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

Point estimates from the base model indicate that the U.S. southeast stock of red grouper *Epinephelus morio* is currently overfished and is experiencing overfishing.

- Estimated time series of stock status (SSB/MSST) shows decline until the mid-1980s, and then steady increase since, but with a decrease in the terminal year. The increase in stock status appears to have been initially driven by strong recruitment, then reinforced by 1992 management regulations. Base-run estimates of spawning biomass have remained below MSST throughout the time series (overfished status in 1976 is not surprising given the heavy fishing pressure that occurred prior to the start of the assessment period).
- Current stock status was estimated in the base run to be SSB2008/MSST = 0.92; uncertainty in this estimate includes the possibility that the stock is not overfished (i.e., SSB > MSST), but also the possibility that the stock is less healthy than estimated by the base run. Age structure estimated by the base run has become repopulated by older fish during the last decade, approaching the (equilibrium) age structure expected at MSY.
- The estimated time series of F/F_{MSY} suggests that overfishing has been occurring throughout the assessment period. The series peaked during the 1980s; since 2000, F/F_{MSY} has been at its lowest levels, but has been increasing since 2005. Current fishery status in the terminal year, with current F represented by the geometric mean from 2006–2008, is estimated by the base run to be $F_{current}/F_{MSY} = 1.35$. This estimate indicates current overfishing and appears robust across MCB trials.

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)	0.14
F_{2008} (per year)	Apical Fishing mortality in 2008	0.340
$F_{current}$ (per year)	Geometric mean of the directed fishing mortality rates in 2006 - 2008	0.298
F_{MSY} (per year)	F_{MSY}	0.221
B_{MSY} (metric tons)	Biomass at MSY	3680
SSB_{2008} (metric tons)	Spawning stock biomass in 2008	2051
SSB_{MSY} (metric tons)	SSB_{MSY}	2592
MSST (metric tons)	(1-M)*SSB_{MSY}	2229
MFMT (per year)	F_{MSY}	0.221
MSY (1000 pounds)	Yield at MSY	1110
OY (1000 pounds)	Yield at F_{OY}	OY (65% F_{MSY})= 1064 OY (75% F_{MSY})= 1089 OY (85% F_{MSY}= 1103
F_{OY} (per year)	F_{OY} = 65%,75%, 85% F_{MSY}	65% F_{MSY}= 0.144 75% F_{MSY}= 0.166 85% F_{MSY}= 0.188
Biomass Status	SSB_{2008}/MSST	0.920
Exploitation Status	$F_{current}/F_{MSY}$	1.35

***All weights are whole weight

Stock Identification and Management Unit

The red grouper fishery has been managed in the US as separate Atlantic and Gulf of Mexico stock units with the boundary being U.S. Highway 1 in the Florida Keys. Significant differences in size and age structure and in growth rates of red grouper north and south of 28°N latitude in the Gulf of Mexico have been determined, supporting a hypothesis that red grouper may have some degree of subpopulation structure. Landings data from 1983 through 1995 indicated a

possible disjunct distribution of red grouper off the Atlantic coast; with the most catches occurring off NC and off southern FL, with relatively little in between.

The SEDAR12 Life History Data Workshop for the Gulf of Mexico stock of red grouper 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. The SEDAR19 LH DW concurred with that report.

Species Distribution:

The red grouper, is associated with reef habitat, especially the adults, in the Western Atlantic from Massachusetts through the Gulf of Mexico and south to Brazil and are reported to occur at depths of 24-120 m.

Stock Life History - summary of life history characteristics of the stock under assessment;

- There are no significant identification issues with red grouper and there are no other common names regularly used for red grouper in the region that may complicate data analysis.
- No published information is available on tagging of Atlantic red grouper from the US South Atlantic. Tagging information from the Florida Keys and GOM suggest that adult red grouper only move short distances
- Natural mortality is thought to vary by age so an age-specific Lorenzen mortality curve was used, scaled to provide the same survivorship to the oldest ages as that of the Hoenig estimate of 0.14 per year.
- The maximum observed age was 26 years.
- The LH WG recommends using L_{inf}=848.2 (mm), K=0.213 (per year), and t_o=-0.66 (yr) in the stock 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
- Red grouper is a protogynous hermaphrodite with asynchronous ovarian organization. Eggs are released in batches, but the fecundity pattern (determinate vs. indeterminate) of red grouper is not known.
- Spawning season is from February through June, with a peak in April

Assessment Methods

The primary model in this assessment was the Beaufort statistical catch-age model (BAM). The model was implemented with the AD Model Builder software, and its structure and equations are detailed in the document, SEDAR-19 RW-01. In essence, a statistical catch-age model simulates a population forward in time while including fishing processes. Quantities to be estimated are systematically varied until characteristics of the simulated populations match available data on the real population. Statistical catch-age models share many attributes with ADAPT-style tuned and untuned VPAs.

Assessment Data

The catch-age model included data from four fleets that caught southeastern U.S. red grouper: commercial lines (handline and longline), commercial other (pots, traps, trawl, diving, miscellaneous), recreational headboat, general recreational. The model was fit to data on annual landings (in units of 1000 lb whole weight for commercial fleets, 1000 fish for recreational fleets), annual discard mortalities (in units of 1000 fish for commercial lines and recreational fleets), annual length compositions of landings, annual age compositions of landings, annual length compositions of discards, three fishery dependent indices of abundance (commercial handline, general recreational, and headboat), and one fishery independent index of abundance (MARMAP chevron traps). Not all of the above data sources were available for all fleets in all years. Annual discard mortalities, as fit by the model, were computed by multiplying total discards (tabulated in the DW report) by the release mortality probability of 0.2.

Release Mortality

- The Life History Working Group reviewed the scientific studies on release mortality available for red grouper. Values ranged from 8 to 70% depending on the depth of capture and if post-release mortality were included.
- The Commercial workgroup recommended using 20% as the point estimate release mortality for red grouper with a sensitivity range of 10-30%.
- The Recreational workgroup recommended a discard mortality of 20%, with a sensitivity range of 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%).
- 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 – 70%. 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 immediate and delayed discard mortality.

Catch Trends

- Commercial lines reached a peak in the late 1990s, followed by a decline until 2005, when the trend again reversed and began to increase throughout the remainder of the assessment period, with the highest landings reported in 2008.
- Commercial "other" landing showed a general decline throughout the assessment period, with fairly stable landings in the last 4 years of the time series
- Headboat landings have been variable over the assessment period, with peaks in 1998 and 2005.
- Recreational landings showed a large decrease early in the time series, were relatively stable from 1993 to 2004, and have been on the increase since 2005.
- In general, estimated landings have been dominated by commercial lines and general recreational fleets, particularly since 1992. Estimated discard mortalities occur on a smaller scale than landings.

Fishing Mortality Trends

- The estimated fishing mortality rates (*F*) peaked during the 1980s, and in the last decade have generally been at their lowest levels of the time series. The two primary contributors are general recreational and commercial line fleets. An increase in fishing mortality rate in the last few years coincides with increased landings from those two fleets.
- In any given year, the maximum *F* at age (i.e., apical F) may be less than that year's sum of fully selected *F*s across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

Stock Abundance and Biomass Trends - summary of abundance, biomass, and recruitment over time

- Estimated abundance at age shows truncation of the older ages until the early 1990s, after which older fish began to repopulate. In the most recent years, older fish (6+) appear to be more abundant than in the early years of the assessment period. These older fish are predominantly male. A notably strong year classes was predicted to have occurred in 2004.
- Estimated biomass at age follows a similar pattern as abundance at age. Total biomass and spawning biomass show similar trends— general decline until the mid-1980s, and general increase since the early 1990s but with a downturn at the end of the time series.

Projections - results of model runs conducted to estimate stock conditions under various potential future levels of fishing mortality

- Projection scenario 1, in which $F = 0$, predicted the stock to achieve at least 50% chance of recovery by 2013. This duration defines the minimum rebuilding time frame (Tmin). Because the stock can rebuild within 10 years, the maximum rebuilding time frame (Tmax) is 10 years. Thus rebuilding that starts in 2011 should occur by the end of 2020, at the latest. The Tmin and Tmax should bracket the target rebuilding time frame (Ttarget).
- Projections with *F* at 100%, 75%, 50%, or 25% of *F*current predicted recovery by 2020 only if *F* were reduced sufficiently below the current level, as did projections with *F* at 65%, 75%, 85%, or 100% of *F*MSY. The value of *F*rebuild showed little sensitivity to *F* in 2010. In general, higher projected *F* resulted in larger annual and cumulative landings, but smaller biomass with a correspondingly smaller buffer from the MSST.

Scientific Uncertainty

- Uncertainty was in part examined through use of multiple models and sensitivity runs. For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates was computed more thoroughly through a mixed Monte Carlo and bootstrap (MCB) approach. The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of “observed” data

and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs.

- In this assessment, the BAM was successively re-fit n=2500 trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of natural mortality and discard mortality. This number of trials was sufficient for convergence of standard errors in management quantities. Of the 2500 trials, approximately 1.3% were discarded, because the model didn't properly converge (in most of these cases a spawner-recruit parameter hit an upper or lower bound, and in one case the optimization did not complete). This left n=2467 trials used to characterize uncertainty.
- Although there is evidence of stock separation (most catches occur off NC and off southern FL, with relatively little in between), the assessment assumed a single unit stock, as suggested by the DW. This assumption imparts an additional and unexplored source of uncertainty. Future assessments could consider spatially explicit assessment models, if data were split accordingly at the DW and if mixing rates could be estimated or assumed. In the meantime, fishery management is not necessarily limited by the assumption of a single unit stock, if managers wished to consider policies that treat portions of the stock distinctly (e.g., regional ABCs).

Significant Assessment Modifications

Changes to the base case, as proposed by the assessment workshop, were made at the request of the SEDAR Review Workshop (RW) for application of the Beaufort Assessment Model (BAM) to red grouper. The primary change made at the RW was the removal of the visual survey (RVC) index of abundance and its corresponding length compositions. The BAM base configuration was re-run without the RVC data, as were sensitivity analyses, Monte Carlo/Bootstrap analyses, and projections. Sensitivity analysis included one additional run not considered at the Assessment Workshop, a run with high discard mortality ($\delta = 0.7$). In addition, the rebuilding time frame was revised to have a duration of 10 years (until 2020).

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 Red Grouper.

Tables

Figures

Table 2: Summary of Life History Parameters:

Table 6.1. Life-history characteristics at age of the population, including average size (mid-year), proportion female, and proportion females mature (all males assumed mature)

Age	Total length (mm)	Total length (in)	CV length	Whole weight (kg)	Whole weight (lb)	Prop. female	Female maturity
1	313.9	12.4	0.09	0.46	1.02	1.00	0.00
2	416.4	16.4	0.09	1.11	2.45	0.96	0.35
3	499.3	19.7	0.09	1.95	4.30	0.93	0.54
4	566.2	22.3	0.09	2.88	6.35	0.88	0.71
5	620.3	24.4	0.09	3.82	8.43	0.80	0.84
6	664.0	26.1	0.09	4.72	10.41	0.70	0.92
7	699.4	27.5	0.09	5.54	12.22	0.59	0.96
8	727.9	28.7	0.09	6.28	13.84	0.47	0.98
9	751.0	29.6	0.09	6.91	15.24	0.35	0.99
10	769.6	30.3	0.09	7.46	16.45	0.24	1.00
11	784.7	30.9	0.09	7.92	17.46	0.15	1.00
12	796.9	31.4	0.09	8.31	18.32	0.09	1.00
13	806.7	31.8	0.09	8.63	19.03	0.05	1.00
14	814.7	32.1	0.09	8.90	19.62	0.02	1.00
15	821.1	32.3	0.09	9.12	20.10	0.00	1.00
16	826.3	32.5	0.09	9.30	20.50	0.00	1.00

Table 3: Catch and discards by fishery sector

a) Landings and discards, as fitted by the BAM (i.e., model input).

	Commercial			Recreational			
	Landings (1000 lb whole weight)		Discards (1000s)	Landings (1000s)		Discards (1000s fish)	
	Lines (handline, longline)	Misc. (diving, pots, other)	Line	Headboat	MRFSS (smooth)	Headboat	MRFSS
1976	263.678	171.480		4.60			
1977	209.245	135.148		5.61			
1978	257.966	152.356		4.77			
1979	234.447	135.079		9.38			
1980	184.857	103.576		8.14			
1981	210.664	125.994		7.96	79.93		15.33
1982	205.599	113.021		6.36	138.64		17.47
1983	203.609	118.816		9.89	237.35		154.68
1984	236.620	141.385		8.56	206.42		175.84
1985	201.470	100.637		8.78	76.69		7.19
1986	249.957	130.830		5.81	91.20		34.29
1987	189.755	118.235		7.04	80.46		114.71
1988	244.353	111.014		5.10	37.99		54.63
1989	230.244	113.742		3.62	74.68		11.93
1990	172.989	102.009		7.33	12.83		21.89
1991	139.206	74.863		2.73	5.95		163.80
1992	128.888	39.960	8.915	3.98	22.65		152.33
1993	168.202	16.477	8.575	4.79	50.32		79.55
1994	165.351	10.094	14.397	5.47	34.43		146.42
1995	230.109	9.413	10.489	5.25	37.21		150.45
1996	279.453	19.121	11.582	5.65	46.47		344.66
1997	310.997	18.837	14.709	8.06	40.68		352.94
1998	431.654	35.487	10.461	10.90	35.31		113.65
1999	404.755	17.033	12.956	7.26	19.40		110.38

2000	342.501	12.356	10.869	5.33	17.63		226.80
2001	327.783	43.889	8.423	4.94	18.37		189.69
2002	331.352	31.312	21.608	4.60	39.25		122.95
2003	307.358	22.158	11.354	4.02	47.95		159.81
2004	289.084	31.624	10.850	10.76	40.40		219.12
2005	202.093	13.270	9.992	11.47	35.42	88.18	230.41
2006	323.546	7.659	4.933	5.24	55.80	22.44	194.77
2007	569.328	15.027	8.571	5.16	77.99	20.30	58.24
2008	590.412	9.382	1.993	2.44	89.13		89.94

Table 3: continued

b) Landings and dead discards in 1000 pounds whole weight, as estimated by the BAM (i.e., model output).

	Landings (1000 lbs)				Discards (1000 lbs)		
	Commercial	Commercial			Commercial		
Year	Lines	Other	Headboat	MRFSS	Lines	Headboat	MRFSS
1976	262.12	170.91	26.55	1713.36	0.00	0.00	0.00
1977	208.43	134.67	35.45	1517.04	0.00	0.00	0.00
1978	257.53	151.64	30.38	1299.14	0.00	0.00	0.00
1979	234.95	134.88	57.28	1110.18	0.00	0.00	0.00
1980	185.02	103.54	49.77	968.90	0.00	0.00	0.00
1981	210.82	125.98	49.81	486.06	0.00	0.00	4.27
1982	205.78	113.12	37.32	793.97	0.00	0.00	4.58
1983	203.57	119.01	49.66	1163.97	0.00	0.00	42.81
1984	235.87	141.99	42.76	1033.00	0.00	6.73	50.51
1985	200.92	100.99	39.64	347.87	0.00	6.42	1.97
1986	250.03	131.15	25.53	403.06	0.00	5.95	10.19
1987	190.07	118.42	31.74	365.16	0.00	5.89	29.68
1988	244.10	111.01	22.20	165.21	0.00	6.79	16.25
1989	228.88	113.86	17.08	350.67	0.00	4.48	3.66
1990	172.95	102.14	39.34	68.88	0.00	3.01	6.42
1991	139.63	74.76	16.37	35.68	0.00	3.49	42.27
1992	129.29	39.95	33.00	198.81	2.82	8.58	48.21
1993	168.24	16.47	37.66	438.81	3.81	11.06	35.40
1994	165.10	10.09	38.36	266.67	6.12	9.30	62.14
1995	229.03	9.41	39.35	288.19	3.44	10.50	49.36
1996	277.91	19.11	43.78	387.29	4.17	15.91	123.80
1997	311.58	18.83	58.36	326.84	7.02	15.82	168.08
1998	433.52	35.47	78.09	272.43	5.42	9.54	58.88
1999	409.53	17.04	57.47	158.83	4.74	6.41	40.36
2000	348.42	12.36	47.64	163.93	3.99	7.80	83.35
2001	331.70	43.93	45.42	183.16	3.19	9.39	71.92
2002	331.50	31.32	41.45	386.64	7.97	11.25	45.16
2003	307.52	22.17	34.55	454.54	4.28	13.89	60.32
2004	289.41	31.65	87.33	360.59	3.69	19.17	74.72
2005	202.52	13.28	90.07	305.12	4.19	37.03	96.81
2006	325.09	7.66	39.29	462.48	2.62	11.90	103.46
2007	569.40	15.03	40.62	638.96	4.18	9.89	28.62
2008	589.30	9.38	21.61	806.81	0.66	8.53	29.82

Table 4: Fishing mortality estimates

Table 6.10. Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1976	0.100	0.233	0.338	0.379	0.395	0.404	0.411	0.415	0.417	0.418	0.419	0.419	0.419	0.418	0.418	0.418
1977	0.098	0.231	0.335	0.373	0.386	0.393	0.397	0.400	0.401	0.402	0.402	0.402	0.401	0.401	0.401	0.401
1978	0.109	0.249	0.356	0.396	0.410	0.418	0.423	0.427	0.428	0.429	0.429	0.428	0.428	0.428	0.427	0.427
1979	0.112	0.256	0.367	0.408	0.423	0.431	0.436	0.440	0.441	0.442	0.442	0.441	0.441	0.441	0.440	0.440
1980	0.107	0.248	0.358	0.399	0.413	0.421	0.426	0.430	0.431	0.432	0.432	0.432	0.432	0.431	0.431	0.431
1981	0.096	0.198	0.260	0.287	0.299	0.307	0.313	0.317	0.319	0.319	0.319	0.318	0.318	0.318	0.317	0.317
1982	0.124	0.274	0.379	0.422	0.439	0.449	0.457	0.461	0.464	0.465	0.465	0.464	0.464	0.464	0.463	0.463
1983	0.235	0.496	0.636	0.709	0.736	0.752	0.763	0.770	0.773	0.775	0.775	0.775	0.775	0.774	0.774	0.774
1984	0.215	0.662	0.938	0.997	1.026	1.054	1.076	1.091	1.100	1.104	1.106	1.106	1.106	1.106	1.105	1.105
1985	0.118	0.344	0.520	0.572	0.614	0.654	0.686	0.708	0.722	0.729	0.733	0.735	0.736	0.736	0.736	0.736
1986	0.159	0.421	0.611	0.679	0.735	0.790	0.834	0.864	0.883	0.893	0.899	0.901	0.902	0.902	0.902	0.902
1987	0.172	0.425	0.561	0.614	0.657	0.697	0.730	0.753	0.767	0.774	0.778	0.779	0.780	0.780	0.780	0.779
1988	0.137	0.286	0.369	0.425	0.481	0.535	0.579	0.609	0.628	0.639	0.644	0.647	0.648	0.649	0.649	0.649
1989	0.125	0.325	0.471	0.525	0.572	0.616	0.652	0.677	0.693	0.701	0.705	0.707	0.708	0.708	0.708	0.708
1990	0.111	0.208	0.240	0.268	0.295	0.322	0.344	0.359	0.368	0.372	0.374	0.375	0.375	0.375	0.375	0.375
1991	0.176	0.256	0.149	0.163	0.179	0.196	0.210	0.219	0.224	0.227	0.228	0.229	0.229	0.228	0.228	0.228
1992	0.065	0.086	0.127	0.269	0.324	0.336	0.333	0.328	0.323	0.320	0.318	0.316	0.315	0.314	0.313	0.313
1993	0.042	0.059	0.174	0.501	0.590	0.611	0.612	0.611	0.609	0.607	0.606	0.606	0.605	0.605	0.604	0.604
1994	0.077	0.099	0.141	0.314	0.390	0.411	0.413	0.412	0.411	0.411	0.410	0.410	0.409	0.409	0.409	0.409
1995	0.056	0.073	0.117	0.279	0.361	0.384	0.387	0.387	0.386	0.385	0.385	0.385	0.384	0.384	0.384	0.384
1996	0.083	0.108	0.158	0.360	0.448	0.472	0.474	0.473	0.471	0.470	0.470	0.469	0.469	0.468	0.468	0.468
1997	0.111	0.142	0.166	0.325	0.416	0.443	0.446	0.445	0.443	0.442	0.442	0.441	0.441	0.441	0.440	0.440
1998	0.072	0.095	0.131	0.284	0.396	0.428	0.431	0.429	0.427	0.425	0.424	0.423	0.423	0.422	0.422	0.422
1999	0.074	0.095	0.101	0.182	0.260	0.284	0.287	0.286	0.285	0.285	0.284	0.284	0.283	0.283	0.283	0.283
2000	0.112	0.140	0.120	0.163	0.215	0.232	0.234	0.233	0.233	0.232	0.232	0.231	0.231	0.231	0.231	0.231
2001	0.083	0.107	0.109	0.180	0.236	0.251	0.250	0.247	0.244	0.242	0.241	0.240	0.239	0.238	0.238	0.238
2002	0.053	0.070	0.109	0.256	0.324	0.341	0.342	0.340	0.338	0.336	0.335	0.334	0.334	0.333	0.333	0.333
2003	0.052	0.069	0.114	0.282	0.350	0.368	0.369	0.368	0.367	0.366	0.365	0.364	0.364	0.363	0.363	0.363
2004	0.047	0.063	0.110	0.252	0.315	0.332	0.332	0.330	0.329	0.327	0.326	0.325	0.325	0.324	0.324	0.324
2005	0.053	0.068	0.091	0.176	0.212	0.222	0.223	0.223	0.222	0.222	0.221	0.221	0.221	0.221	0.221	0.221
2006	0.058	0.074	0.090	0.188	0.235	0.248	0.250	0.250	0.250	0.250	0.249	0.249	0.249	0.249	0.249	0.249
2007	0.040	0.053	0.086	0.220	0.289	0.309	0.312	0.312	0.311	0.311	0.311	0.310	0.310	0.310	0.310	0.310
2008	0.042	0.055	0.095	0.251	0.318	0.337	0.340	0.340	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339

Table 5: Stock abundance and biomass

Table 6.2. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1976	387.1	361.1	169.0	542.5	160.0	34.5	24.6	11.7	12.5	4.5	2.2	1.1	0.6	0.3	0.2	0.3	1712.2
1977	370.0	259.6	227.3	99.6	313.2	91.9	19.8	14.2	6.8	7.2	2.6	1.3	0.7	0.4	0.2	0.3	1415.0
1978	454.7	248.5	163.8	134.5	57.9	181.4	53.4	11.6	8.3	4.0	4.3	1.5	0.7	0.4	0.2	0.3	1325.4
1979	411.1	302.2	154.0	94.8	76.3	32.7	102.8	30.4	6.6	4.8	2.3	2.4	0.9	0.4	0.2	0.3	1222.3
1980	226.9	272.3	185.9	88.2	53.2	42.6	18.3	57.7	17.2	3.7	2.7	1.3	1.4	0.5	0.2	0.3	972.6
1981	267.5	151.0	168.8	107.5	50.0	30.0	24.1	10.4	33.0	9.8	2.1	1.5	0.7	0.8	0.3	0.3	857.9
1982	451.5	180.0	98.5	107.6	68.0	31.6	19.0	15.3	6.6	21.1	6.3	1.4	1.0	0.5	0.5	0.4	1009.1
1983	492.1	295.3	108.8	55.7	59.5	37.4	17.3	10.5	8.5	3.7	11.6	3.5	0.8	0.6	0.3	0.5	1105.9
1984	357.9	288.1	142.9	47.6	23.1	24.3	15.2	7.0	4.3	3.4	1.5	4.7	1.4	0.3	0.2	0.3	922.3
1985	380.8	213.9	118.1	46.2	14.8	7.1	7.3	4.5	2.1	1.2	1.0	0.4	1.4	0.4	0.1	0.2	799.5
1986	263.1	250.7	120.5	58.1	22.0	6.8	3.2	3.2	1.9	0.9	0.5	0.4	0.2	0.6	0.2	0.1	732.4
1987	434.3	166.3	130.7	54.1	24.9	9.0	2.7	1.2	1.2	0.7	0.3	0.2	0.2	0.1	0.2	0.1	826.0
1988	296.0	270.8	86.4	61.7	24.7	11.0	3.9	1.1	0.5	0.5	0.3	0.1	0.1	0.1	0.0	0.1	757.3
1989	168.1	191.1	161.6	49.4	34.0	13.0	5.5	1.9	0.5	0.2	0.2	0.1	0.1	0.0	0.0	0.1	626.1
1990	138.3	109.9	109.7	83.4	24.7	16.4	6.0	2.5	0.8	0.2	0.1	0.1	0.1	0.0	0.0	0.0	492.3
1991	256.8	91.7	70.9	71.4	53.8	15.6	10.2	3.7	1.5	0.5	0.1	0.1	0.1	0.0	0.0	0.0	576.7
1992	462.6	159.5	56.4	50.6	51.2	38.3	11.1	7.2	2.6	1.1	0.4	0.1	0.0	0.0	0.0	0.0	841.2
1993	158.4	321.2	116.3	41.1	32.6	31.5	23.6	6.9	4.5	1.7	0.7	0.2	0.1	0.0	0.0	0.0	738.9
1994	257.9	112.5	240.6	80.9	21.0	15.4	14.7	11.1	3.3	2.2	0.8	0.3	0.1	0.0	0.0	0.0	760.9
1995	534.5	176.9	81.0	172.8	49.8	12.1	8.8	8.5	6.5	1.9	1.3	0.5	0.2	0.1	0.0	0.0	1054.9
1996	601.1	374.6	130.7	59.6	110.3	29.6	7.1	5.2	5.1	3.9	1.1	0.8	0.3	0.1	0.0	0.0	1329.4
1997	178.4	409.7	267.2	92.3	35.1	60.1	15.9	3.8	2.8	2.8	2.1	0.6	0.4	0.2	0.1	0.0	1071.5
1998	114.4	118.3	282.5	187.2	56.3	19.7	33.2	8.9	2.2	1.6	1.6	1.2	0.4	0.2	0.1	0.1	827.6
1999	271.7	78.9	85.5	205.0	118.8	32.3	11.1	18.8	5.1	1.2	0.9	0.9	0.7	0.2	0.1	0.1	831.2
2000	281.6	186.9	57.0	63.9	144.2	78.1	20.9	7.2	12.4	3.3	0.8	0.6	0.6	0.5	0.1	0.2	858.4
2001	323.4	186.5	129.1	41.8	45.8	99.1	53.3	14.4	5.0	8.6	2.3	0.6	0.4	0.4	0.3	0.2	911.3
2002	412.1	220.5	133.2	95.7	29.5	30.8	66.4	36.1	9.9	3.5	5.9	1.6	0.4	0.3	0.3	0.4	1046.5
2003	468.7	289.5	163.3	98.8	62.5	18.2	18.9	41.0	22.6	6.2	2.2	3.7	1.0	0.3	0.2	0.4	1197.3
2004	884.3	329.5	214.7	120.5	62.8	37.5	10.8	11.3	24.9	13.7	3.8	1.3	2.3	0.6	0.2	0.4	1718.7
2005	500.5	624.8	245.9	159.1	79.0	39.1	23.2	6.7	7.1	15.7	8.7	2.4	0.8	1.5	0.4	0.3	1715.3
2006	125.2	351.5	463.7	185.6	112.5	54.4	26.9	16.1	4.7	5.0	11.1	6.1	1.7	0.6	1.0	0.5	1366.9
2007	179.8	87.5	259.5	350.6	129.8	75.8	36.6	18.2	11.0	3.2	3.4	7.6	4.2	1.2	0.4	1.1	1170.0
2008	426.5	128.0	66.0	196.9	237.5	82.8	47.9	23.3	11.7	7.1	2.1	2.2	4.9	2.7	0.8	1.0	1241.3
2009	355.8	302.9	96.2	49.6	129.2	147.2	50.9	29.7	14.5	7.3	4.4	1.3	1.4	3.1	1.7	1.1	1196.6

Table 6.5. Estimated biomass at age (mt) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1976	179.2	401.2	329.5	1562.5	611.6	162.9	136.2	73.7	86.6	33.2	17.3	9.3	5.2	3.0	1.7	2.6	3615.6
1977	171.2	288.5	443.2	287.0	1197.2	433.7	109.9	88.9	47.1	54.0	20.4	10.5	5.6	3.1	1.8	2.5	3164.6
1978	210.4	276.1	319.4	387.3	221.1	856.3	295.9	72.7	57.6	29.9	33.7	12.6	6.5	3.4	1.9	2.6	2787.4
1979	190.3	335.8	300.3	273.1	291.7	154.4	569.7	190.7	45.9	35.6	18.1	20.2	7.5	3.8	2.0	2.6	2442.0
1980	105.0	302.6	362.5	254.1	203.3	201.2	101.5	362.4	118.8	28.0	21.3	10.7	12.0	4.4	2.2	2.7	2092.8
1981	123.8	167.8	329.2	309.6	191.0	141.6	133.5	65.2	228.1	73.1	16.9	12.8	6.4	7.1	2.6	2.9	1811.6
1982	208.9	200.0	192.0	309.9	260.0	149.0	105.3	96.1	45.9	157.2	49.6	11.3	8.5	4.3	4.7	3.6	1806.3
1983	227.7	328.1	212.1	160.5	227.5	176.5	96.1	65.6	58.6	27.4	92.1	28.7	6.6	4.9	2.4	4.7	1719.6
1984	165.6	320.1	278.6	137.1	88.4	114.7	84.1	44.1	29.4	25.6	11.8	39.1	12.2	2.8	2.1	2.9	1358.6
1985	176.2	237.7	230.3	133.1	56.7	33.4	40.4	28.2	14.3	9.3	7.9	3.6	11.9	3.7	0.8	1.5	989.0
1986	121.8	278.5	234.9	167.3	84.1	32.3	17.5	20.0	13.4	6.6	4.2	3.5	1.6	5.2	1.6	1.0	993.5
1987	201.0	184.8	254.8	155.8	95.0	42.4	14.8	7.5	8.2	5.3	2.5	1.6	1.3	0.6	1.9	0.9	978.4
1988	137.0	300.9	168.5	177.6	94.4	51.9	21.4	7.0	3.4	3.6	2.3	1.1	0.7	0.5	0.2	1.2	971.6
1989	77.8	212.4	315.2	142.4	129.9	61.4	30.7	11.8	3.7	1.7	1.8	1.1	0.5	0.3	0.3	0.7	991.6
1990	64.0	122.1	213.9	240.3	94.3	77.2	33.5	15.7	5.8	1.8	0.8	0.8	0.5	0.2	0.1	0.4	871.5
1991	118.9	101.9	138.3	205.7	205.8	73.8	56.5	23.4	10.6	3.8	1.1	0.5	0.5	0.3	0.1	0.3	941.6
1992	214.1	177.3	110.0	145.6	195.7	181.0	61.3	45.1	18.1	8.0	2.8	0.8	0.4	0.4	0.2	0.3	1161.3
1993	73.3	356.9	226.8	118.3	124.6	148.9	130.8	43.3	31.4	12.4	5.4	1.9	0.6	0.2	0.2	0.4	1275.5
1994	119.4	125.0	469.2	232.9	80.2	72.7	81.7	69.8	22.7	16.2	6.3	2.7	1.0	0.3	0.1	0.3	1300.5
1995	247.4	196.6	157.9	497.8	190.4	57.2	48.7	53.2	44.7	14.3	10.0	3.9	1.7	0.6	0.2	0.3	1524.8
1996	278.2	416.2	254.9	171.6	421.6	139.7	39.4	32.6	35.0	28.8	9.1	6.3	2.4	1.0	0.4	0.3	1837.3
1997	82.6	455.2	521.0	265.9	134.1	283.6	88.1	24.1	19.6	20.7	16.8	5.2	3.6	1.4	0.6	0.3	1922.8
1998	52.9	131.4	551.0	539.1	215.1	93.1	184.1	55.5	15.0	11.9	12.4	9.9	3.1	2.1	0.8	0.5	1877.9
1999	125.7	87.6	166.7	590.4	454.1	152.3	61.3	117.8	35.0	9.2	7.3	7.5	6.0	1.9	1.3	0.8	1824.9
2000	130.3	207.7	111.1	184.0	551.2	368.5	115.9	45.3	85.6	24.9	6.5	5.0	5.2	4.1	1.3	1.4	1848.2
2001	149.7	207.3	251.7	120.4	175.0	467.8	295.4	90.3	34.7	64.3	18.4	4.7	3.7	3.8	3.0	1.9	1892.0
2002	190.7	245.0	259.8	275.7	112.6	145.5	367.9	226.4	68.2	25.8	47.0	13.3	3.4	2.7	2.7	3.4	1990.3
2003	216.9	321.6	318.5	284.5	238.9	85.7	104.5	257.2	155.9	46.1	17.2	31.0	8.8	2.3	1.7	3.9	2094.8
2004	409.3	366.2	418.7	347.0	240.2	177.1	60.0	71.1	172.2	102.4	29.8	11.0	19.8	5.6	1.4	3.5	2435.3
2005	231.6	694.3	479.4	458.3	302.0	184.4	128.5	42.3	49.4	117.5	68.8	19.8	7.3	13.1	3.7	3.2	2803.6
2006	57.9	390.6	904.3	534.7	430.1	257.0	149.2	101.1	32.8	37.5	87.7	50.8	14.6	5.4	9.6	4.9	3068.2
2007	83.2	97.2	506.0	1009.9	496.0	358.0	202.6	114.4	76.2	24.2	27.2	63.0	36.5	10.4	3.8	10.1	3118.8
2008	197.4	142.2	128.6	567.1	907.6	390.9	265.6	146.0	81.0	52.9	16.5	18.4	42.5	24.5	7.0	9.1	2997.3
2009	164.7	336.6	187.6	142.9	493.9	695.0	282.1	186.1	100.6	54.7	35.1	10.8	12.1	27.7	15.8	10.2	2756.1

Table 6: Spawning stock biomass and recruitment

Year	SSB (mt)	Recruits (1000 fish)
1976	2158	387.1
1977	2002	370.0
1978	1749	454.7
1979	1492	411.1
1980	1290	226.9
1981	1152	267.5
1982	1054	451.5
1983	847	492.1
1984	572	357.9
1985	415	380.8
1986	418	263.1
1987	391	434.3
1988	427	296.0
1989	475	168.1
1990	488	138.3
1991	552	256.8
1992	623	462.6
1993	683	158.4
1994	717	257.9
1995	809	534.5
1996	920	601.1
1997	1057	178.4
1998	1153	114.4
1999	1200	271.7
2000	1247	281.6
2001	1260	323.4
2002	1248	412.1
2003	1240	468.7
2004	1306	884.3
2005	1589	500.5
2006	1944	125.2
2007	2125	179.8
2008	2051	426.5

Figure 1: Landings by fishery sector

Figure 6.12. Observed (open circles) and estimated (line, solid circles) commercial lines landings (1000 lb whole weight).

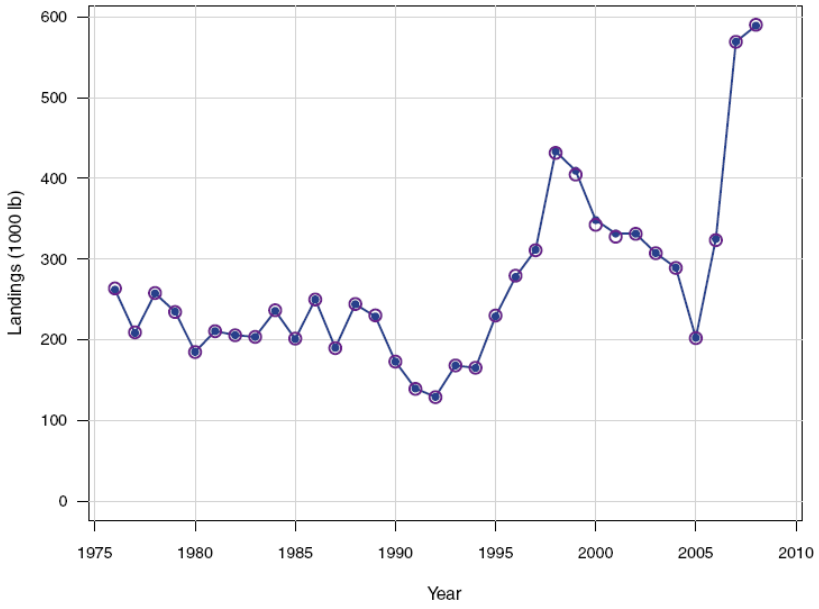


Figure 6.13. Observed (open circles) and estimated (line, solid circles) commercial other (1000 lb whole weight).

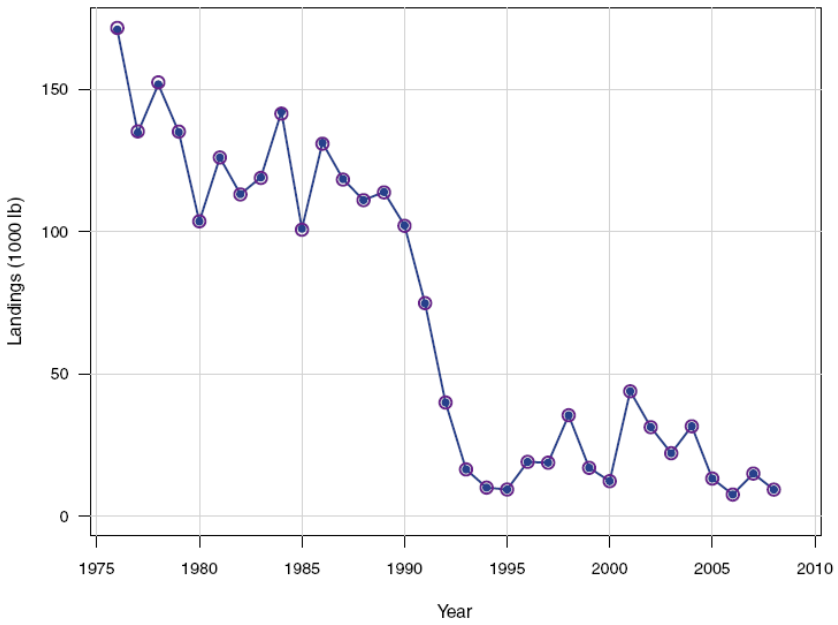


Figure 1: continued

Figure 6.14. Observed (open circles) and estimated (line, solid circles) headboat landings (1000 fish).

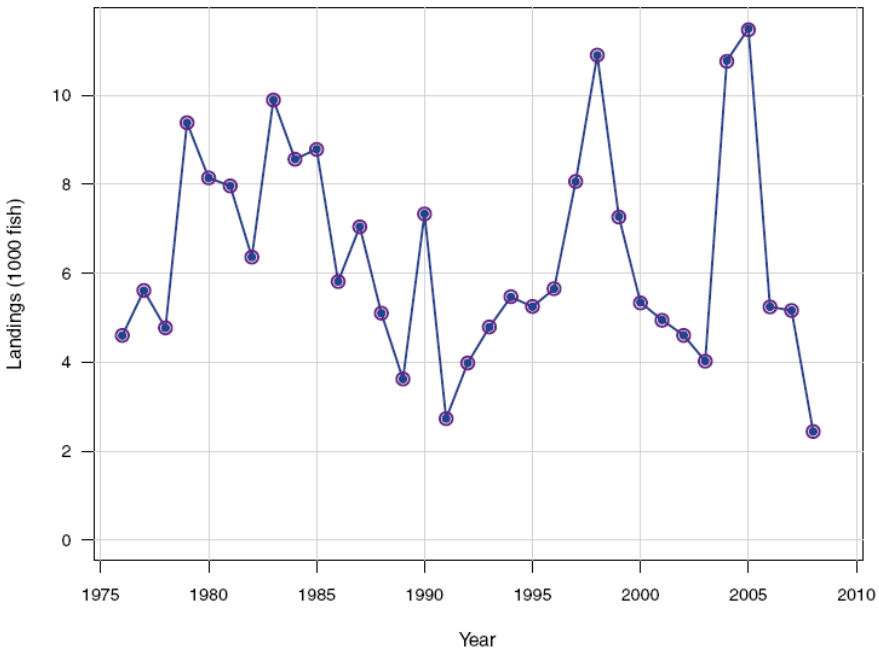


Figure 6.15. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 fish). In years without observations, values were predicted using average F (see §III for details).

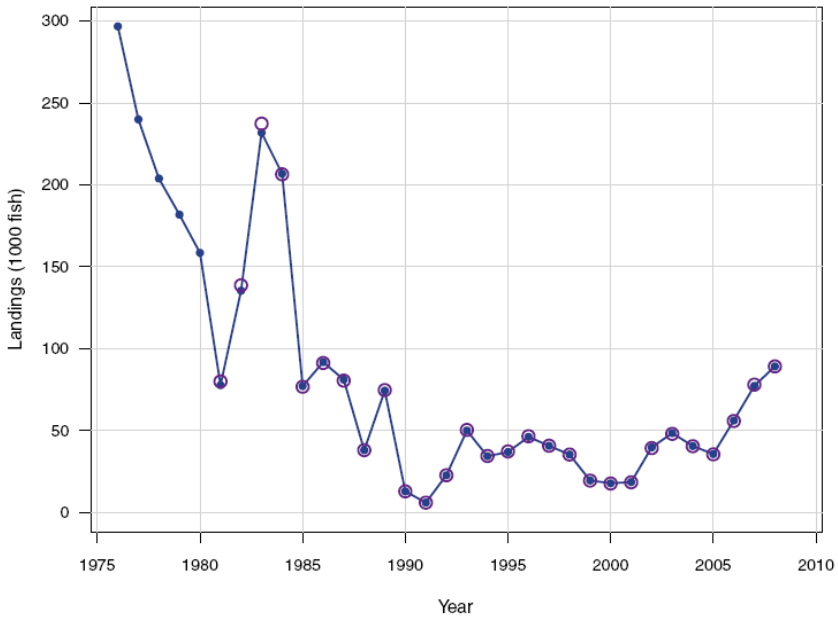


Figure 2: Discards by fishery sector

Figure 6.16. Observed (open circles) and estimated (line, solid circles) commercial handline discard mortalities (1000 dead fish). In years without observations, values were predicted using average F (see §III for details).

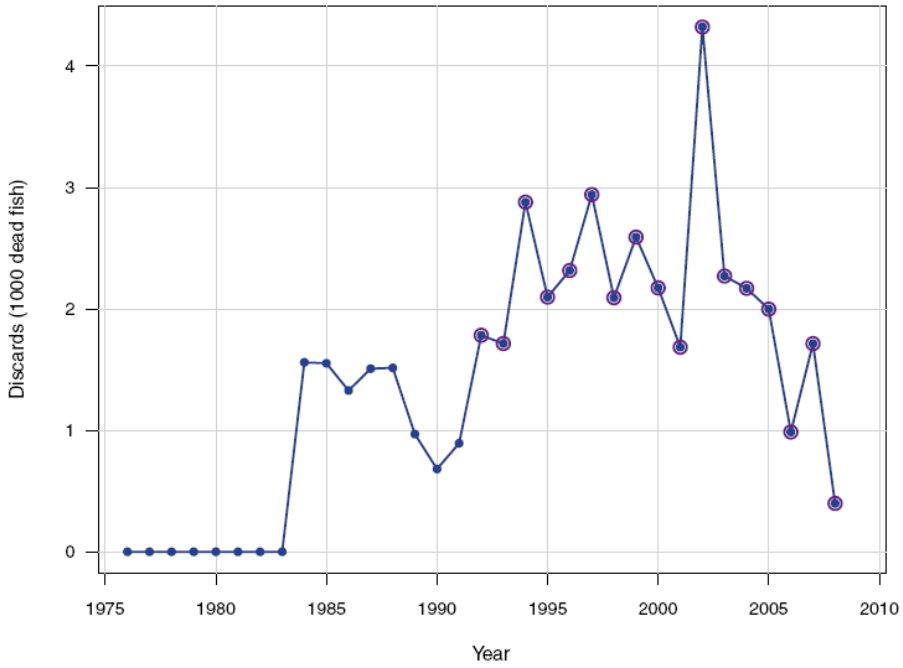


Figure 6.17. Observed (open circles) and estimated (line, solid circles) headboat discard mortalities (1000 dead fish). In years without observations, values were predicted using average F (see §III for details).

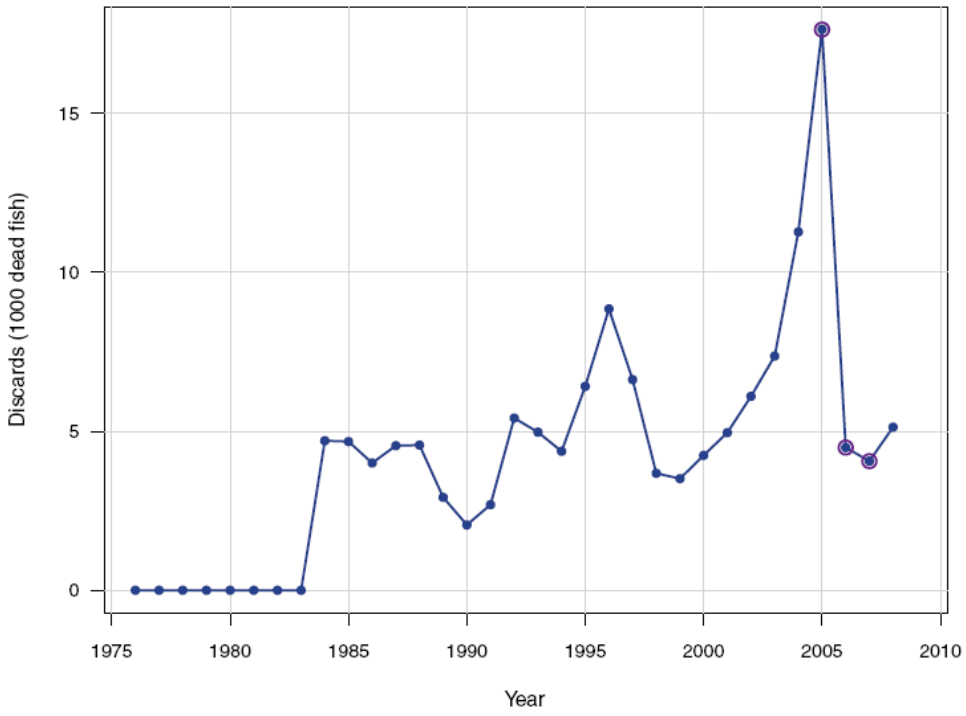


Figure 2: continued

Figure 6.18. Observed (open circles) and estimated (line, solid circles) general recreational discard mortalities (1000 dead fish).

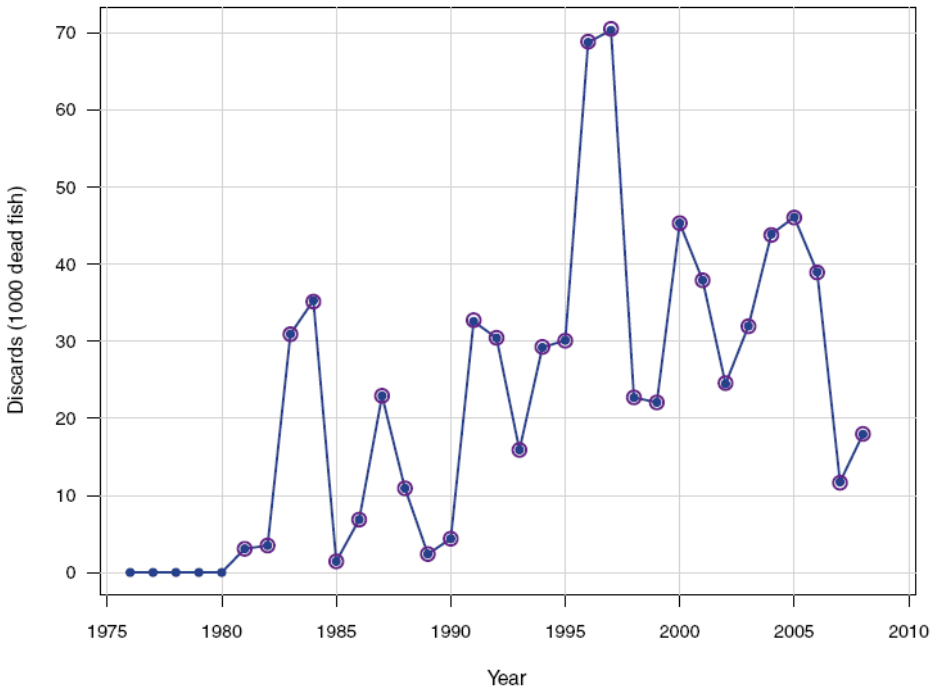


Figure 3: Fishing Mortality

Figure 6.33. Estimated fully selected fishing mortality rate (per year) by fishery. cl refers to commercial lines, co to commercial other, hb to headboat, rec to general recreational, cl.D to commercial discard mortalities, hb.D to headboat discard mortalities, and rec.D to general recreational discard mortalities.

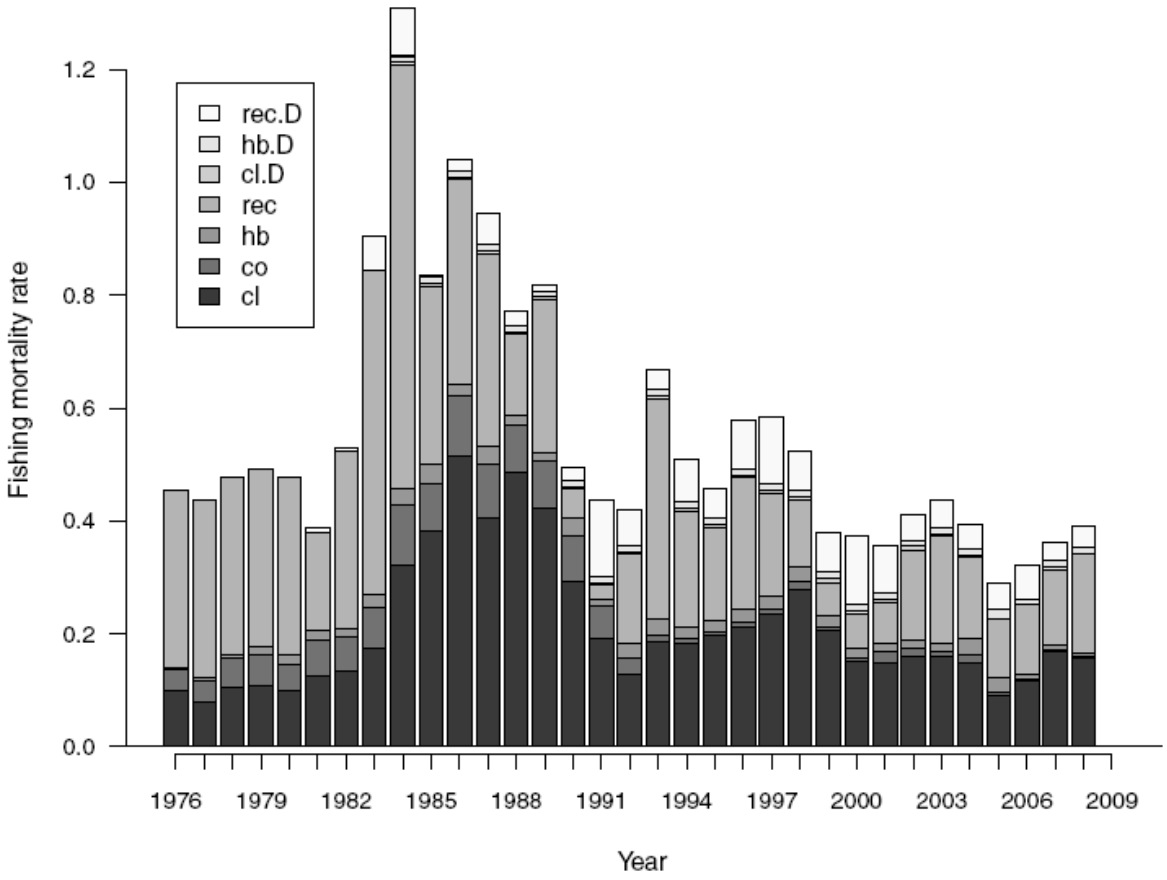


Figure 4: Stock Biomass

Figure 6.25. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicate B_{MSY}. Bottom panel: Estimated spawning biomass (total mature biomass) at time of peak spawning.

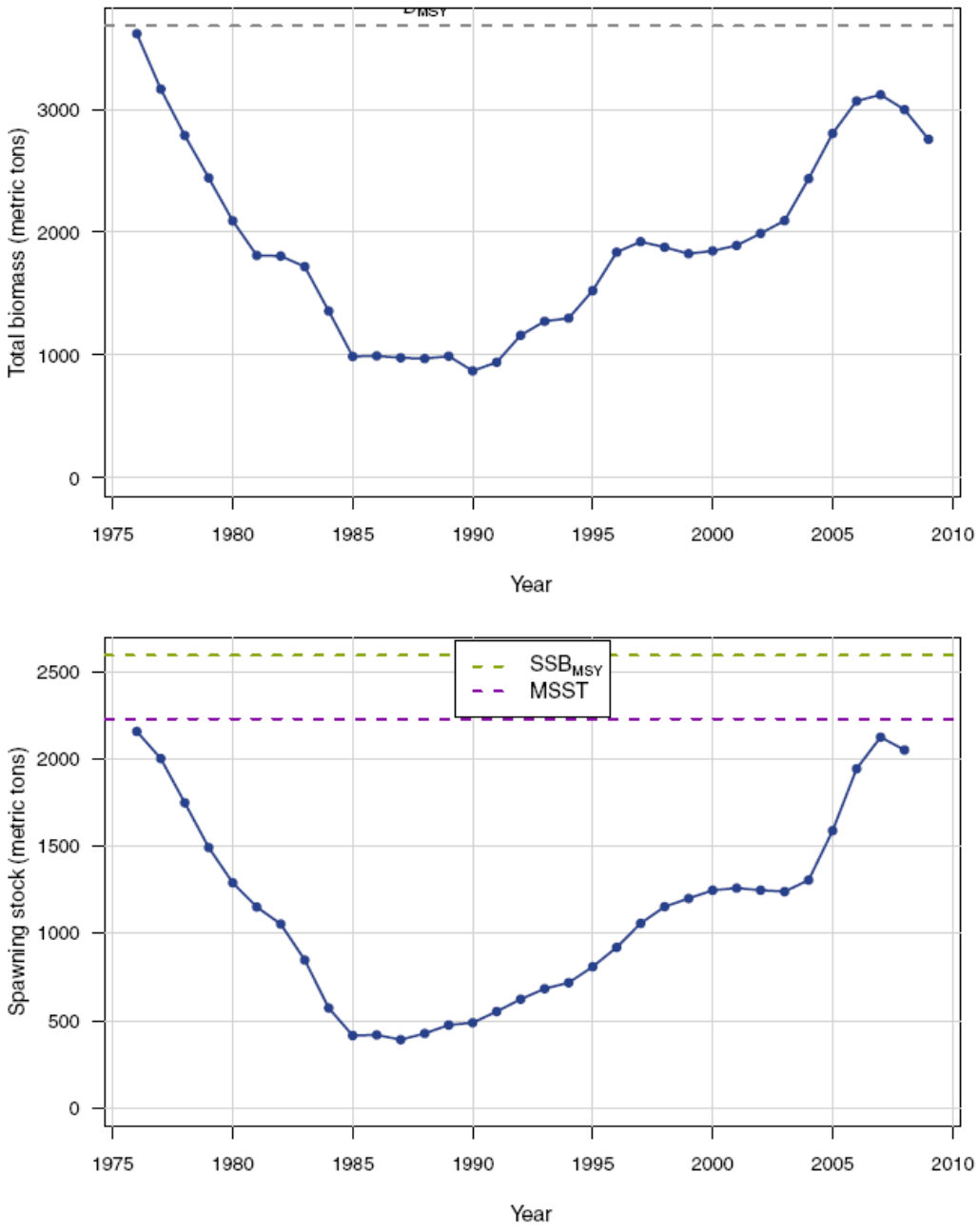


Figure 5: Abundance Indices

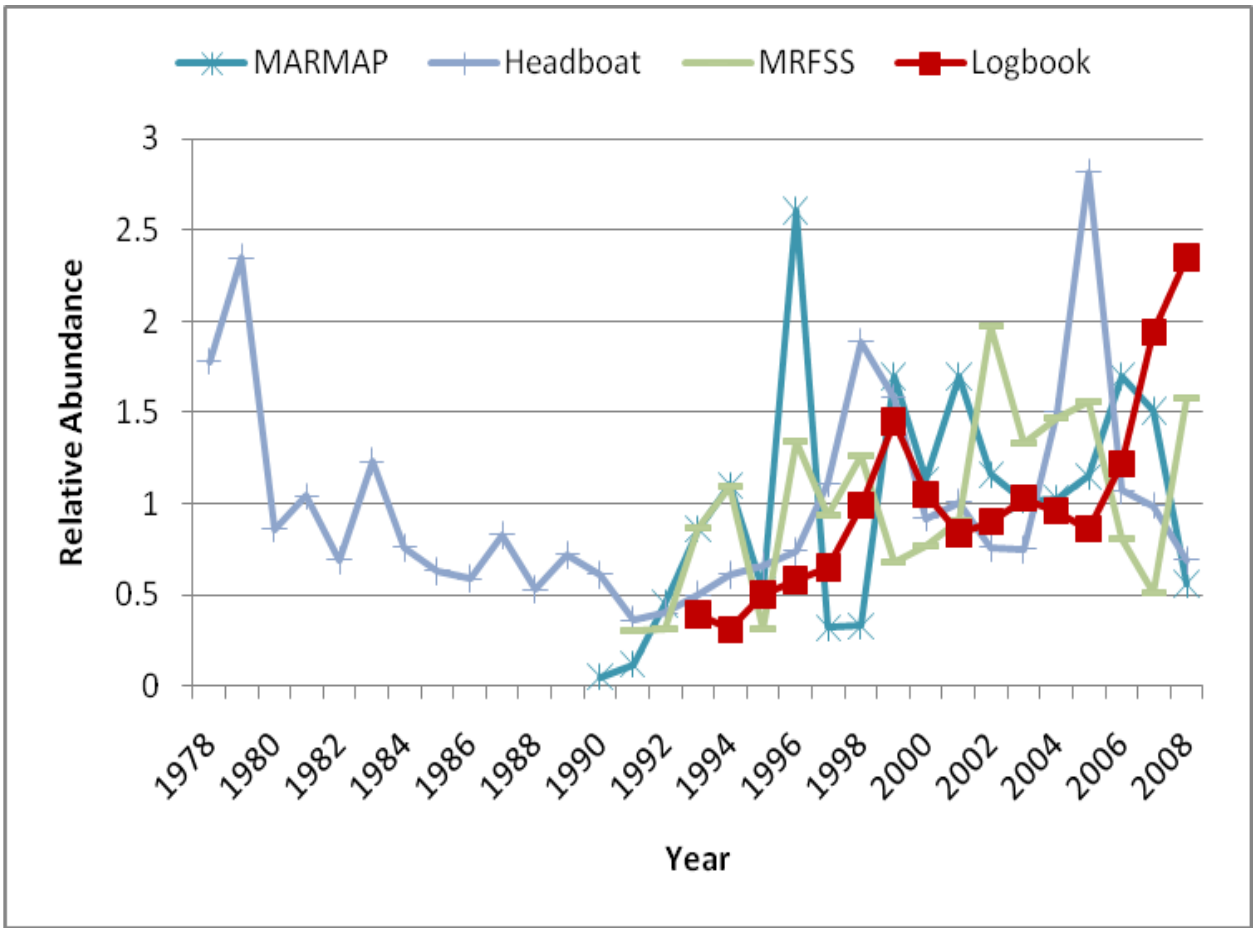
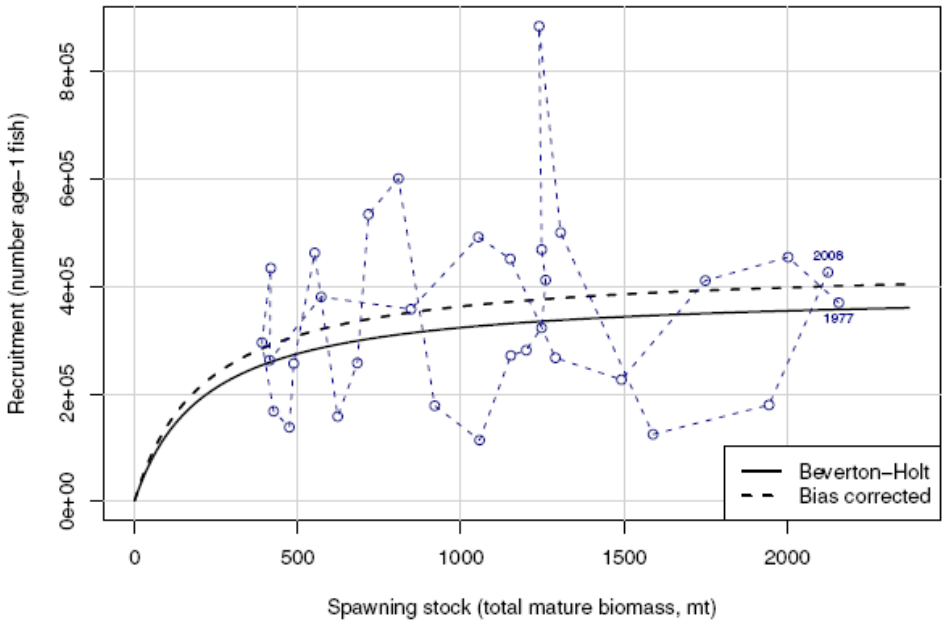


Figure 6: Stock-Recruitment

Figure 6.37. Top panel: Beverton-Holt spawner-recruit curves, with and without lognormal bias correcti
Bottom panel: log of recruits (number age-1 fish) per spawner (total mature biomass) as a function of spawne
Years on each panel indicate year of recruitment generated from spawning biomass one year prior.



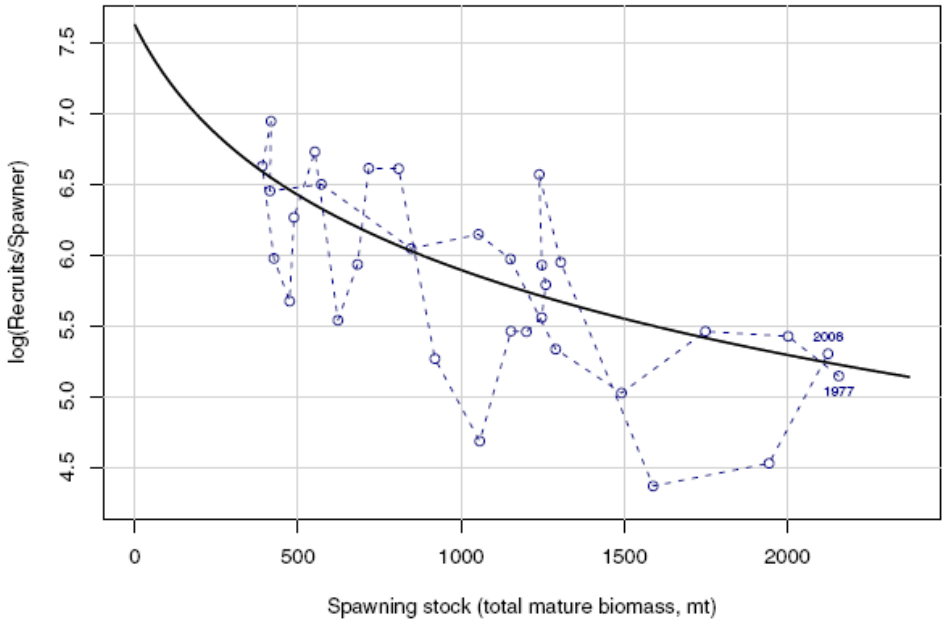


Figure 7: Yield per Recruit

Figure 6.40. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the y% levels provide $F_{y\%}$. Both curves are based on average selectivity from the end of the assessment period.

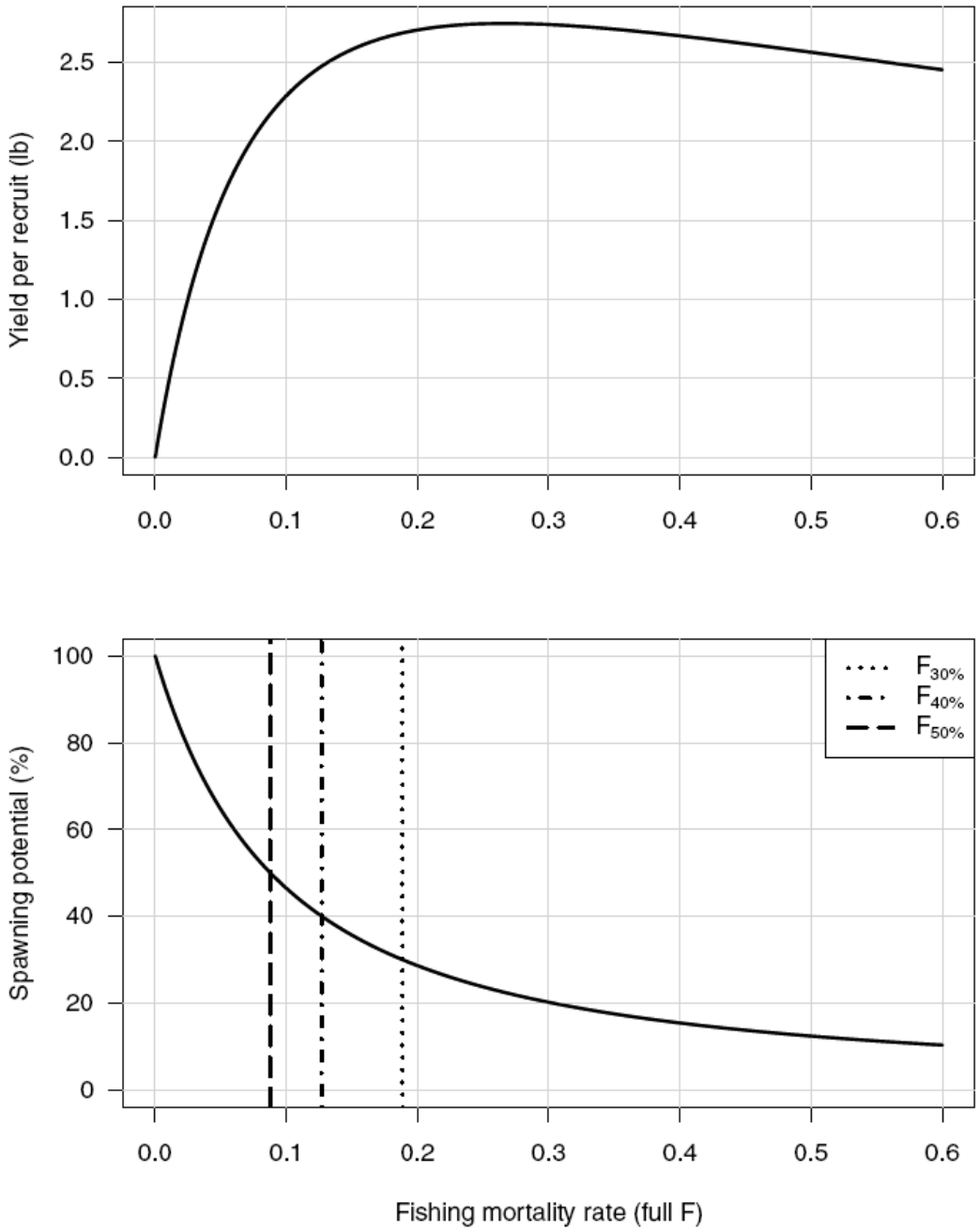


Figure 8: Stock Status and Control Rule

Figure 6.44. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5^{th} and 95^{th} percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (MSST). *Bottom panel: F relative to* F_{MSY}.

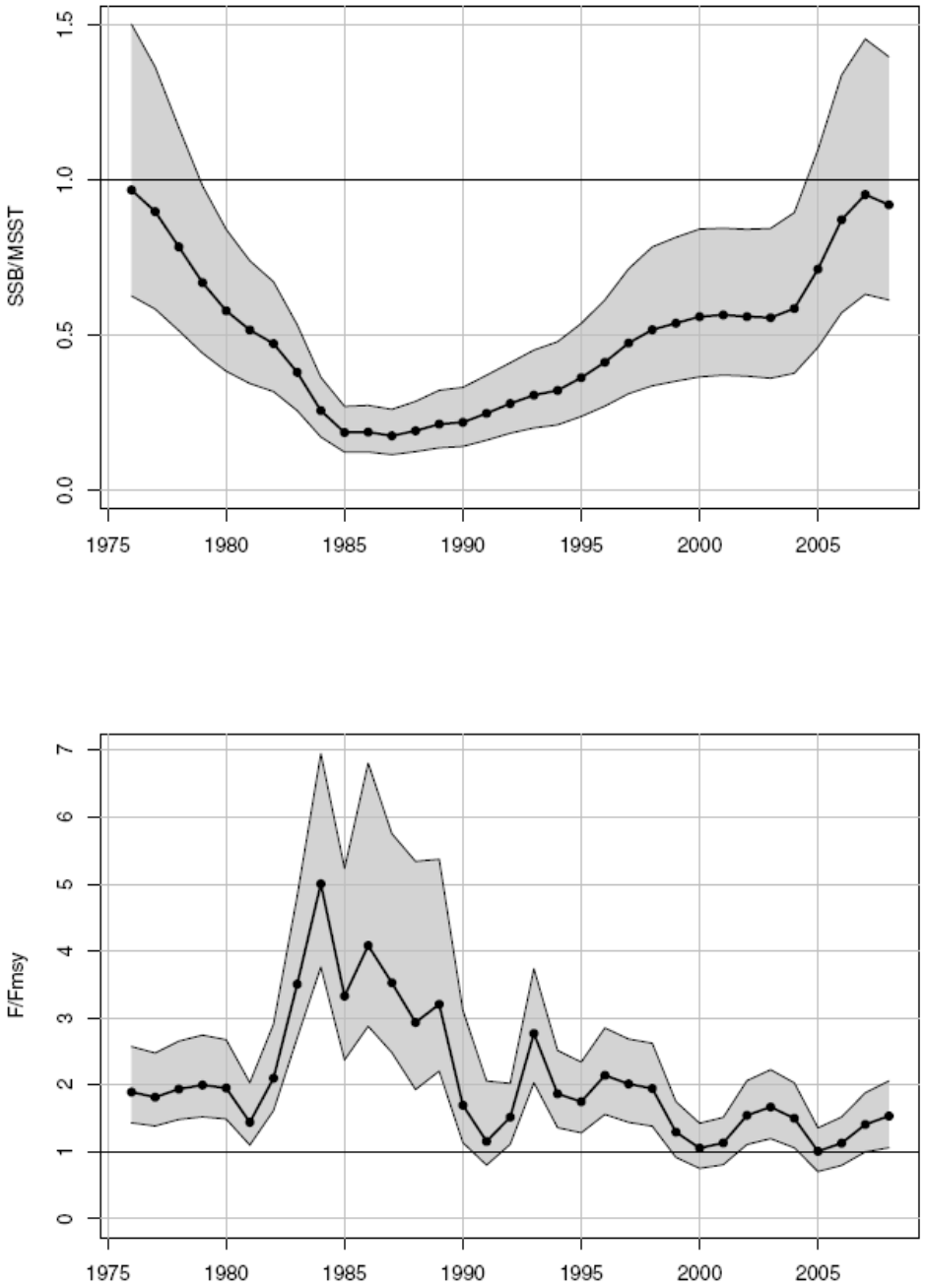


Figure 8: continued

Figure 6.50. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.

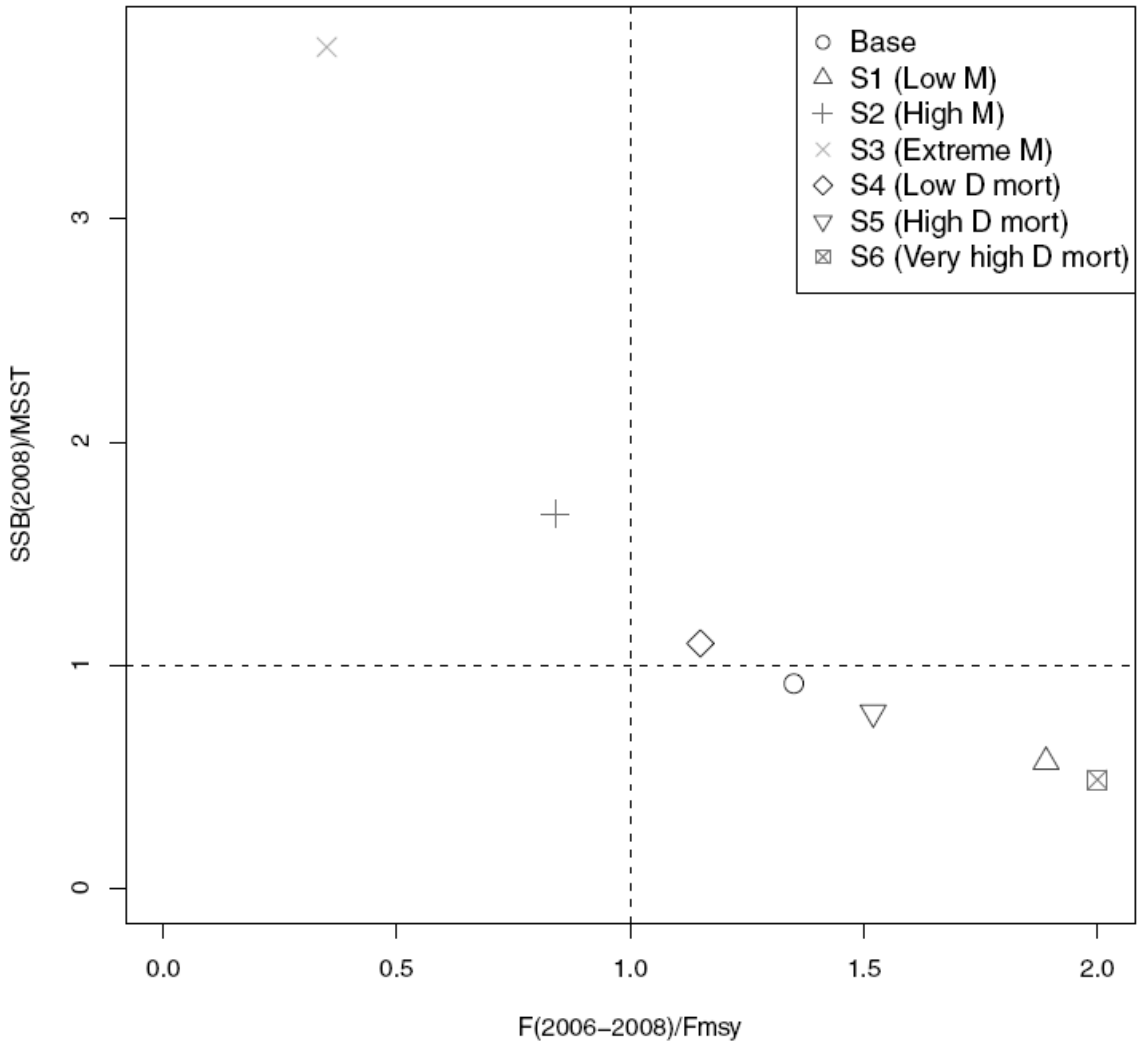


Figure 9: Projections

Figure 6.51. Projection results under scenario 1—fishing mortality rate fixed at F = 0. Curve represents the proportion of projection replicates for which SSB(mid-year) has reached at least SSB_{MSY} = 2592 *mt.*

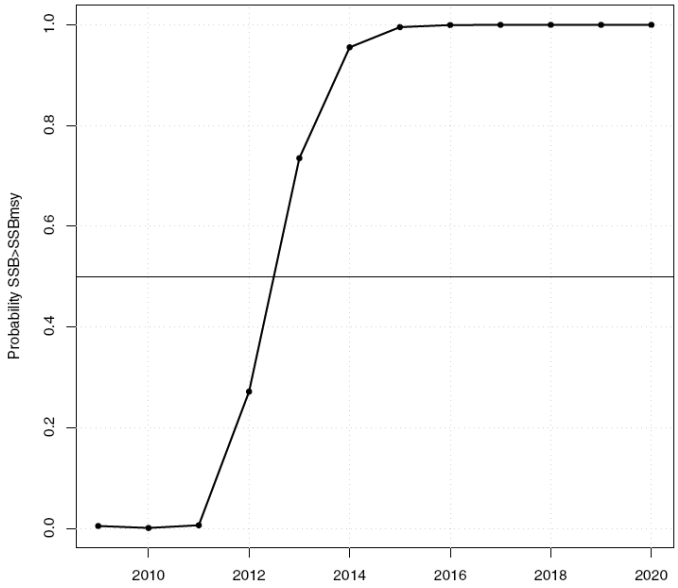


Figure 6.52. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{current}$. *Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

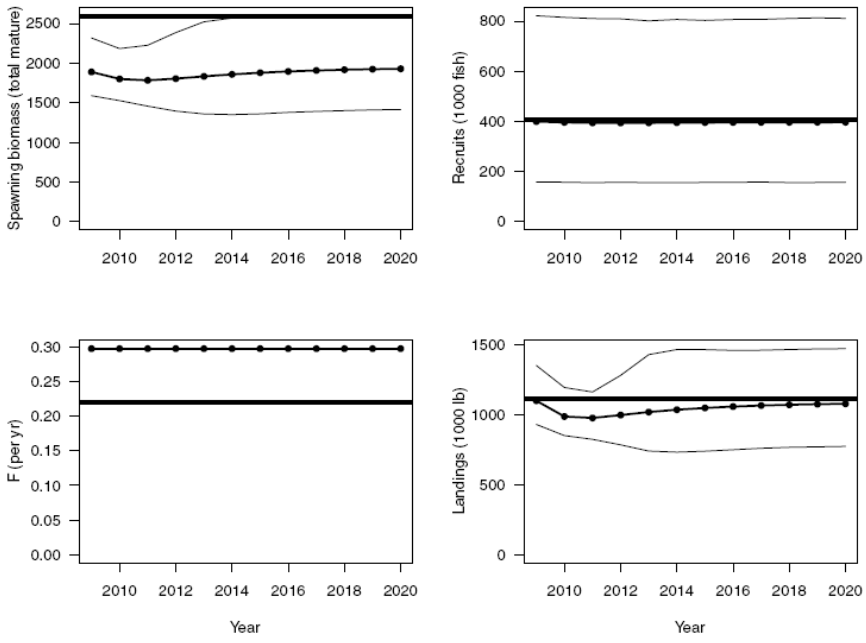


Figure 9: continued

Figure 6.53. Projection results under scenario 3—fishing mortality rate fixed at F = $F_{current}$ in 2009 and F = 75%$F_{current}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

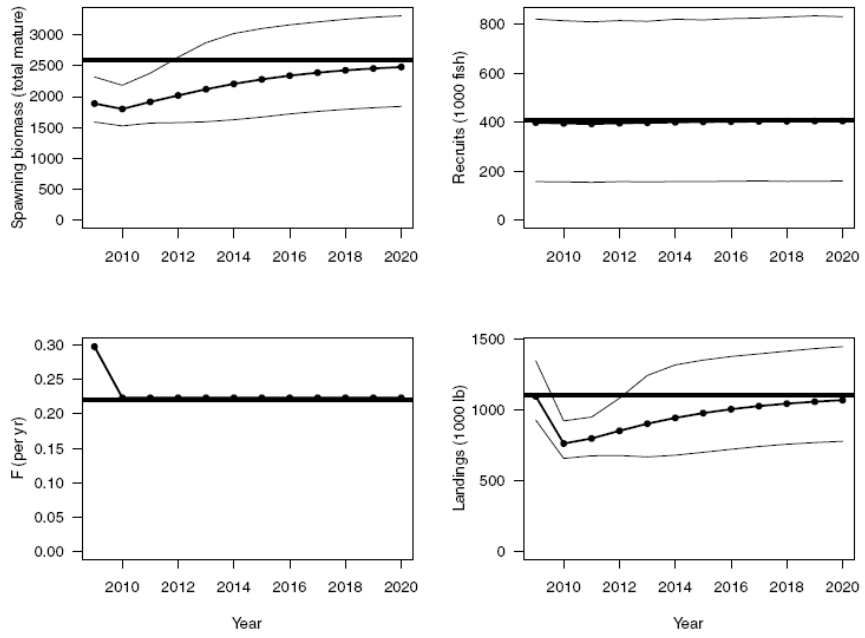


Figure 6.54. Projection results under scenario 4—fishing mortality rate fixed at F = $F_{current}$ in 2009 and F = 50%$F_{current}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thi lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-relate quantities. Spawning stock (SSB) is at mid-year.

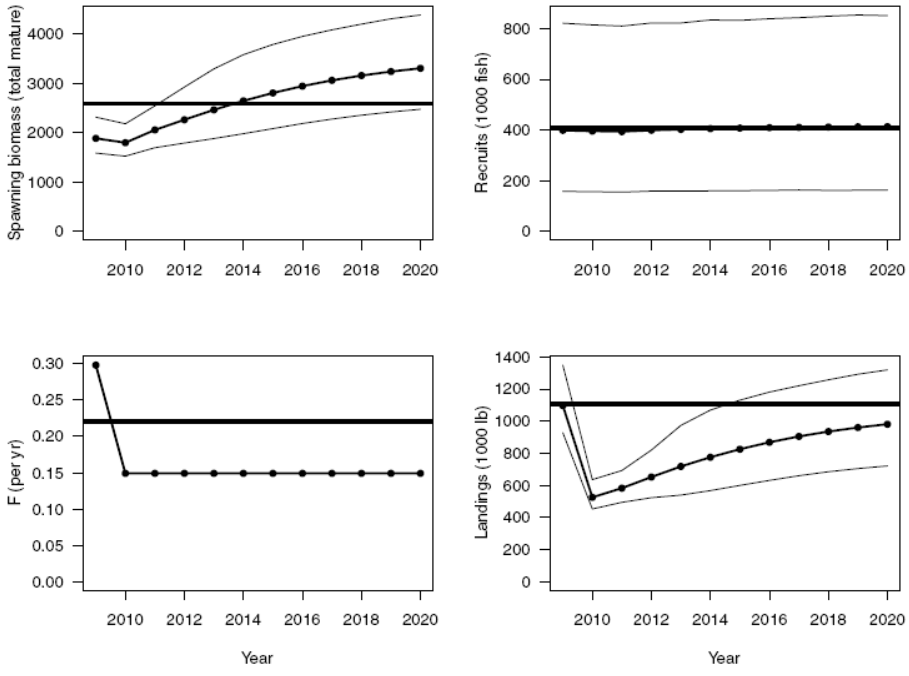


Figure 9: continued

Figure 6.55. Projection results under scenario 5—fishing mortality rate fixed at F = $F_{current}$ in 2009 and F = 25%$F_{current}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

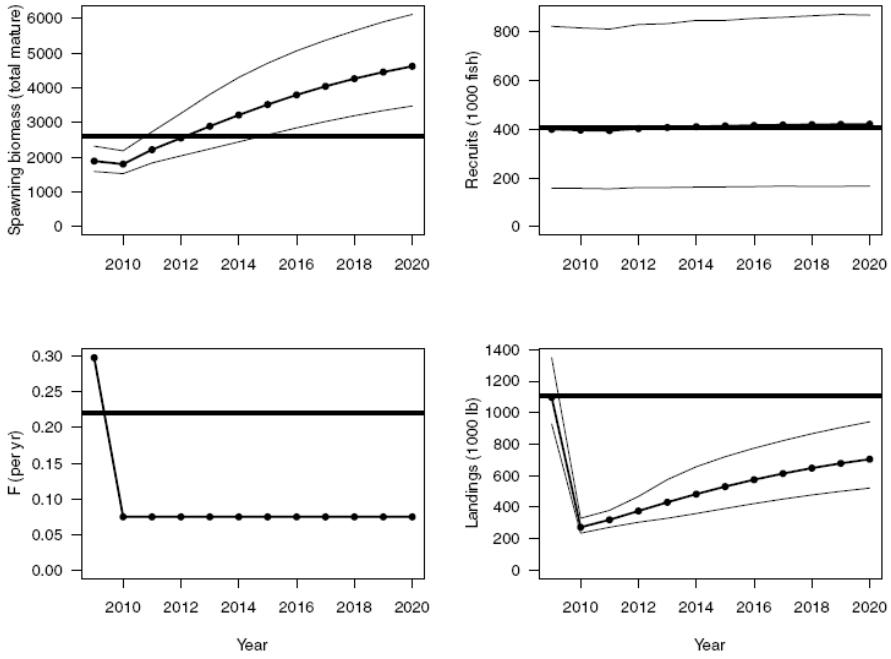


Figure 6.56. Projection results under scenario 6—fishing mortality rate fixed at F = 65%F_{MSY}. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

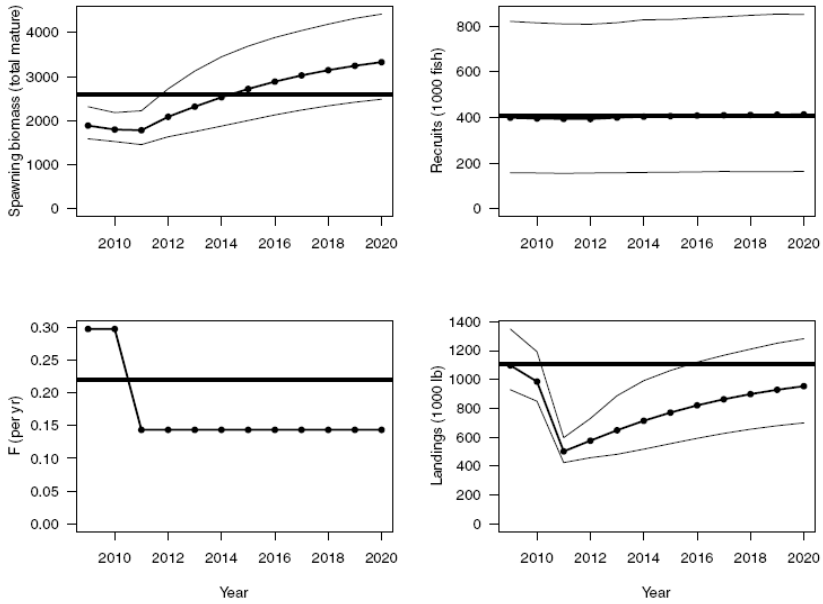


Figure 9: continued

Figure 6.57. Projection results under scenario 7—fishing mortality rate fixed at F = 75%F_{MSY}. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

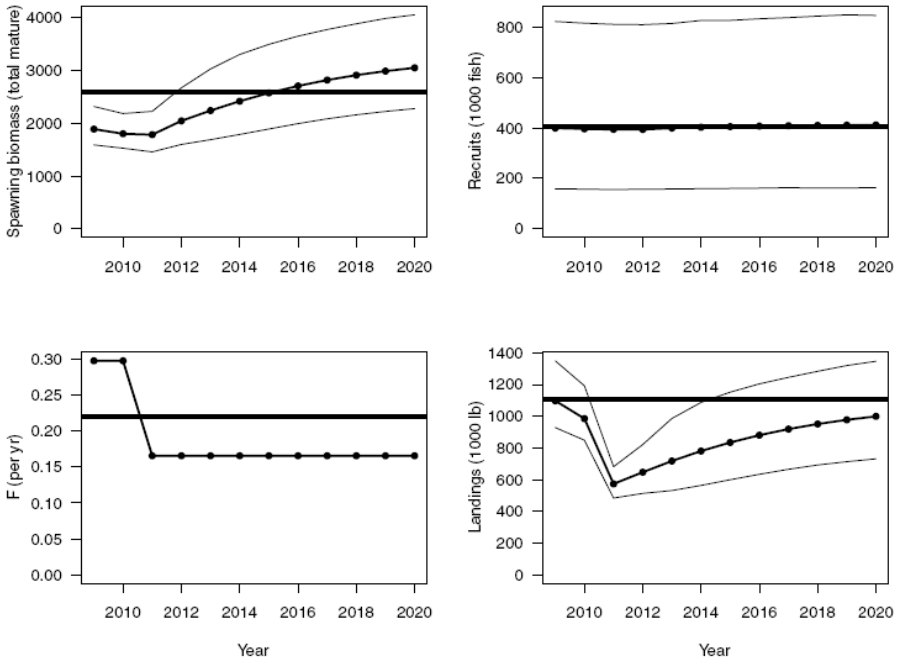


Figure 6.58. Projection results under scenario 8—fishing mortality rate fixed at F = 85%F_{MSY}. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

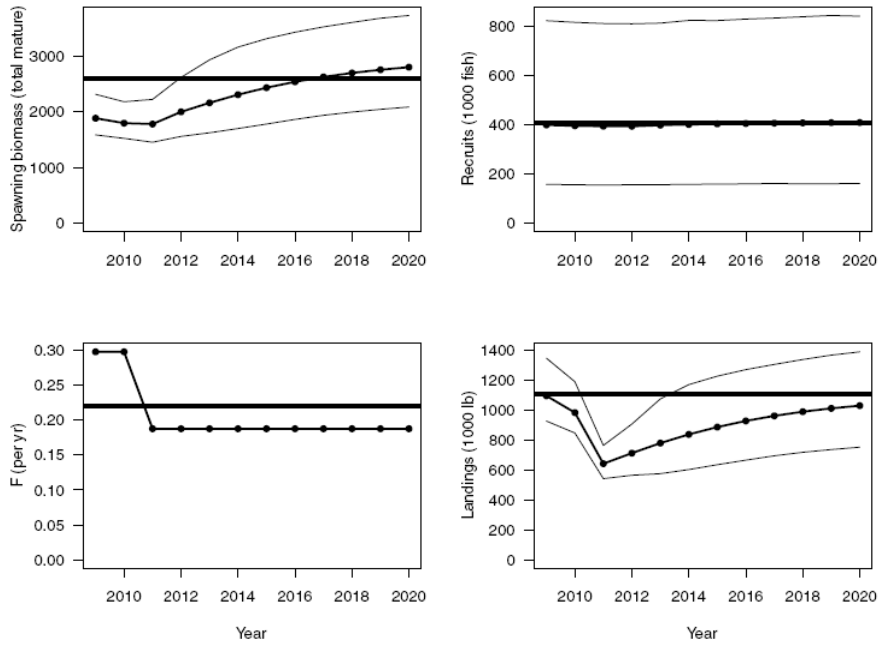


Figure 9: continued

Figure 6.59. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{MSY}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

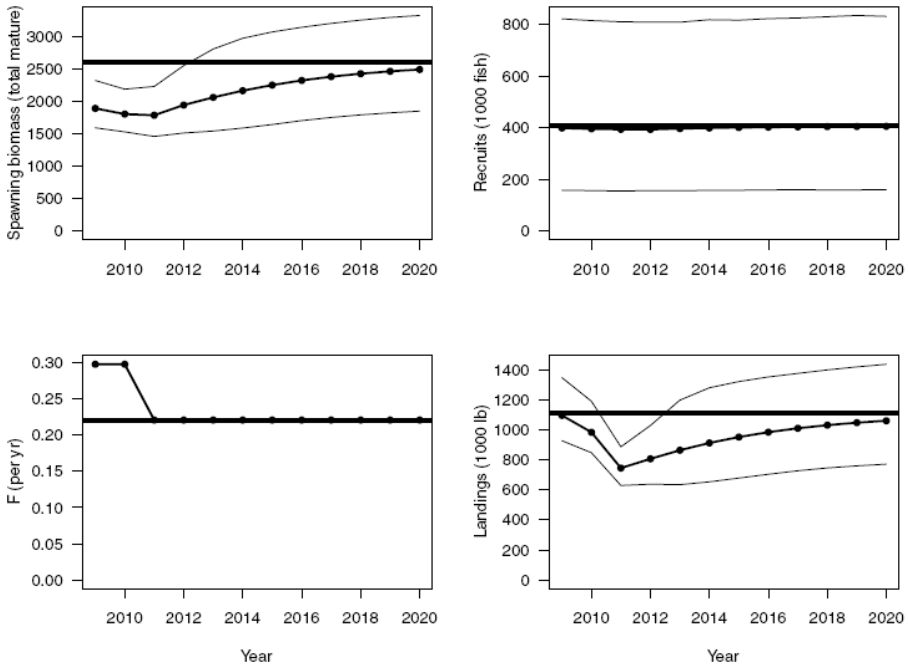


Figure 6.60. Projection results under scenario 10—fishing mortality rate fixed at $F = F_{rebuild}$, after an initialization period with $F = F_{current}$ in 2009 and 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

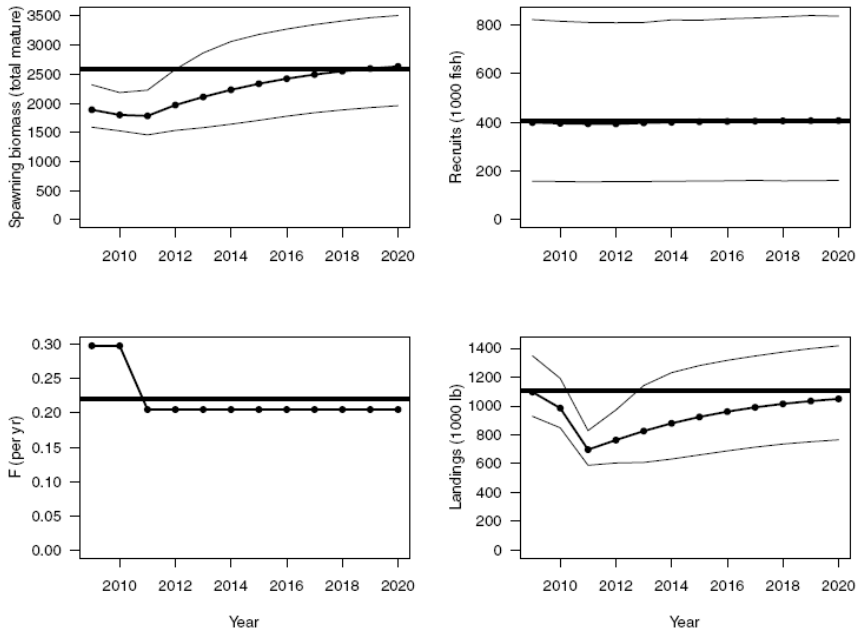


Figure 9: continued

Figure 6.61. Projection results under scenario 11—fishing mortality rate fixed at $F = F_{rebuild}$, after an initialization period with $F = F_{current}$ in 2009 and $F = 75\%F_{current}$ 2010. Expected values represented by dotted solid lines and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

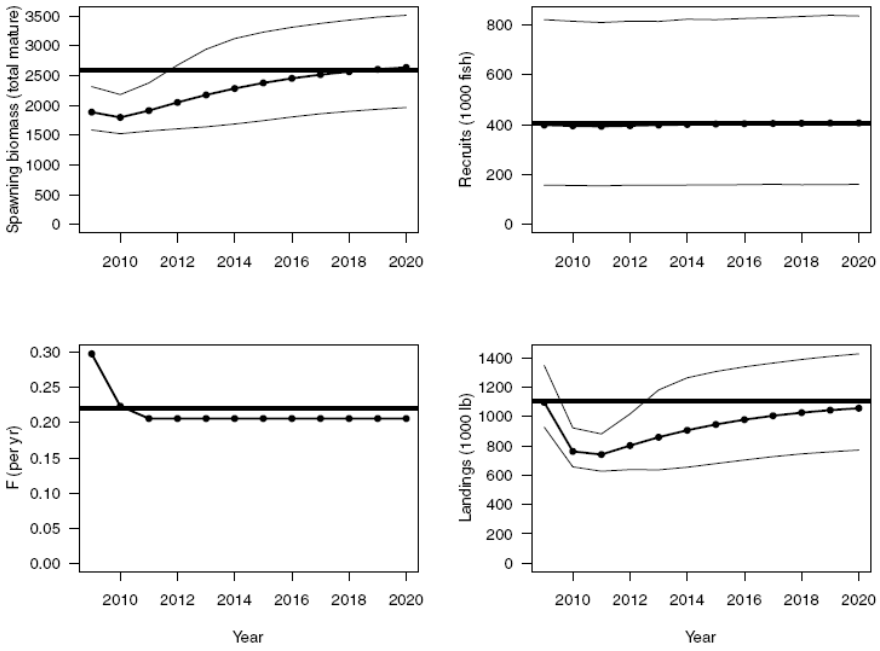


Figure 6.62. Projection results under scenario 12—fishing mortality rate fixed at $F = F_{rebuild}$, after an initialization period with $F = F_{current}$ in 2009 and $F = 50\%F_{current}$ 2010. Expected values represented by dotted solid lines and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.

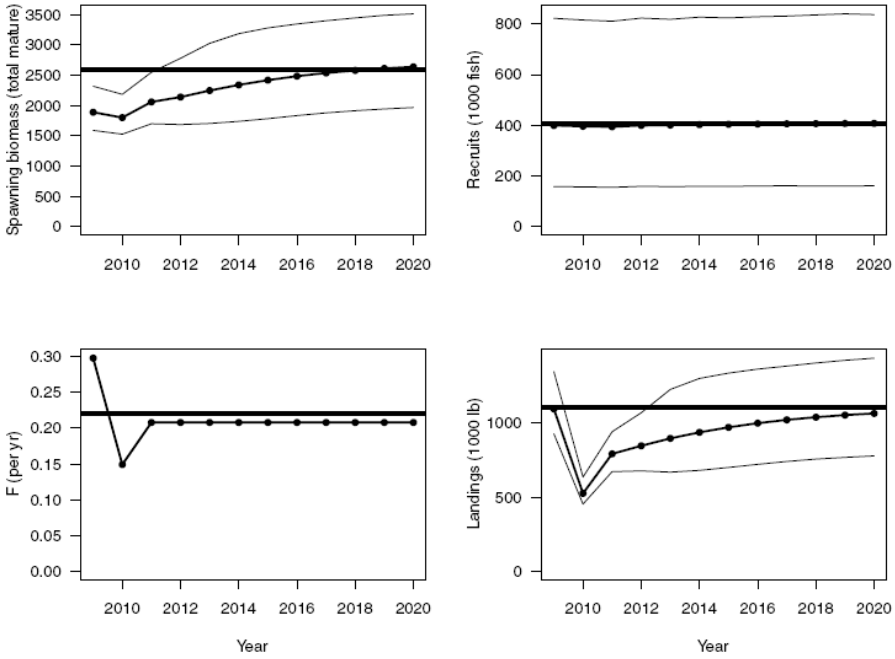


Figure 9: continued

Figure 6.63. Projection results under scenario 13—fishing mortality rate fixed at F = $F_{rebuild}$, after an initialization period with F = $F_{current}$ in 2009 and F = 25%$F_{current}$ 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.