3.5 Georges Bank yellowtail

Catch and Survey Indices

Exploitation of Georges Bank yellowtail flounder began in the mid 1930s with catches peaking in the 1960s and early 1970s followed by a decline in the 1980s and early 1990s and an increasing trend over the most recent four years (Figure 3.5.1). Both research survey abundance indices for Georges Bank yellowtail flounder show an overall decline and rebuilding pattern from the 1960s to present (Figure 3.5.1). It is thought that the large catches of the 1960s and 1970s reduced the population abundance so much that the reduced catches in the 1980s were still associated with high fishing mortality rates. Fishing mortality was not reduced until the mid 1990s when strict management regulations were implemented by both the US and Canada. The stock demonstrated a rapid rebuilding and has still appears to be increasing according to the most recent stock assessment.

Stock Assessment

The most recent assessment for Georges Bank yellowtail flounder was reviewed by the Transboundary Resource Assessment Committee (TRAC) in 2001 (Stone et al. 2001). The stock was analyzed with virtual population analysis (VPA), with supporting analysis provided by surplus production modeling. The VPA assessment used data for years 1973 through 2000 and ages 1 through 6+ and was felt to be representative of stock dynamics for the time period. Plots of stock and recruitment estimates from the VPA are provided in Figure 3.5.2. Recruitment has increased with increasing spawning stock size overall, with the most recent year class estimate occurring near the mean of top quartile of spawning stock size. However, the most recent year class is the most poorly estimated in the VPA and may increase or decrease as more catch is taken from the cohort.

Yield and Spawning Stock Biomass per Recruit

The fishing mortality reference points F(0.1) and F40%MSP given in Figure 3.5.2 were calculated for this exercise using ages 1 through 6+ in order to be consistent with the projections described below, and thus may differ slightly from previously reported values (see Table 3.5.2). From the yield per recruit analysis, F(0.1)=0.265 and Fmax=0.8 (both are fully recruited Fs). From the spawning stock biomass per recruit analysis, F40%MSP=0.248 (fully recruited F) with an associated spawning stock biomass per recruit of 1.0925 kg.

Empirical Nonparametric Approach

If F40%MSP is assumed to be an adequate proxy for Fmsy, then the fishing mortality threshold is 0.248. This fishing mortality rate produces 1.093 kg of spawning stock biomass per recruit and 0.2398 kg of yield per recruit (including discards). The strong correlation between the VPA and hindcast stock and recruitment data led to use of hindcast recruitment from the period 1963-1972 in addition to the VPA recruitment data. With this combined dataset, there appears to be two levels of recruitment split at 5,000 mt of spawning biomass. Thus, the arithmetic average of recruitment for spawning biomasses greater than 5,000 mt was used as a proxy for recruitment at maximum sustainable yield; this recruitment is 53.8 million fish. Multiplying this recruitment level by the per recruit biomasses associated with F40%MSP results in a Bmsy proxy of 58,800 mt and an MSY proxy of 12,900 mt assuming that all fish caught are landed.

Parametric Model Approach

Maximum likelihood fits of the 14 parametric stock-recruitment models to the Georges Bank yellowtail flounder data from 1973-1999 are listed below (Table 3.5.1, see Table 2.2.1 for model acronyms). The six hierarchical criteria are applied to each of the models to determine the set of candidate models.

The priors for the Beverton and Holt steepness parameter and Ricker slope parameter from Myers et al (1999) were thought to be insufficient for the yellowtail stocks as the only data sets used to develop the prior were Georges Bank and Southern New England yellowtail stocks. Thus, models PBH, PABH, P2BH, P2ABH, PRK, and PARK are not considered. Criteria 1-4 and 6 are satisfied by all remaining models. The fifth criteria is not satisfied by any of the remaining autoregressive error models. Models BH, PRBH, RK and PRK provided nearly equal statistical fits to the stock-recruitment data. These four models have maximum recruitment levels below 45 million fish, which is within the 90th percentile of the observed recruitment levels. However, examination of hindcast stock and recruitment showed a strong match between the VPA and hindcast values in the years of overlap, with the hindcast stock and recruitment in the year classes prior to the VPA at higher levels on average than the VPA (Figure 3.5.3). This observation led to the creation of a seventh criteria: expected recruitment at high stock sizes is consistent with hindcast recruitment. The recruitment for year classes 1963-1972 was used to generate the prior for unfished recruitment for the PRHCBH and PRHCABH models. Application of the seventh criteria left the PRHCBH model as the only candidate parametric model for Georges Bank yellowtail flounder.

The results of using the PRHCBH model as the best fit parametric model are shown below (Figures 3.5.4-3.5.7). The standardized residual plot of the fit of the PRHCBH model to the stock-recruitment data shows that the standardized residuals generally lie within ± two standard deviations of zero (Figure 3.5.4), with the exception of the 1982 year class.

In the equilibrium yield plot (Figure 3.5.5), the yield surface is relatively flat in the neighborhood of the point estimate of Fmsy=0.32. This estimate of Fmsy is greater than the calculated values for F(0.1) (0.265) and F40%MSP (0.248), which are traditional proxies for Fmsy. This difference is most likely due to the high growth rate, strong resiliency, and current partial recruitment pattern for this stock. For comparison, Fmsy generates approximately 34% of maximum spawning potential. The point estimates of Smsy (63,200 mt) and MSY (17,600 mt) appear consistent with the nonparametric proxy estimate of Smsy, once the hindcast stock and recruitment data are considered, and previous estimates of MSY. The stock-recruitment plot (Figure 3.5.6) shows that expected recruitment values near Smsy are around 68 million fish, which is within the maximum observed range from the VPA data and below the average of the 1963-1972 hindcast recruitments.

Parameter uncertainty plots show histograms of 5000 MCMC sample estimates of MSY, Smsy, and Fmsy drawn from the posterior distribution of the MLE (Figure 3.5.7). For MSY, the 80 percent credibility interval was (16,400, 18,900) with a median of 17,600 mt. For Smsy, the 80 percent credibility level was (57,900, 67,700) with a median of 62,700 mt. For Fmsy, the 80 percent credibility level was (0.285, 0.365) with a median of 0.325. Overall, the point estimates of MSY, Smsy, and Fmsy were nearly identical to the medians of the MCMC samples.

Reference Points

Based on the conformance of the recruitment-biomass per recruit analyses and the parametric stock-recruitment relationship, the following management parameters are considered most appropriate: Bmsy=58,800 mt, Fmsy=0.248 (fully recruited F), and MSY=12,900 mt (including discards). This level of yield is expected by building the stock size through reduced fishing mortality, relative to historical levels that were above 1.0, increased survivorship of young fish relative to the historical use of much smaller mesh size when peak catches were taken, and an expectation that on average recruitment will stay within the range predicted by the most recent stock assessment The median recruitment, stock-recruitment scatterplot, and replacement lines under F=0 and F=0.248 are given in Figure 3.5.8.

Projections

Given that the empirical approach was assumed to provide the most appropriate fit for the stock and recruitment data, projections were conducted assuming two empirical cumulative distribution functions: one for spawning biomasses below 5,000 mt and one for spawning biomasses above 5,000 mt. Since the last year in the VPA was 2000, catch for 2001 was estimated using the US landings from Jan-Nov (7,062 mt), the proportion of US landings in Jan-Nov in 2000 by gear type, the average US discard:landings ratio for 1995-2000 (9.6%), and an estimate of Canadian catch in 2001 (2,890 mt). The 2001 catch estimate is 7,740 mt. For 2002, the fishery was assumed to achieve the target rate of F(0.1), which was calculated as 0.265 (fully recruited F) for these projections. For years 2003 through 2009, the fishery was assumed to fish at a rate of F40%MSP (0.248 fully recruited F). Under these assumptions, there is a 40.4% chance that the spawning biomass in 2009 will be at least as large as Bmsy (Figure 3.5.9). Thus, a rebuilding fishing mortality rate must be calculated. A fishing mortality rate of 0.22 (fully recruited F) gives a 51.4% probability that the spawning biomass in 2009 will be at least as large as Bmsy (Figure 3.5.9). Based on these projections, the median fishing mortality rate in 2001 was 0.185 which can be increased 19% to the Frebuild level of 0.22 and still achieve the rebuilding goal of Bmsy. Under these conditions, the median spawning stock biomass in 2009 will be 59,300 mt with an 80% confidence interval of 42,900 mt to 78,000 mt (Figure 3.5.10). The associated median catch will be 11,600 mt with an 80% confidence interval of 8,500 mt to 15,200 mt (Figure 3.5.11)

Table 3.5.1. Summary of parametric fits for Georges Bank yellowtail flounder.

Georges Bank Yellowtail Flounder

	Prior	Prior	Prior	Prior	Prior	Prior	Prior	Prior	Prior	Prior	Prior	Prior	Prior	Prior
	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	BH	ABH	PBH	PABH	PRBH	PRABH	P2BH	P2ABH	RK	ARK	PRK	PARK	**PRHCBH**	PRHCABH
Posterior Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00
Odds Ratio for Most Likely Model													**1.00**	
Normalized Likelihood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
Model AIC Ratio	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	BH	**ABH**	**PBH**	**PABH**	**PRBH**	**PRABH**	**P2BH**	**P2ABH**	**RK**	**ARK**	**PRK**	**PARK**	**PRHCBH**	**PRHCABH**
Number_of_data_points	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Number_of_parameters	3	4	3	4	3	4	3	4	3	4	3	4	3	4
Fit_negloglikelihood	108.162	105.653	108.249	105.994	108.309	105.669	108.413	105.962	108.388	106.105	108.910	106.94	108.788	106.937
Penalty_steepness	0	0	-1.61707	-1.497	0	0	-1.31856	-1.36112	0	0	0	0	0	0
Penalty_slope	0	0	0	0	0	0	0	0	0	0	1.24421	1.05932	0	0
Penalty_unfished_R	0	0	0	0	2.34124	2.32852	2.38292	2.33588	0	0	0	0	2.14173	2.14266
Negative_loglikelihood	108.162	105.653	106.632	104.497	110.650	107.997	109.478	106.937	108.388	106.105	110.155	108	110.930	109.08
Bias-corrected_AIC	223.368	221.124	223.542	221.806	223.661	221.156	223.870	221.743	223.820	222.028	224.864	223.699	224.619	223.693
Diagnostic Comments	predicted R at high S below mean from hindcast	auto-correlation implies long period forcing	insufficient information for steepness prior	insufficient information for steepness prior	predicted R at high S below mean from hindcast	auto-correlation implies long period forcing	insufficient information for steepness prior	insufficient information for steepness prior	predicted R at high S below mean from hindcast	auto-correlation implies long period forcing	insufficient information for slope prior	insufficient information for slope prior	**model selected**	auto-correlation implies long period forcing
Parameter Point Estimates														
********************************														
MSY	10.10	7.86	11.44	9.69	8.39	8.39	8.34	8.12	9.94	9.14	11.57	9.40	17.55	17.72
FMSY	0.370	0.440	0.345	0.360	0.400	0.425	0.375	0.370	0.640	0.710	0.525	0.505	0.320	0.325
SMSY	31.82	21.18	38.41	31.29	24.63	23.33	25.95	25.58	19.22	16.16	26.63	22.39	63.15	62.86
alpha	47.4957	33.7564	55.9377	46.3317	37.8815	36.6725	38.9316	38.1003	1.56768	1.67495	1.35976	1.32092	90.0315	89.6324
expected_alpha	58.4841	41.7738	68.972	56.9967	46.7517	45.2635	48.1262	47.0907	1.93716	2.07107	1.69432	1.65452	111.96	111.34
beta	7.62838	3.41912	10.4767	7.96709	5.06115	4.1212	6.06283	6.06457	-0.049435	-0.060086	-0.033962	-0.040039	19.84	18.8743
steepness	0.810	0.870827	0.785	0.798832	0.836	0.858682	0.814	0.81096	N/A	N/A	N/A	N/A	0.756	0.764303
R_at_input_SMAX	39.23	30.8432	43.38	37.9741	33.23	32.9243	33.35	32.6333	29.00	21.9529	41.24	31.8355	58.16	58.9148
expected_R_at_input_SMAX	48.30	38.1687	53.49	46.7153	41.02	40.6371	41.22	40.3336	35.83	27.1447	51.39	39.8755	72.32	73.1829
unfished_S	122.10	88.7816	142.31	118.581	98.41	96.0444	100.27	98.0008	52.04	44.5986	69.62	58.0868	226.07	225.944
unfished_R	44.70	32.5046	52.10	43.4148	36.03	35.1637	36.71	35.8799	19.05	16.3284	25.49	21.2667	82.77	82.7222
sigma	0.645162	0.652836	0.647244	0.643688	0.648672	0.648802	0.651184	0.650928	0.650579	0.65159	0.663288	0.67109	0.660282	0.658588
phi	N/A	0.442203	N/A	0.386796	N/A	0.429107	N/A	0.413701	N/A	0.404685	N/A	0.401559	N/A	0.357835
sigmaw	N/A	0.585539	N/A	0.593586	N/A	0.586033	N/A	0.592613	N/A	0.595851	N/A	0.614607	N/A	0.61498
last_residual_R	N/A	3.24529	N/A	-3.39503	N/A	1.24743	N/A	1.69255	N/A	9.01503	N/A	0.566479	N/A	-22.8067
last_logresidual_R	N/A	0.101033	N/A	-0.095793	N/A	0.0376375	N/A	0.0514181	N/A	0.310536	N/A	0.0169164	N/A	-0.516012
expected_lognormal_error_	1.23136	1.23751	1.23301	1.23019	1.23416	1.23426	1.23617	1.23597	1.23569	1.2365	1.24605	1.25255	1.24357	1.24218
prior_mean_steepness	N/A	N/A	0.75	0.75	N/A	N/A	0.75	0.75	N/A	N/A	N/A	N/A	N/A	N/A
prior_se_steepness	N/A	N/A	0.07	0.07	N/A	N/A	0.07	0.07	N/A	N/A	N/A	N/A	N/A	N/A
prior_mean_slope	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.79	0.79	N/A	N/A
prior_se_slope	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.34	0.34	N/A	N/A
prior_mean_unfished_R	N/A	N/A	N/A	N/A	35.35	35.35	35.35	35.35	N/A	N/A	N/A	N/A	82.98	82.98
prior_se_unfished_R	N/A	N/A	N/A	N/A	4.09	4.09	4.09	4.09	N/A	N/A	N/A	N/A	3.39	3.39

Table 3.5.2. Yield and biomass per recruit of Georges Bank yellowtail flounder.

The NEFC Yield and Stock Size per Recruit Program - PDBYPRC
PC Ver.2.0 [Method of Thompson and Bell (1934)] 1-Jan-1999

Run Date: 19- 2-2002; Time: 11:52:02.03
GEORGES BANK YELLOWTAIL FLOUNDER - 2002

Proportion of F before spawning: 0.4167
Proportion of M before spawning: 0.4167
Natural Mortality is Constant at: 0.200
Initial age is: 1; Last age is: 6
Last age is a PLUS group;
Original age-specific PRs, Mats, and Mean Wts from file:
==> C:\groundfish\ypr\gbyt_ypr.dat

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	0.0060	1.0000	0.0000	0.181	0.181
2	0.3150	1.0000	0.5200	0.349	0.349
3	0.6480	1.0000	0.8600	0.462	0.462
4	1.0000	1.0000	0.9800	0.578	0.578
5	1.0000	1.0000	1.0000	0.710	0.710
6	1.0000	1.0000	1.0000	0.948	0.948

Summary of Yield per Recruit Analysis:

Slope of the Yield/Recruit Curve at F=0.00: --> 2.5847
F level at slope=1/10 of the above slope (F0.1): -----> 0.265
Yield/Recruit corresponding to F0.1: -----> 0.2444
F level to produce Maximum Yield/Recruit (Fmax): -----> 0.800
Yield/Recruit corresponding to Fmax: -----> 0.2802
F level at 40 % of Max Spawning Potential (F40): -----> 0.248
SSB/Recruit corresponding to F40: --------> 1.0925

1
Listing of Yield per Recruit Results for:

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	0.00	0.00000	0.00000	5.5167	3.3366	3.6975	2.7314	100.00
	0.10	0.22655	0.15910	4.3893	2.3163	2.5736	1.7285	63.28
	0.20	0.34186	0.22291	3.8178	1.8175	2.0055	1.2441	45.55
F0.1	0.26	0.39118	0.24444	3.5742	1.6120	1.7642	1.0468	38.33
F40%	0.25	0.37959	0.23976	3.6314	1.6597	1.8208	1.0925	40.00
	0.30	0.41255	0.25241	3.4690	1.5251	1.6602	0.9639	35.29
	0.40	0.46084	0.26697	3.2318	1.3346	1.4266	0.7838	28.69
	0.50	0.49627	0.27431	3.0588	1.2012	1.2570	0.6593	24.14
	0.60	0.52359	0.27795	2.9259	1.1030	1.1276	0.5689	20.83
	0.70	0.54548	0.27963	2.8200	1.0278	1.0252	0.5004	18.32
	0.80	0.56351	0.28025	2.7332	0.9684	0.9418	0.4469	16.36
Fmax	0.80	0.56356	0.28025	2.7330	0.9682	0.9416	0.4468	16.36
	0.90	0.57871	0.28028	2.6604	0.9202	0.8723	0.4041	14.79
	1.00	0.59177	0.28001	2.5981	0.8802	0.8134	0.3690	13.51
	1.10	0.60314	0.27958	2.5441	0.8465	0.7626	0.3397	12.44
	1.20	0.61318	0.27907	2.4966	0.8177	0.7183	0.3148	11.53
	1.30	0.62214	0.27853	2.4544	0.7927	0.6793	0.2935	10.75
	1.40	0.63020	0.27799	2.4166	0.7707	0.6445	0.2749	10.07
	1.50	0.63750	0.27747	2.3825	0.7513	0.6134	0.2587	9.47
	1.60	0.64417	0.27696	2.3515	0.7339	0.5853	0.2442	8.94
	1.70	0.65030	0.27647	2.3231	0.7182	0.5597	0.2314	8.47
	1.80	0.65595	0.27601	2.2970	0.7040	0.5364	0.2198	8.05
	1.90	0.66119	0.27557	2.2729	0.6911	0.5150	0.2093	7.66
	2.00	0.66607	0.27515	2.2506	0.6792	0.4952	0.1998	7.32

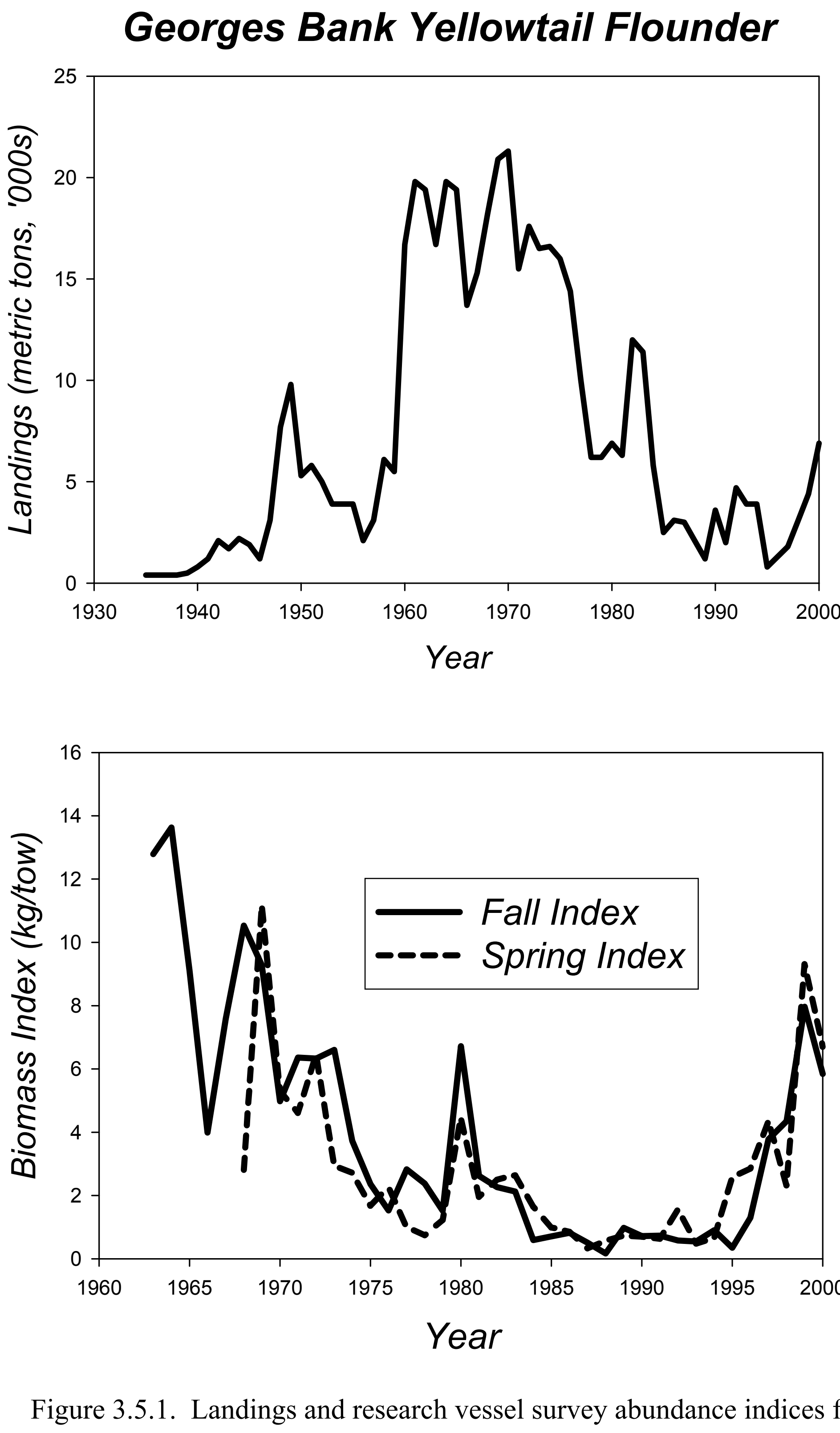
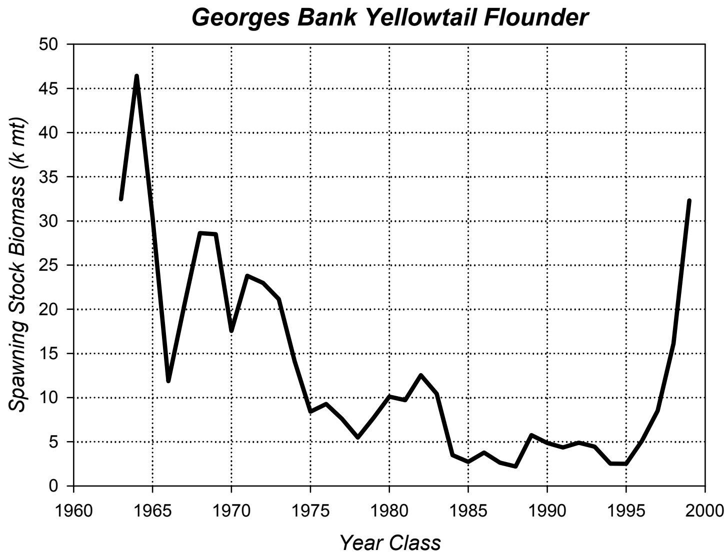
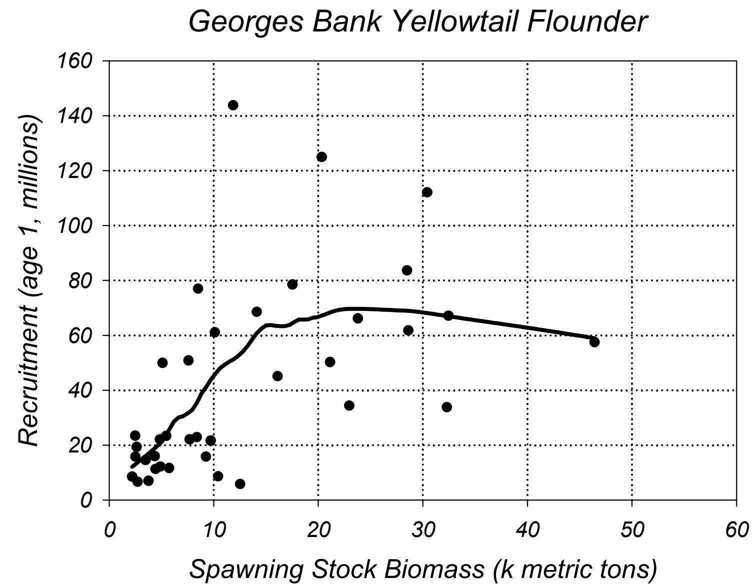


Figure 3.5.1. Landings and research vessel survey abundance indices for Georges Bank yellowtail flounder.

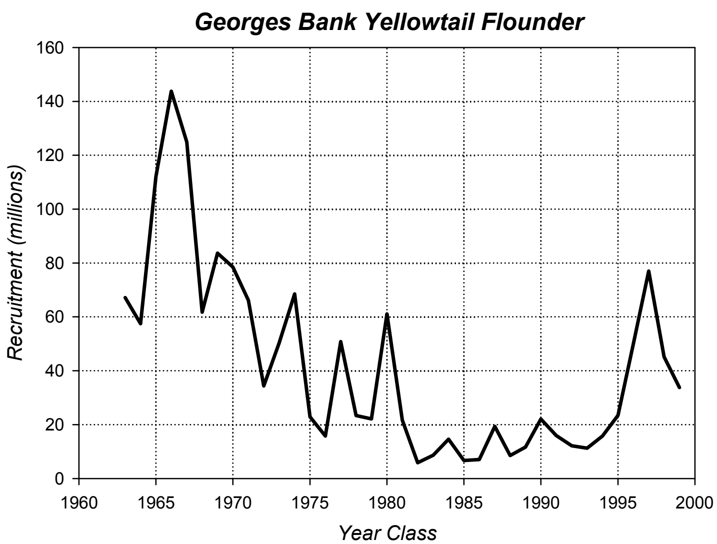
(a)



(c)



(b)



		F0.1	F40%MSP
F reference point		0.265	0.248
ssb per recruit at F		1.047	1.093
	Recruitment (millions)	SS Biomass at F0.1	SS Biomass at F40%
n	37	37	37
mean	42.03	44.00	45.94
min	5.82	6.09	6.36
max	143.75	150.51	157.12
10th %'tile	8.58	8.99	9.38
25th %'tile	15.76	16.50	17.23
50th %'tile	23.44	24.54	25.62
75th %'tile	61.77	64.67	67.51
90th %'tile	80.56	84.35	88.05
Std Dev	34.97	36.62	38.23
CV	0.83	0.87	0.91
For Top Quartile of SSB			
Mean	69.15	72.40	75.58
Median	63.96	66.97	69.91
For SSB>5,000 mt			
Mean	53.78	56.30	58.78
Median	67.93	71.12	74.25

Figure 3.5.2. Spawning stock (a), recruitment (age 1 millions, b), and scatterplot (c) for Georges Bank yellowtail flounder. Data are the calculated spawning stock biomasses for various recruitment scenarios multiplied by the expected SSB per recruit for F0.1 and F40% MSP, assuming recent patterns of growth, maturity and partial recruitment at age (Table 3.5.2). Smoother in the stock-recruitment plot is lowess with tension = 0.5. Year classes from 1963-1972 are hindcast from VPA-fall survey correlations (Figure 3.5.3).

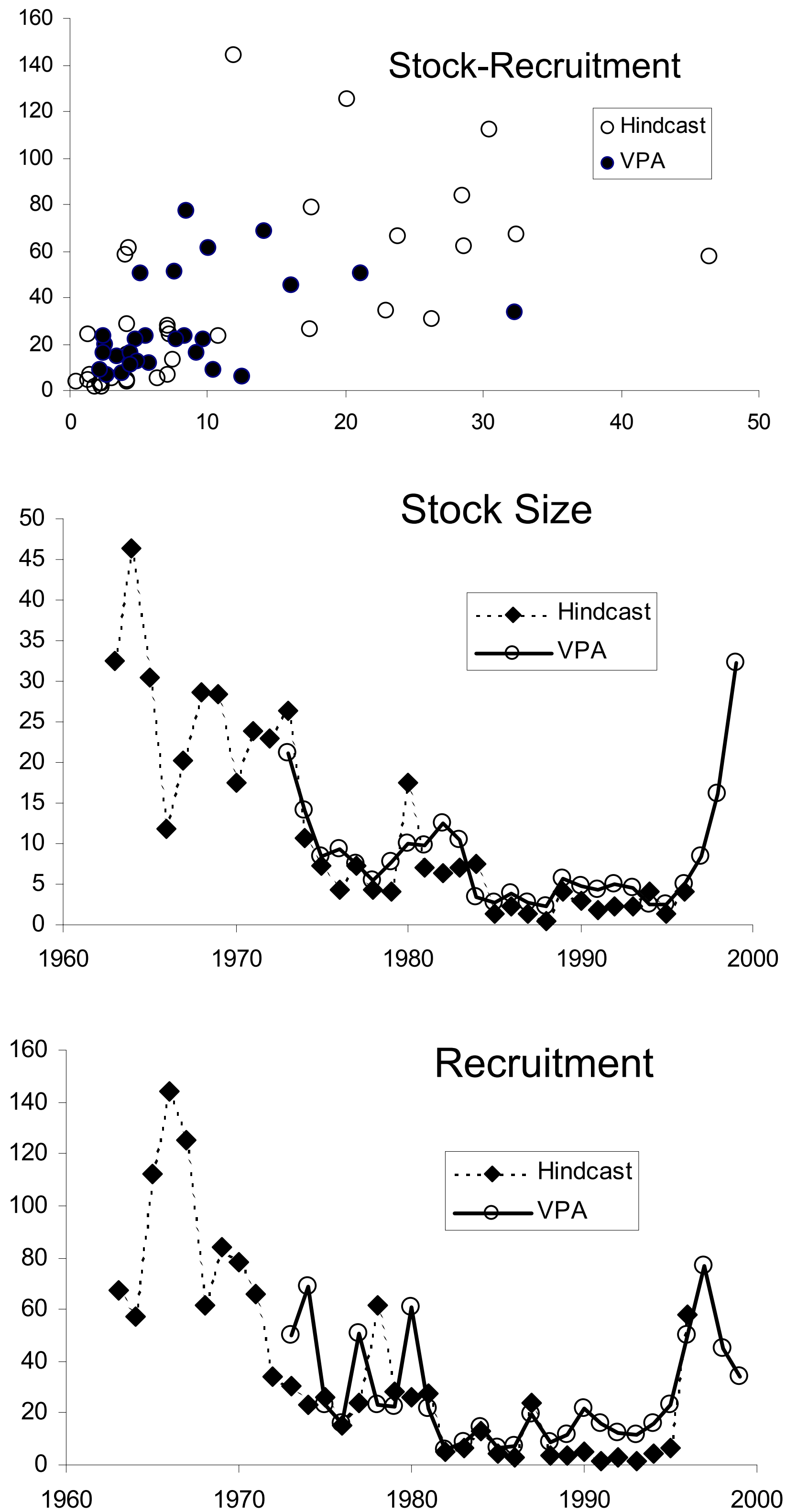


Figure 3.5.3. Comparison of stock and recruitment data from virtual population analysis (VPA) and hindcast for Georges Bank yellowtail flounder.

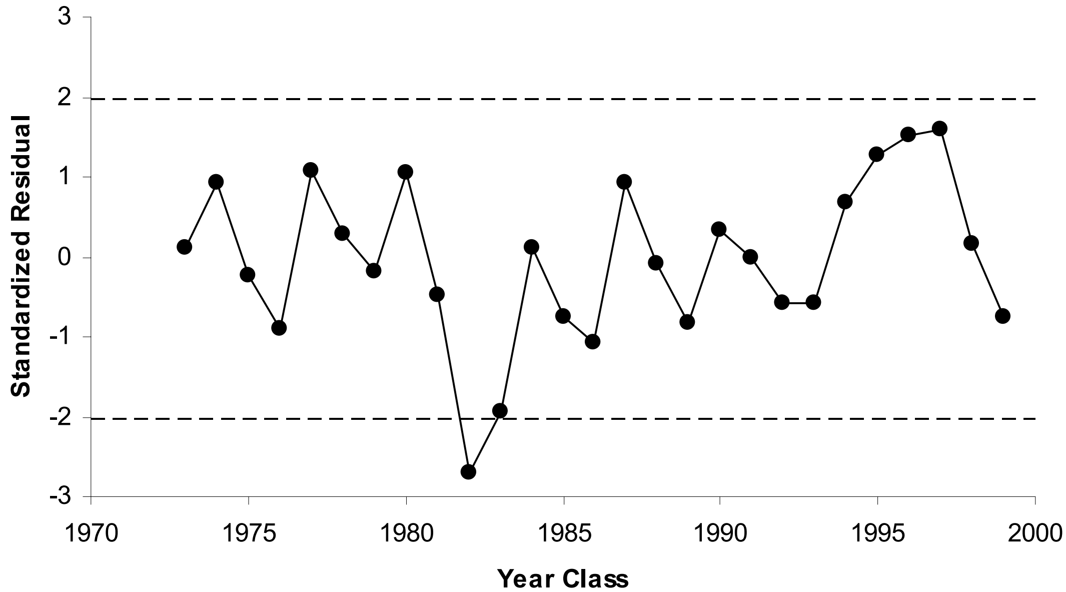


Figure 3.5.4. Standardized residuals from best fit parametric model (PRHCBH) for Georges Bank yellowtail flounder.

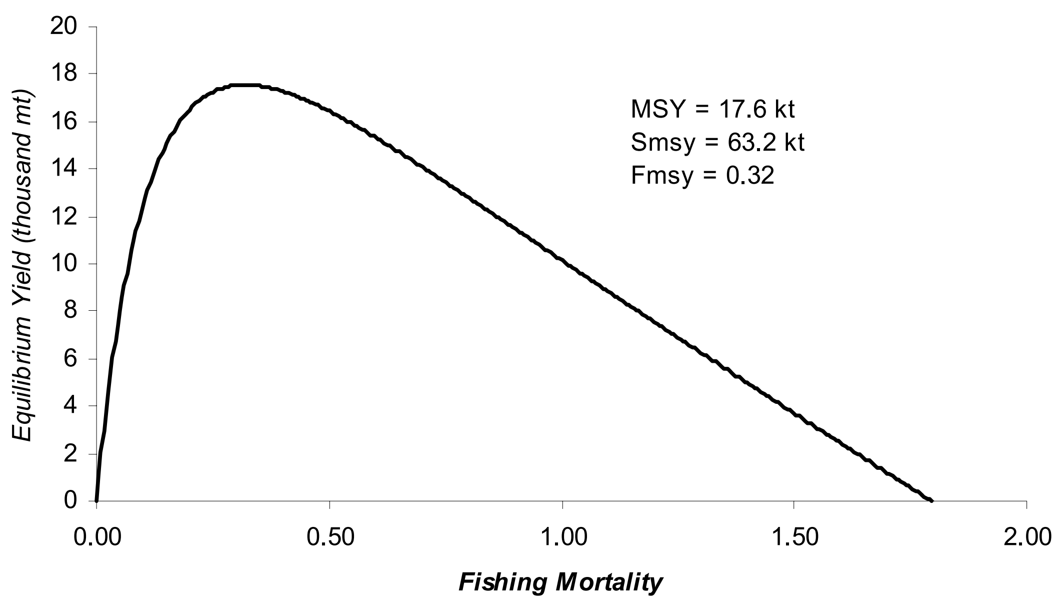


Figure 3.5.5. Equilibrium yield from best fit parametric model (PRHCBH) for Georges Bank yellowtail flounder

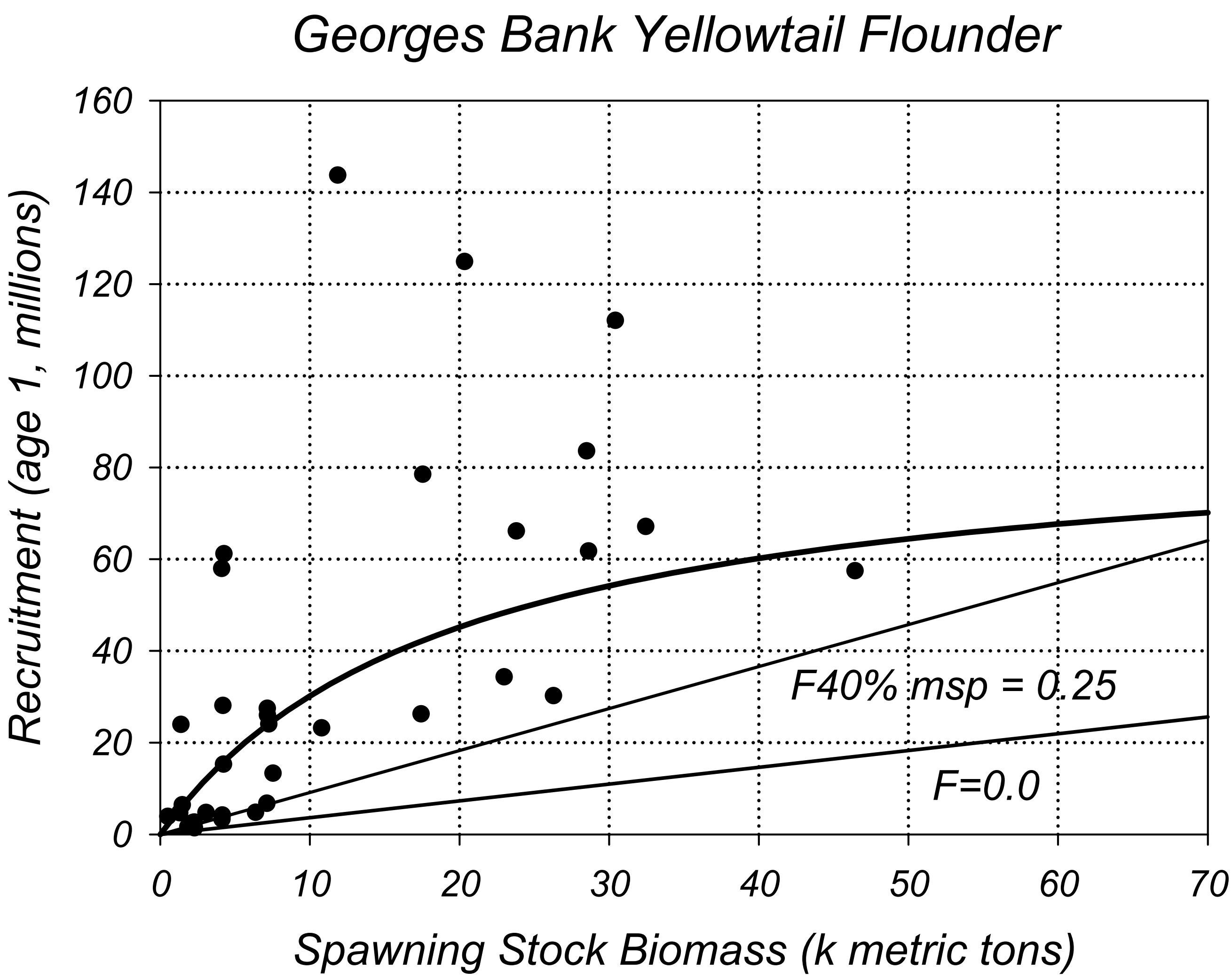
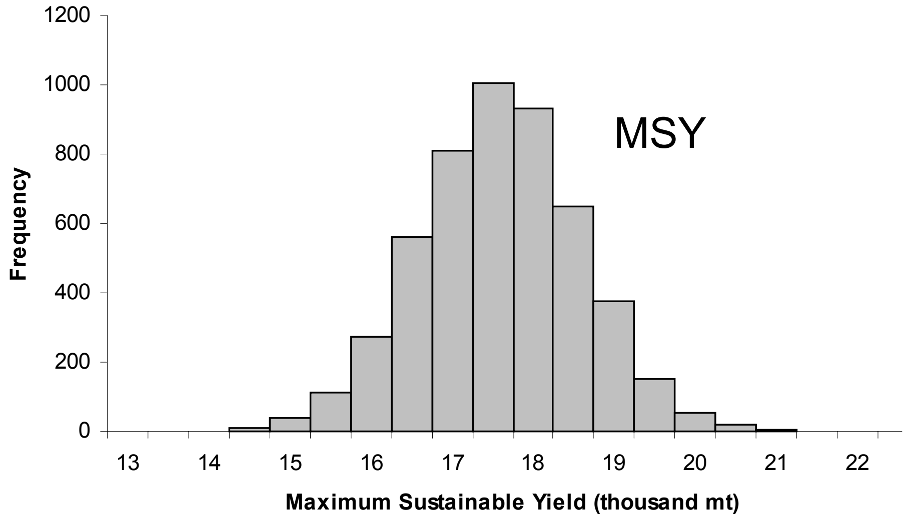
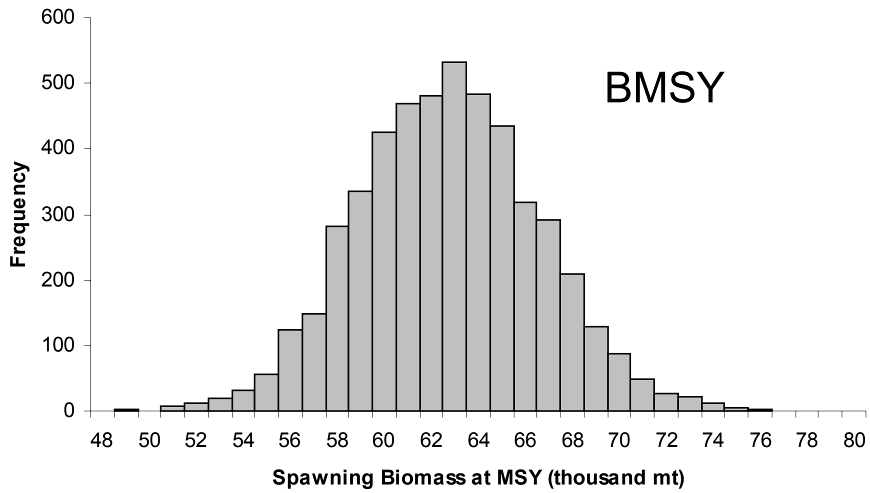


Figure 3.5.6. Stock recruitment relationship for best fit parametric model (PRHCBH) for Georges Bank yellowtail flounder. Hindcast stock-recruitment data points are overplotted, along with the predicted S-R line and replacement lines for F=100% msp=0.00 and F40%msp = 0.25.





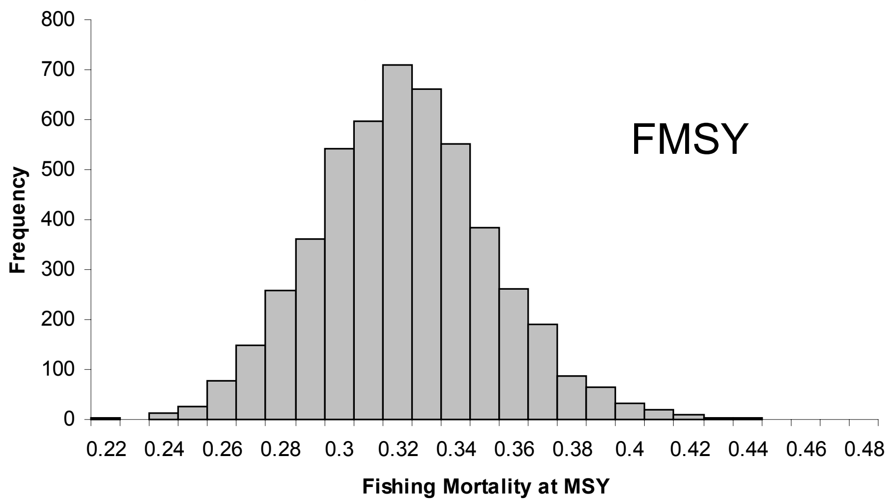


Figure 3.5.7. Histograms of uncertainty in MSY, BMST and FMSY from 5000 MCMC evaluations of best fit parametric model (PRHCBH) for Georges Bank yellowtail flounder.

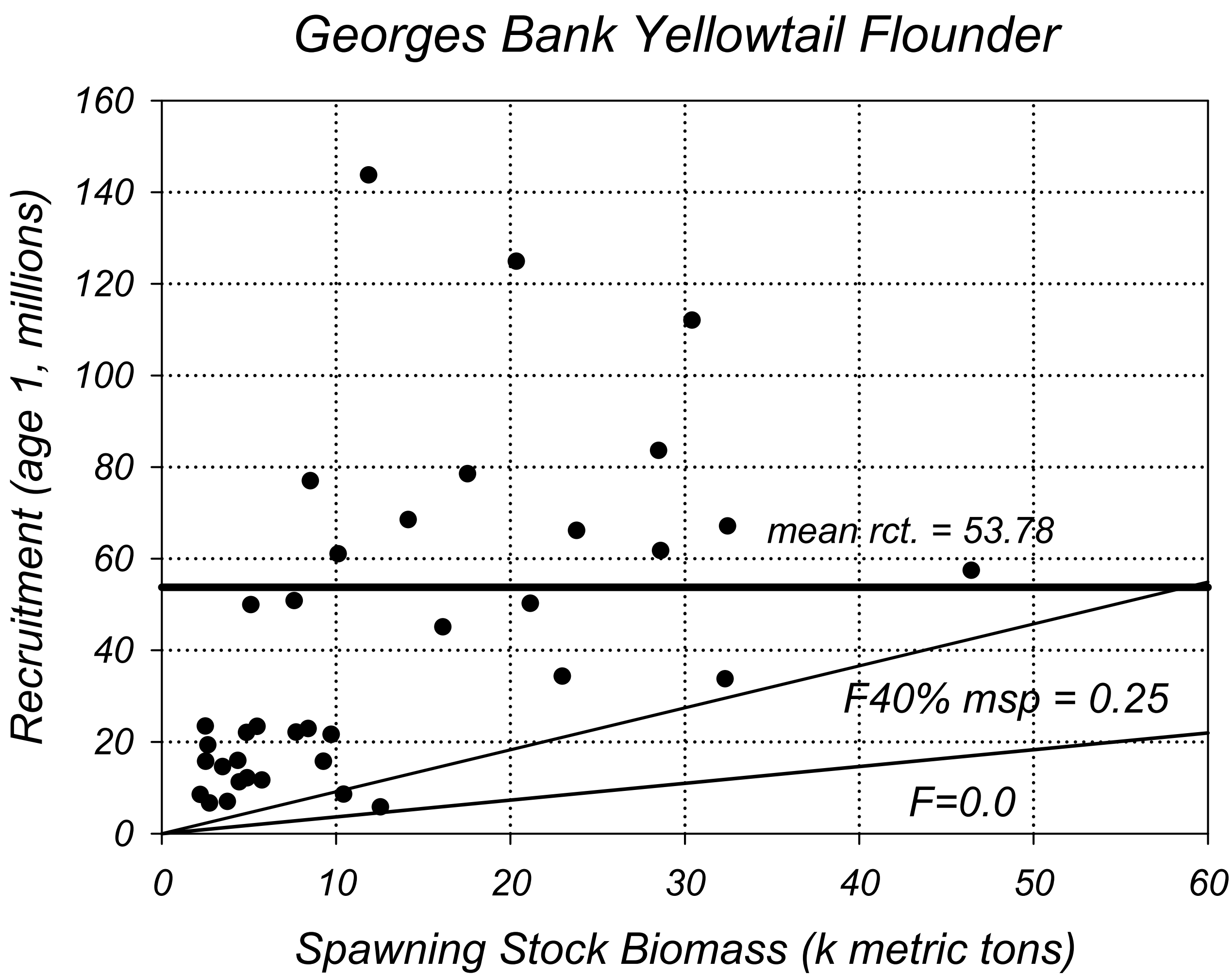


Figure 3.5.8. Stock and recruitment data for Georges Bank yellowtail. For the empirical non-parametric approach the mean recruitment above 5,000 mt of spawning stock biomass is plotted, along with replacement lines for F=0.0 and F 40% msp = 0.248.

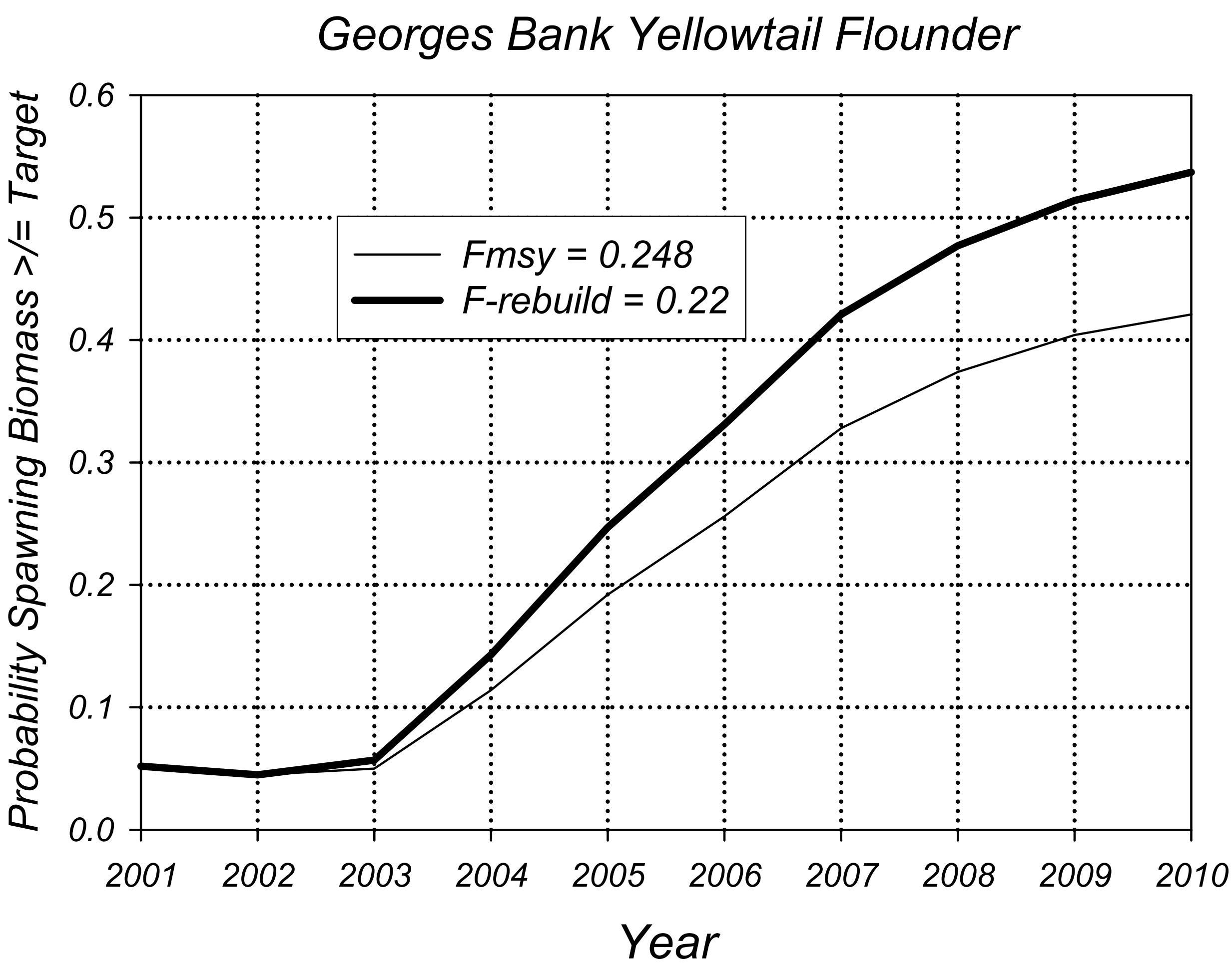


Figure 3.5.9. Probability that Georges Bank yellowtail spawning biomass will exceed Bmsy (58,800 mt) annually under two fishing mortality scenarios: Fmsy and F required to rebuild the stock to Bmsy by 2009.

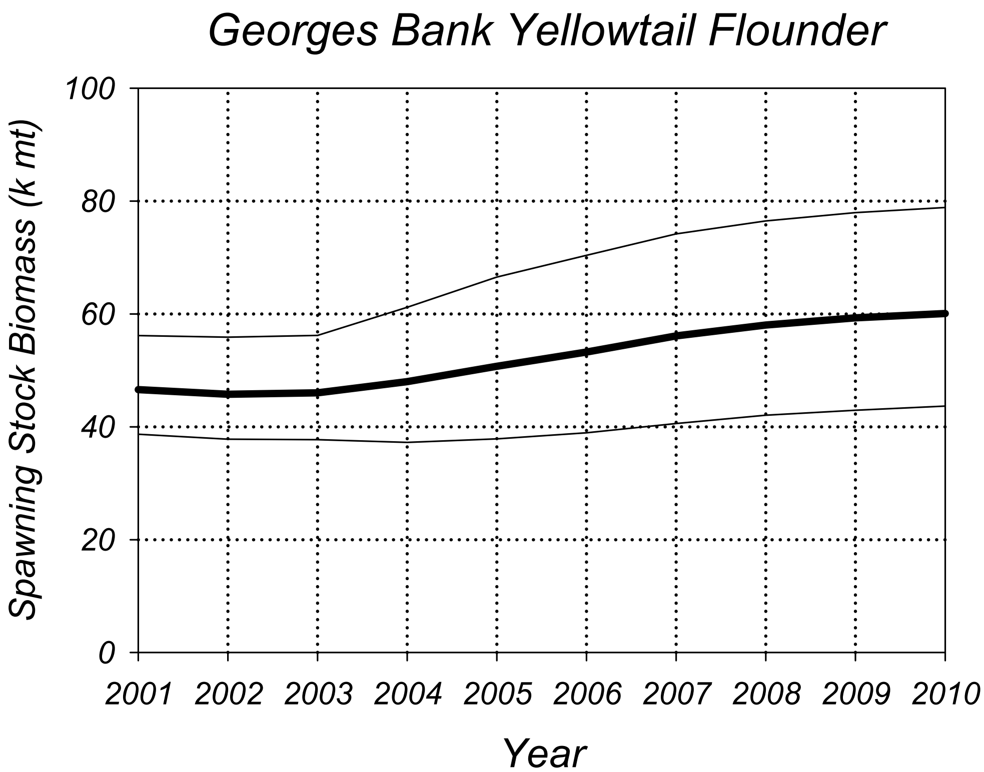


Figure 3.5.10. Median and 80% confidence interval of predicted spawning biomass for Georges Bank yellowtail flounder under F-msy fishing mortality rates.

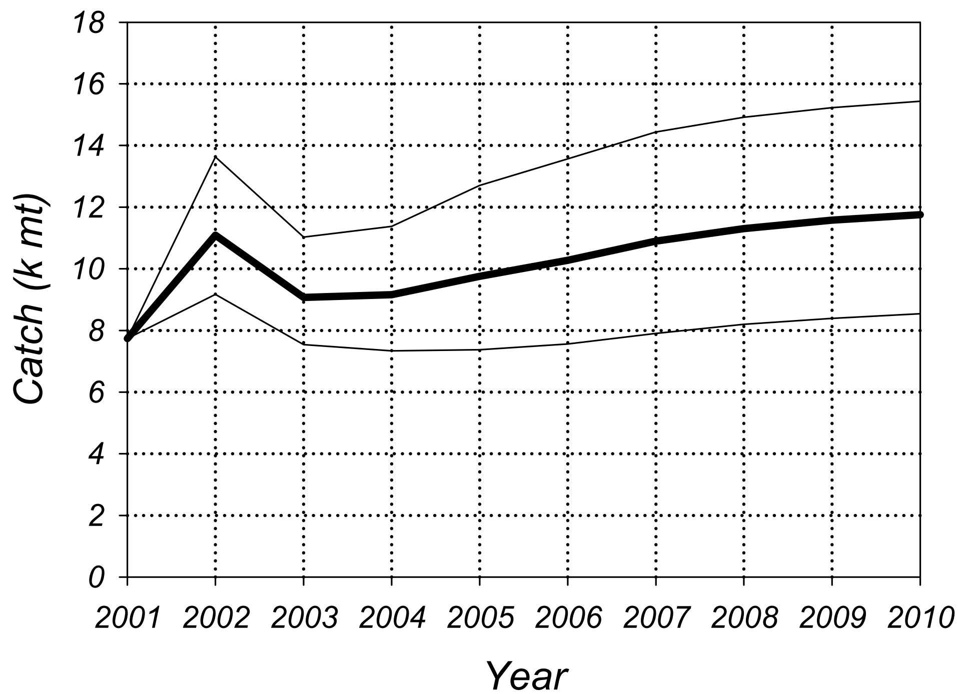


Figure 3.5.11. Median and 80% confidence interval of predicted catch for Georges Bank yellowtail flounder under F-msy fishing mortality rates.