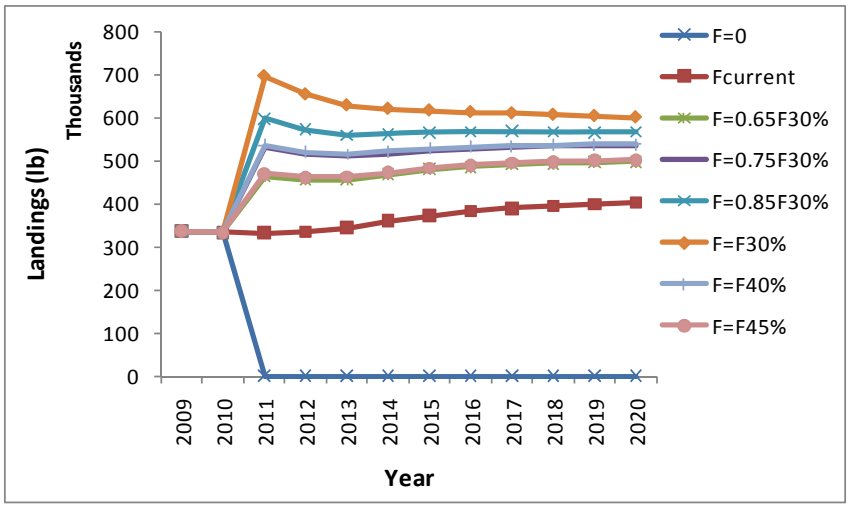


Figure 8: (Figure A3.3.5.22.) Fishing mortality ratios ($F_{2008}/F_{30\%SPR}$) and spawning biomass ratios ($SSB_{2008}/SSB_{F30\%SPR}$) for the exploratory and sensitivity runs.

a.



b.



c.

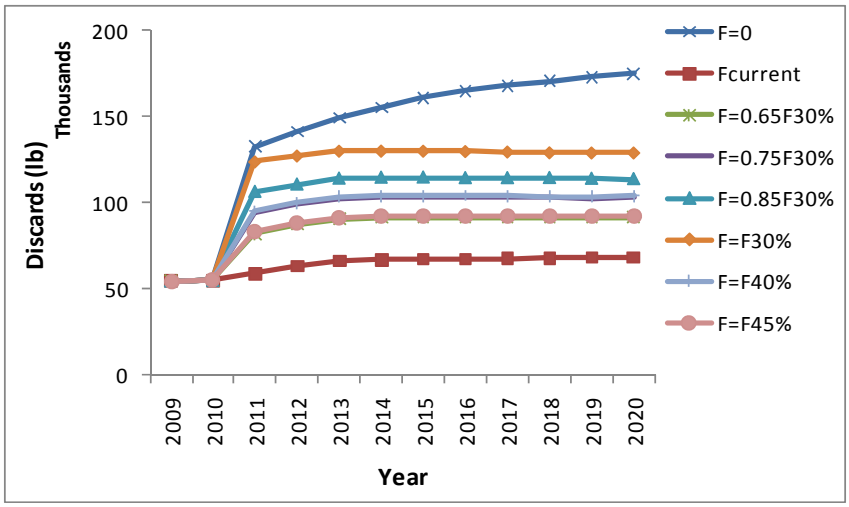


Figure 9: (Figure A3.3.5.26.) Comparison of projections for spawning biomass (a), landings (b) and discards across alternative fishing mortality rates. The equivalent figure in the original report was Figure 3.3.5.23.