E. Cape Cod/Gulf of Maine yellowtail flounder

by Chris Legault, Larry Alade, Steve Cadrin, Jeremy King, and Sally Sherman

Additional details and supporting information can be found in the Appendix of the GARM-III Report (NEFSC 2008).

1.0 Background

The Cape Cod-Gulf of Maine yellowtail flounder stock was most recently assessed at the Groundfish Assessment Review Meeting (GARM) in 2005 (Cadrin et al. 2005). That assessment was based on a virtual population analysis (VPA) with a 5+ age group formulation. At the time it was recognized that this formulation was sub-optimal because the age 3 partial recruitment had to be 1.0 even though this age was thought to be less than fully selected. The stock exhibited high fishing mortality rates and low abundance. Reference point estimation was derived from spawning stock biomass per recruit and yield per recruit analyses, with the assumption of constant recruitment. The value for F40% (i.e. the proxy for F_{MSY}) was 0.17 and the corresponding SSB_{MSY} and MSY were 12,600 mt and 2,300 mt, respectively. The estimate of SSB_{2004} (1,111 mt) was 9% of SSB_{MSY} and the estimate of F_{2004} (0.75) was four times F_{MSY}, indicating that the stock was severely overfished and overfishing was occurring. The current benchmark assessment revises and updates the 1994-2007 fishery catch estimates to reflect recommendations at the GARM III Data meeting (GARM 2007), and updates research survey abundance indices and analytical models (VPA) though 2007/2008 as recommended at both the GARM III Methods meeting (GARM 2008a) and the GARM III Biological Reference Points meeting (GARM 2008b). The VPA analysis now uses a 6+ formulation which allows appropriate estimation of age 3 partial recruitment. Biological reference points for this stock were re-evaluated based on recommendations at the GARM III Biological Reference Points meeting (GARM 2008b) to determine the status of the stock.

2.0 Fishery

Landings

Landings of yellowtail flounder from the Cape Cod-Gulf of Maine stock (Figure E1) during 1994-2007 were derived from the new trip-based allocation described in the GARM III Data meeting (GARM 2007, Palmer 2008, Wigley et al. 2007a, Table E1, Figure E2). Changes to previous estimates were minimal and uncertainty in the landings due to the random component of the allocation was insignificant (Legault et al. 2008). Landings at age and mean weight at age were determined by port sampling of small, medium, large, and unclassified market categories and pooled age-length keys by half year. Sampling intensity has increased in recent years (Table E2) resulting in lower variability in landings at age estimates (Table E3).

Discards

Discarded catch for years 1994-2007 was estimated using the Standardized Bycatch Reporting Methodology recommended in the GARM III Data meeting (GARM 2007, Wigley et al. 2007b). Observed ratios of discards of yellowtail flounder to kept of all species for large mesh otter trawl, small mesh otter trawl, scallop dredge, and gillnet were applied to the total landings by these gears by half-year. Uncertainty in the discard estimates was estimated based on the

SBRM approach detailed in the GARM III Data meeting (GARM 2007, Wigley et al. 2007b, Table E4). Discards were approximately 15% of the catch in years 1994-2006 (Table E1; Figure E1). Discards at age and associated mean weights at age were estimated from sea sampled lengths and pooled observer and survey age-length keys

Total Catch at Age

Total catch at age was formed by adding the landings and discards (Table E5a-c). Average weight at age was computed as the catch weighted average of the weights at age from these two sources (Table E6).

3.0 Research Surveys

Survey abundance and biomass indices are reported in Table E7a-f. Estimates are from valid tows in the Cape Cod-Gulf of Maine area [offshore strata 25-27, 39, 40 (stratum 27 excluded from the fall series); inshore strata 56-66; Massachusetts strata 17-36] standardized according to net, vessel, and door changes. Massachusetts survey indices were slightly revised to account for more accurate delineation of survey strata. These four bottom trawl surveys are presented as minimum swept area estimates to allow direct interpretation of the catchability estimates associated with each survey and age combination. Two new series were included in this assessment from the Maine-New Hampshire inshore survey, but were available only as stratified mean catch/tow. Survey data do not show any strong trends overall (Figure E3).

4.0 Assessment

Input Data and Model Formulation

The previous VPA formulation for the Cape Cod-Gulf of Maine yellowtail flounder stock had the plus group set at age 5 (Cadrin and King 2003, Cadrin et al. 2005). This formulation estimated the F on the oldest true age (4) from the F on age 3. However, it was recognized that this was not appropriate because the age 3 yellowtail are not fully selected, while ages 4 and older are. At the time, the age 6+ formulation exhibited a strong retrospective pattern and so the age 5+ formulation was adopted for management purposes. Mohn's rho retrospective statistics (Mohn 1999), calculated based on a seven year series of retrospective estimates were used to quantify the relative bias in terminal year estimates of fishing mortality (F), spawning stock biomass (SSB) and recruitment (R). The degree of retrospective pattern in the final status was compared to the estimates of precision to determine whether or not an adjustment was required. Based on this comparison, no adjustment for retrospective pattern was undertaken.

Model Selection Process

Due to the change in estimated landings and discards, the age 6+ formulation was examined first. This VPA was estimated with relatively good precision, CVs for N 30-42% and q 13-75% (Table E8). Significantly, this formulation did not exhibit a strong retrospective pattern (Table E9; Figures E4-E6). Given the estimated partial recruitment on age 3 in recent years was well below one (Figure E9), the age 5+ formulation was not considered, and the GARM III benchmark assessment panel recommended use of the age 6+ formulation to provide scientific advice.

Assessment Results

VPA assessment results show that population abundance has an increasing trend since 2004 and indicates a moderately strong 2005 year class entering the fishery (Table E10). The fishing mortality rates have been high during the entire assessment period, but decreased in 2007 (Table E11). Spawning stock biomass has varied without much trend during the assessment period (Table E12). The 2007 estimates of F and SSB were well estimated as seen in the relatively tight 80% confidence intervals derived from bootstrapping (Table E13a). The Mohn's Rho adjusted estimates for SSB were well within the confidence bounds of the bootstrap estimates (Table E13b). Adopting the panel recommendations at the GARM III final benchmark assessment meeting, the point estimates were used for final status determination.

Diagnostics

Residuals for indices of abundance do not show strong patterns, although occasional year effects are apparent in some surveys (Figure E7). The estimated catchability coefficients have reasonable magnitudes (<1.0) with the NEFSC surveys exhibiting flat-topped patterns while the two state surveys (MADMF and MENH) showing dome patterns (Figure E8). Back-calculated partial recruitment patterns from the fishery are flat-topped due to the formulation of the VPA, but also show a decrease in selectivity of age 2 and 3 yellowtail in recent years potentially due to mesh size regulations (Figure E9).

5.0 Biological Reference Points

Method and Special Considerations

As in the GARM III Biological Reference Points assessment, the estimated stock and recruitment values did not follow a parametric relationship (Figure E10) and so the non-parametric approach was undertaken. Hindcast recruitment estimates were derived by regressing the estimated numbers of recruits from the stock assessments on the NEFSC Fall survey index at age 1 (Figure E11). Following the recommendation of the GARM III Biological Reference Points review (GARM 2008b), all recruitment values (both estimated in the VPA and hindcast) were used to estimate the SSB_{MSY} and MSY proxies.

The GARM III Biological Reference Points Panel recommended that the hindcast recruitment values be checked for consistency with the catch which occurred during those years. This check was first attempted by averaging the recruitment and catch values for years 1977-1984, averaging the first five years of partial recruitment and weight at age in the VPA, and solving for the resulting full F. It was found that no F could produce the average catch given the average R. However, examination of the patterns of R and C during the hindcast period indicated that a pulse of recruitment had translated into a pulse of catch during this short time period. So a non-equilibrium approach was applied which assumed equilibrium population age structure in 1977 and the estimated hindcast recruitment values in years 1977-1984, and solved for the annual F in these years to match the observed catch. This approach was successful (Figure E12) but required high F, similar to the F at the start of the VPA. This analysis confirmed the hindcast estimates of recruitment are reasonable and can be used in setting the biological reference points.

Recent five year averages of partial recruitment, maturity, and weight at age were used in yield per recruit analysis to estimate $F_{40\%}$ as a proxy for F_{MSY} (Table E14). Applying F_{MSY} for 100 years in stochastic projections, while sampling recruitment from the empirical distribution

described above, allowed estimation of SSB_{MSY} and MSY as the median values at the end of the 100 year projections (see Legault 2008).

Final Values: F_{MSY}, SSB_{MSY}, MSY

The estimated values of F_{MSY} (0.239), SSB_{MSY} (7790 mt), and MSY (1720 mt) are quite similar those from the GARM III Biological Reference Points meeting and slightly different from the GARM II meeting (Table E15). The change in F_{MSY} from GARM II to GARM III is due to changes in partial recruitment and weight at age. Specifically, the GARM II estimates used weight at age that would be expected under a rebuild stock, while the current estimates use the recent five year average for weight at age, meaning much lower weight at age in the plus group because the stock has been overfished for many years. The Cape Cod-Gulf of Maine yellowtail F_{MSY} is now quite similar to the other two yellowtail stocks, while previously it had been much lower due to the slower growth exhibited in this stock. Dividing the 2007 values of F (0.36) and SSB (1,922 mt) by F_{MSY} and SSB_{MSY}, respectively, results in a current status of overfishing (F_{2007}=1.7 F_{MSY}) and overfished (SSB_{2007}=25% SSB_{MSY}) (Figure E13).

6.0 Projections

Initial Conditions

The recent five year average of partial recruitment, maturity, and weight at age used in the yield per recruit analysis were also used in projections (Table E14). The population abundance at age at the start of 2008 was derived from the bootstrap results, with the recruitment estimate generated as the geometric mean of the estimated recruitments during 1985-2007 from each bootstrap solution. Catch in 2008 was assumed equal to the catch in 2007 (627 mt).

$F_{REBUILD}$

The Cape Cod-Gulf of Maine yellowtail flounder stock is currently in a rebuilding plan with end date of 2023. The $F_{REBUILD}$ (0.238) was found by iteratively solving for the F which applied in years 2009-2023 resulted in median 2023 SSB equal to SSB_{MSY}.

Projected Catch in 2009

Median catch in 2009 was estimated under three scenarios for F in 2009: 1) $F_{STATUS\ QUO}$, meaning the F_{2009} is set equal to F_{2007}, 2) F_{MSY}, and 3) $F_{REBUILD}$ (Table E16). All three scenarios estimated catch higher than the 2007 catch while still allowing SSB to increase. Note that neither the $F_{STATUS\ QUO}$ nor the F_{MSY} projections would result in rebuilding to SSB_{MSY} with at least 50% probability by 2023.

7.0 Summary

Based on this assessment, the Cape Cod-Gulf of Maine yellowtail flounder stock continues to be overfished (SSB_{2007}/ SSB_{MSY} = 0.25) and overfishing is continuing (F_{2007}/ F_{MSY} = 1.73). However, fishing mortality has been declining since 2004 and is currently at the lowest level observed in the time series. Spawning stock biomass has increased the past two years and could continue to increase with the support of the moderately strong 2005 year class. The age 6+ VPA formulation is recommended as the basis for management because it does not exhibit a retrospective pattern, has good diagnostics, and the age 5+ formulation makes the untenable

assumption that age 3 partial recruitment is full. Given that the 2005 year class is strong in the Georges Bank and Southern New England-Mid Atlantic yellowtail stocks as well, a source of uncertainty for this assessment is whether the coinciding strong year class is due to favorable environmental conditions or due to migration among the stocks.

8.0 Panel Discussion/Comments

Conclusions

The Panel accepted the VPA formulation as Final, as best available estimate of stock status, and as a sufficient basis for management advice. The assessment displayed a small retrospective pattern which did not require adjustment. The Panel noted that the model fit here appeared to be the best of the three yellowtail stocks.

As recommended by the GARM III 'BRP' review, the hindcast recruitment estimates for 1977 – 84 were checked for consistency with the catch that occurred during those years. The analysis confirmed that these catches were consistent with the hindcast recruitment estimates assuming a high fishing mortality similar to what was observed in the early years. Thus, these hindcast recruitment estimates were accepted by the Panel.

Movement amongst the three yellowtail stocks and growth differences amongst these stocks complicates their assessment

Research Recommendations

The Panel had no specific research recommendations for this stock.

9.0 References

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Table E1. Landings, discards, catch (metric tons), and proportion of total catch which is discards for Cape Cod-Gulf of Maine yellowtail flounder.

Year	Landings	Discards	Catch	% Discard
1935	400	100	500	20%
1936	400	100	500	20%
1937	500	200	700	29%
1938	500	200	700	29%
1939	600	200	800	25%
1940	900	300	1200	25%
1941	1300	400	1700	24%
1942	1512	500	2012	25%
1943	1334	400	1734	23%
1944	1531	500	2031	25%
1945	1214	400	1614	25%
1946	1214	400	1614	25%
1947	1122	300	1422	21%
1948	710	200	910	22%
1949	1221	400	1621	25%
1950	1387	400	1787	22%
1951	862	200	1062	19%
1952	837	200	1037	19%
1953	840	200	1040	19%
1954	1114	300	1414	21%
1955	1320	400	1720	23%
1956	1426	400	1826	22%
1957	2426	700	3126	22%
1958	1639	500	2139	23%
1959	1564	500	2064	24%
1960	1539	500	2039	25%
1961	1822	600	2422	25%
1962	1900	600	2500	24%
1963	3600	1000	4600	22%
1964	1857	600	2457	24%
1965	1506	500	2006	25%
1966	1835	300	2135	14%
1967	1591	800	2391	33%
1968	1581	600	2181	28%
1969	1422	300	1722	17%
1970	1310	400	1710	23%
1971	1718	700	2418	29%
1972	1521	300	1821	16%
1973	1724	0	1724	0%
1974	2158	200	2358	8%
1975	2220	0	2220	0%
1976	3845	100	3945	3%
1977	3722	0	3722	0%
1978	4071	400	4471	9%
1979	4439	500	4939	10%
1980	5567	600	6167	10%
1981	3574	600	4174	14%
1982	3635	400	4035	10%
1983	2209	300	2509	12%
1984	1365	20	1385	1%
1985	1171	154	1326	12%
1986	1205	367	1572	23%
1987	1353	271	1624	17%
1988	1275	355	1630	22%
1989	1117	437	1555	28%
1990	3222	1239	4461	28%
1991	1737	515	2251	23%
1992	1031	715	1746	41%
1993	786	145	932	16%
1994	1143	208	1352	15%
1995	1368	147	1515	10%
1996	1176	336	1512	22%
1997	1134	552	1686	33%
1998	1310	311	1621	19%
1999	1303	149	1452	10%
2000	2439	148	2587	6%
2001	2381	239	2620	9%
2002	2057	100	2157	5%
2003	1834	136	1970	7%
2004	913	273	1186	23%
2005	715	282	997	28%
2006	534	85	620	14%
2007	483	144	627	23%

Table E2. Cape Cod-Gulf of Maine landings (metric tons) and number of lengths available from port samples by half year and market category along with number of ages available for age-length key and number of lengths sampled per 100 metric tons.

		Landings (metric tons)						Number of Lengths							
Year	half	unclass	large	small	medium	Total		unclass	large	small	medium	Total		Number of Ages	Lengths / 100 mt
1994	1	77	191	201	8	476			170	261		431			
	2	24	351	285	6	667			144	106		250			
	Total	101	543	486	14	1143			314	367		681		175	60
1995	1	88	325	346	6	765			491	276		767			
	2	18	321	254	9	603			264	407		671			
	Total	106	646	600	15	1368			755	683		1438		327	105
1996	1	55	270	373	17	714			87			87			
	2	18	233	205	5	462		118	640	495		1253			
	Total	73	503	578	22	1176		118	727	495		1340		367	114
1997	1	46	221	312	11	590			633	388		1021			
	2	20	338	177	10	544			869	996		1865			
	Total	66	558	489	21	1134			1502	1384		2886		703	254
1998	1	194	246	333	22	795			67	281		348			
	2	50	230	232	3	515				619		619			
	Total	244	476	566	25	1310			67	900		967		259	74
1999	1	176	160	222	24	582			150			150			
	2	90	340	284	7	720			268	116		384			
	Total	267	499	506	31	1303			418	116		534		78	41
2000	1	343	442	522	50	1357		464	642	2831	231	4168			
	2	109	471	485	17	1082		102	916	1155		2173			
	Total	452	913	1007	66	2439		566	1558	3986	231	6341		1423	260
2001	1	315	380	382	27	1104		105	218	344		667			
	2	159	611	491	18	1278		534	727	774		2035			
	Total	474	990	873	44	2381		639	945	1118		2702		630	113
2002	1	181	322	187	21	711		304	496	764		1564			
	2	173	596	542	35	1346		225	1098	1646	101	3070			
	Total	354	918	729	56	2057		529	1594	2410	101	4634		1131	225
2003	1	349	264	283	15	910		565	416	1188	133	2302			
	2	234	390	280	19	923		421	1572	1424	574	3991			
	Total	583	654	562	35	1834		986	1988	2612	707	6293		1479	343
2004	1	168	160	143	30	501		263	574	778	679	2294			
	2	73	151	176	12	412		162	267	349	120	898			
	Total	241	311	320	42	913		425	841	1127	799	3192		794	350
2005	1	102	169	116	0	388		2007	186	540		2733			
	2	88	146	92	2	327		667	409	618		1694			
	Total	190	314	208	2	715		2674	595	1158		4427		858	619
2006	1	63	150	96	1	310		214	187	581		982			
	2	57	105	62	0	225		93	1257	1883		3233			
	Total	119	255	158	1	534		307	1444	2464		4215		1029	789
2007	1	59	128	53	1	241		564	295	732		1591			
	2	45	118	79	0	242		350	2631	2282		5263			
	Total	104	245	133	2	483		914	2926	3014		6854		1484	1419
Grand Total		3374	7827	7214	375	18791		7158	15674	21834	1838	46504		10737	247

Table E3. Cape Cod-Gulf of Maine yellowtail flounder coefficient of variation for landings at age by year.

Year	age 1	age 2	age 3	age 4	age 5	age 6+
1994		46%	11%	17%	33%	22%
1995		53%	18%	15%	31%	51%
1996		32%	7%	18%	51%	76%
1997		15%	10%	14%	30%	47%
1998		54%	6%	21%	33%	
1999		53%	13%	22%	111%	128%
2000		13%	5%	7%	27%	41%
2001		19%	5%	17%	30%	48%
2002	73%	13%	6%	11%	26%	55%
2003		16%	6%	8%	21%	30%
2004		28%	8%	8%	19%	28%
2005		20%	6%	8%	18%	32%
2006		15%	9%	9%	35%	25%
2007		10%	4%	7%	24%	35%

Table E4. Cape Cod-Gulf of Maine yellowtail flounder discards (metric tons) and coefficient of variation by gear and year.

	Otter Trawl Large Mesh		Otter Trawl Small Mesh		Scallop Dredge		Gillnet	
Year	D (mt)	CV	D (mt)	CV	D (mt)	CV	D (mt)	CV
1994	3	58%	13	0%	163	15%	30	141%
1995	32	91%	7	47%	32	11%	76	56%
1996	121	98%	2	51%	148	40%	64	70%
1997	27	35%	9	3%	354	29%	162	47%
1998	33	67%	3	0%	228	9%	48	51%
1999	91	36%	0	27%	27	19%	31	43%
2000	53	48%	2	44%	27	12%	67	58%
2001	127	30%	1	43%	98	7%	13	41%
2002	70	20%	6	53%	13	10%	11	40%
2003	88	28%	1	95%	24	7%	22	58%
2004	220	28%	5	47%	17	3%	32	17%
2005	225	24%	1	36%	4	43%	51	56%
2006	68	29%	3	21%	4	18%	9	89%
2007	81	19%	10	21%	34	59%	19	50%

Table E5a. Cape Cod-Gulf of Maine yellowtail flounder landings at age (thousands of fish).

Year	age 1	age 2	age 3	age 4	age 5	age 6+
1985	6	876	839	635	329	121
1986	0	2232	695	273	40	8
1987	0	684	2101	309	116	53
1988	1	918	1281	744	199	41
1989	0	838	1284	287	38	9
1990	0	717	6663	472	35	28
1991	0	361	1065	1718	291	74
1992	0	410	1030	644	188	14
1993	0	34	868	723	110	54
1994	0	107	1365	668	198	108
1995	0	379	1442	1136	176	170
1996	0	448	1911	426	49	8
1997	0	630	1175	632	119	13
1998	0	51	1896	575	134	0
1999	0	511	2028	379	26	7
2000	0	925	2773	1355	127	30
2001	0	942	3317	822	144	24
2002	20	997	2338	885	107	34
2003	0	614	1930	1151	148	70
2004	0	86	1182	453	227	66
2005	0	100	759	523	80	45
2006	0	106	506	351	76	53
2007	0	115	512	341	54	14

Table E5b. Cape Cod-Gulf of Maine yellowtail flounder discards at age (thousands of fish).

Year	age 1	age 2	age 3	age 4	age 5	age 6+
1985	681	369	68	0	0	0
1986	95	1993	90	32	0	0
1987	19	1201	230	0	0	0
1988	451	1664	221	0	0	0
1989	118	1459	528	11	0	0
1990	84	2180	2738	21	0	0
1991	465	1011	700	234	7	0
1992	1709	3569	930	87	3	0
1993	159	391	206	72	0	0
1994	19	710	332	47	11	1
1995	37	147	335	52	3	0
1996	26	339	516	219	55	0
1997	8	850	831	215	61	7
1998	38	443	616	75	18	3
1999	9	231	265	18	6	0
2000	2	189	209	52	6	5
2001	20	400	404	27	0	0
2002	37	207	111	21	1	0
2003	10	245	193	49	4	0
2004	13	389	412	118	15	9
2005	15	394	502	63	2	3
2006	7	84	156	39	7	0
2007	14	158	221	69	18	0

Table E5c. Cape Cod-Gulf of Maine yellowtail flounder catch at age (thousands of fish).

Year	age 1	age 2	age 3	age 4	age 5	age 6+
1985	686	1245	907	635	329	121
1986	95	4225	785	304	40	8
1987	19	1885	2331	309	116	53
1988	452	2582	1503	744	199	41
1989	118	2297	1812	298	38	9
1990	84	2897	9400	493	35	28
1991	465	1372	1765	1953	298	74
1992	1709	3979	1961	731	191	14
1993	159	425	1074	795	111	54
1994	19	817	1697	716	210	109
1995	37	526	1777	1188	178	170
1996	26	787	2428	645	104	9
1997	8	1480	2007	847	180	20
1998	38	495	2512	650	152	3
1999	9	743	2292	397	32	7
2000	2	1114	2981	1408	133	35
2001	20	1342	3721	849	145	24
2002	58	1204	2449	905	109	34
2003	10	859	2122	1200	152	70
2004	13	475	1594	571	243	75
2005	15	494	1262	585	82	48
2006	7	189	662	390	84	54
2007	14	274	732	410	71	14

Table E6. Cape Cod-Gulf of Maine yellowtail flounder catch weight at age (kg).

Year	age 1	age 2	age 3	age 4	age 5	age 6+
1985	0.132	0.266	0.357	0.489	0.600	0.786
1986	0.103	0.250	0.428	0.534	0.730	0.996
1987	0.056	0.232	0.393	0.548	0.652	0.916
1988	0.123	0.206	0.338	0.523	0.696	0.841
1989	0.129	0.270	0.383	0.650	0.928	1.317
1990	0.079	0.254	0.370	0.550	0.824	0.970
1991	0.124	0.236	0.342	0.517	0.737	1.021
1992	0.053	0.135	0.325	0.498	0.602	1.169
1993	0.089	0.160	0.358	0.418	0.737	0.999
1994	0.089	0.174	0.354	0.512	0.674	0.904
1995	0.055	0.307	0.340	0.422	0.643	0.790
1996	0.109	0.266	0.383	0.462	0.609	1.266
1997	0.145	0.278	0.369	0.478	0.615	0.865
1998	0.079	0.209	0.393	0.609	0.856	0.707
1999	0.148	0.344	0.406	0.604	0.601	0.801
2000	0.101	0.349	0.432	0.566	0.623	0.835
2001	0.226	0.344	0.412	0.573	0.765	0.898
2002	0.218	0.362	0.440	0.565	0.774	1.042
2003	0.087	0.322	0.415	0.535	0.672	0.945
2004	0.077	0.251	0.372	0.460	0.609	0.831
2005	0.062	0.261	0.369	0.514	0.694	0.921
2006	0.106	0.305	0.392	0.478	0.781	0.926
2007	0.036	0.282	0.397	0.492	0.630	0.855

Table E7a. NEFSC Spring survey indices of minimum swept area abundance for Cape Cod-Gulf of Maine yellowtail flounder in 000s of fish and metric tons.

Year	age 1	age 2	age 3	age 4	age 5	age 6+	B (mt)
1985	18.1	310.9	334.0	80.7	49.9	12.7	237.3
1986	6.3	692.5	76.5	52.8	38.4	0.0	181.6
1987	20.5	524.5	773.5	208.9	177.0	487.2	975.5
1988	345.6	1459.2	355.9	197.8	103.6	59.4	415.7
1989	58.2	714.8	473.2	122.1	127.3	0.0	283.0
1990	0.0	727.5	2025.3	81.7	0.0	32.6	639.2
1991	136.7	1167.4	945.7	327.1	74.1	15.4	585.0
1992	59.7	353.0	708.2	192.4	7.0	0.0	295.1
1993	24.5	253.0	403.4	217.3	0.0	0.0	193.3
1994	113.8	863.0	517.7	310.4	197.9	66.6	393.9
1995	70.4	401.2	1535.5	1163.6	157.3	18.4	785.9
1996	5.7	211.1	552.1	775.3	129.3	0.0	427.7
1997	8.1	360.4	781.4	596.5	111.2	0.0	506.1
1998	0.0	279.7	1135.6	347.9	55.4	0.0	445.7
1999	6.8	327.2	1402.4	715.3	128.2	56.7	763.1
2000	26.9	3717.7	6558.6	911.5	64.3	32.2	3669.2
2001	0.0	463.4	1882.8	397.4	83.3	0.0	882.5
2002	5.8	603.3	2729.3	1259.0	82.3	20.0	1425.2
2003	36.1	333.3	928.4	678.6	303.9	9.8	737.6
2004	141.7	230.4	1010.1	138.4	54.2	0.0	415.0
2005	34.3	224.7	1474.6	495.6	0.0	0.0	546.1
2006	52.0	429.4	1319.7	466.0	36.6	12.9	489.8
2007	19.5	836.8	2410.2	1648.8	82.5	0.0	1334.3
2008	90.0	670.7	3017.5	656.2	56.9	17.8	1141.6

Table E7b. NEFSC Fall survey indices of minimum swept area abundance for Cape Cod-Gulf of Maine yellowtail flounder in 000s of fish and metric tons.

Year	age 1	age 2	age 3	age 4	age 5	age 6+	B (mt)
1985	1482.0	568.3	483.1	0.0	0.0	0.0	502.0
1986	398.5	1108.1	97.5	0.0	0.0	0.0	291.8
1987	181.6	436.4	160.8	14.6	11.9	0.0	178.9
1988	1006.1	1475.7	142.5	43.2	0.0	0.0	362.2
1989	474.0	1408.6	609.3	83.8	57.9	0.0	602.0
1990	957.0	1695.7	785.8	12.4	2.7	0.0	641.1
1991	503.0	449.2	448.3	90.8	0.0	0.0	328.8
1992	810.3	887.2	604.1	305.0	58.9	45.8	621.5
1993	1215.6	1232.5	164.2	27.1	0.0	0.0	302.4
1994	795.3	2370.2	835.3	265.1	114.0	0.0	868.8
1995	179.3	218.2	345.7	91.1	55.1	0.0	251.8
1996	340.5	935.1	1585.2	379.3	42.9	0.0	841.0
1997	337.5	799.8	950.5	403.1	187.7	37.0	732.6
1998	328.6	959.8	385.0	317.1	75.2	0.0	526.6
1999	1324.0	2602.6	1777.8	544.0	228.1	8.7	1924.7
2000	287.9	2183.9	1443.4	73.6	0.0	0.0	1116.9
2001	43.3	1227.9	730.1	30.4	0.0	0.0	608.3
2002	128.5	458.0	180.3	48.9	6.2	0.0	227.6
2003	192.0	2822.8	593.9	139.6	81.2	0.0	1107.9
2004	76.2	371.3	202.1	7.8	0.0	0.0	157.9
2005	533.7	425.2	174.6	21.2	0.0	0.0	200.2
2006	780.3	487.2	273.8	22.0	0.0	0.0	259.4
2007	119.9	2095.7	1539.5	490.7	40.1	0.0	1110.1

Table E7c. MADMF Spring survey indices of minimum swept area abundance for Cape Cod-Gulf of Maine yellowtail flounder in 000s of fish and metric tons.

Year	age 1	age 2	age 3	age 4	age 5	age 6+	B (mt)
1985	497.0	2105.0	1908.9	411.9	120.2	92.2	1330.9
1986	501.9	4329.5	464.1	68.5	19.2	15.3	1208.0
1987	681.0	1275.2	1346.4	267.2	69.3	40.7	937.2
1988	813.9	3487.9	665.1	183.8	0.0	11.2	960.3
1989	203.4	4953.0	910.6	252.1	12.0	0.0	1128.0
1990	260.0	2752.2	4106.5	176.7	38.0	9.0	1734.3
1991	15.7	1211.3	822.4	509.7	111.9	36.9	781.6
1992	323.2	2204.8	2112.5	559.5	359.6	20.7	1467.0
1993	188.2	1625.2	1489.1	495.5	62.2	79.9	1088.6
1994	607.6	5237.6	1739.9	357.4	82.0	26.5	1416.7
1995	1659.1	2801.8	5042.4	635.8	253.9	5.7	2123.2
1996	290.1	3230.8	2758.7	1419.0	393.6	14.6	1805.8
1997	133.1	2988.6	2082.4	724.2	87.2	0.0	1298.3
1998	157.7	841.1	2369.4	228.6	38.7	4.4	916.7
1999	65.1	1290.6	2134.2	239.8	17.8	0.0	309.3
2000	158.5	3766.2	5789.5	1941.2	238.9	82.7	2073.2
2001	32.2	1681.2	6305.2	1739.3	280.3	0.0	1075.0
2002	115.8	296.3	3236.1	1244.8	58.5	40.7	586.2
2003	12.7	1873.4	1796.1	1977.9	301.7	11.9	748.0
2004	42.4	608.2	1987.9	978.5	124.1	5.1	1093.3
2005	92.1	1537.7	3878.1	1018.3	19.0	6.4	1745.8
2006	167.3	1648.9	5100.0	1370.4	60.5	25.2	2249.5
2007	127.1	3237.2	4743.2	1731.2	182.7	0.0	2527.2

Table E7d. MADMF Fall survey indices of minimum swept area abundance for Cape Cod-Gulf of Maine yellowtail flounder in 000s of fish and metric tons.

Year	age 1	age 2	age 3	age 4	age 5	age 6+	B (mt)
1985	1564.3	447.5	282.7	0.0	0.0	4.9	358.8
1986	712.5	1357.1	55.5	9.1	2.0	0.0	375.5
1987	1605.9	629.6	135.1	19.4	5.5	0.0	289.3
1988	2457.5	3083.3	622.7	41.3	0.0	0.0	1074.2
1989	723.4	1431.2	263.4	28.3	0.0	0.0	400.9
1990	1425.3	3273.6	1327.8	1.6	0.0	0.0	942.1
1991	1031.0	1409.6	1379.1	235.1	0.0	0.0	629.9
1992	1968.6	993.5	569.5	129.3	55.6	0.0	524.7
1993	2301.8	1998.7	1591.4	393.0	0.0	0.0	831.3
1994	562.2	2375.3	349.2	36.1	0.0	0.0	650.1
1995	2356.2	3484.5	1235.5	0.0	0.0	0.0	1278.4
1996	468.3	815.5	463.4	32.8	0.0	0.0	325.1
1997	274.7	1410.3	171.3	21.7	12.6	0.0	378.5
1998	1617.8	1438.8	464.0	0.0	0.0	0.0	570.5
1999	1296.7	2669.9	846.5	134.8	16.5	0.0	557.4
2000	317.1	1825.2	808.5	56.1	23.9	8.6	366.0
2001	188.4	1638.3	868.6	29.7	0.0	0.0	338.9
2002	427.3	178.9	626.4	250.7	9.9	0.0	140.3
2003	151.1	1612.4	856.7	655.8	16.0	0.0	533.2
2004	638.2	2381.7	1743.6	522.6	2.5	0.0	1198.3
2005	242.1	1165.0	1047.0	56.2	0.0	0.0	545.0
2006	343.3	1370.4	1044.4	112.0	0.0	0.0	691.5
2007	105.1	1206.5	931.8	155.7	0.0	0.0	611.0

Table E7e. MENH Spring survey indices of abundance (stratified mean catch/tow) for Cape Cod-Gulf of Maine yellowtail flounder.

Year	age 1	age 2	age 3	age 4	age 5	age 6+
2001	0.000	0.599	2.087	0.535	0.132	0.000
2002	0.000	0.226	1.981	0.845	0.048	0.041
2003	0.000	0.473	0.805	0.850	0.114	0.000
2004	0.000	0.151	1.241	0.492	0.039	0.000
2005	0.021	0.287	1.107	0.280	0.003	0.000
2006	0.000	0.148	0.560	0.152	0.014	0.003
2007	0.000	0.859	2.661	1.071	0.129	0.000

Table E7f. MENH Fall survey indices of abundance (stratified mean catch/tow) for Cape Cod-Gulf of Maine yellowtail flounder.

Year	age 1	age 2	age 3	age 4	age 5	age 6+
2000	0.053	1.799	0.640	0.030	0.010	0.000
2001	0.062	0.907	0.419	0.011	0.000	0.000
2002	0.000	0.202	0.560	0.177	0.005	0.000
2003	0.000	0.950	0.334	0.258	0.000	0.000
2004	0.032	1.374	0.780	0.184	0.000	0.000
2005	0.000	0.252	0.212	0.000	0.000	0.000
2006	0.000	0.121	0.120	0.002	0.000	0.000

Table E8. Diagnostics for VPA estimates.

Stock Numbers Predicted in Terminal Year Plus One (2008)

Age	N	Std. Error	CV
2	2886	1221	0.42
3	6575	2032	0.31
4	2295	692	0.30
5	615	189	0.31

Catchability Values for Each Survey Used in Estimate

INDEX	Catchability	Std. Error	CV
NEFSC_S 1	0.004	0.001	0.257
NEFSC_S 2	0.090	0.011	0.126
NEFSC_S 3	0.283	0.041	0.146
NEFSC_S 4	0.348	0.057	0.164
NEFSC_S 5	0.413	0.095	0.230
NEFSC_S 6	0.393	0.154	0.393
NEFSC_F 1	0.059	0.010	0.164
NEFSC_F 2	0.206	0.028	0.136
NEFSC_F 3	0.231	0.034	0.149
NEFSC_F 4	0.166	0.049	0.292
NEFSC_F 5	0.549	0.216	0.393
MADMF_S 1	0.023	0.006	0.239
MADMF_S 2	0.341	0.044	0.129
MADMF_S 3	0.663	0.087	0.132
MADMF_S 4	0.587	0.098	0.167
MADMF_S 5	0.503	0.084	0.166
MADMF_S 6	0.350	0.099	0.284
MADMF_F 1	0.106	0.018	0.172
MADMF_F 2	0.306	0.045	0.146
MADMF_F 3	0.302	0.051	0.170
MADMF_F 4	0.134	0.043	0.318
MADMF_F 5	0.123	0.050	0.408
MENH_S 2	6.61E-05	1.22E-05	0.184
MENH_S 3	4.03E-04	5.82E-05	0.144
MENH_S 4	5.01E-04	8.64E-05	0.173
MENH_S 5	2.20E-04	1.02E-04	0.462
MENH_F 2	1.35E-04	5.22E-05	0.387
MENH_F 3	1.89E-04	4.17E-05	0.220
MENH_F 4	8.05E-05	6.01E-05	0.747

Table E9. Mohn's rho retrospective statistic for F, SSB, and R.

Peel	F	SSB	R
2000	-56%	67%	-45%
2001	-18%	19%	-75%
2002	-22%	-11%	-31%
2003	14%	-15%	-40%
2004	56%	4%	21%
2005	12%	12%	-10%
2006	-8%	18%	-2%
Average	**-3%**	**13%**	**-26%**

Table E10. Estimated population abundance at age (000s).

Year	age 1	age 2	age 3	age 4	age 5	age 6+	sum
1985	11698	3324	1736	777	403	148	18086
1986	5778	8959	1607	613	81	16	17053
1987	8201	4645	3563	615	231	106	17360
1988	23080	6697	2116	853	228	47	33021
1989	8673	18488	3172	406	52	12	30803
1990	7361	6994	13067	985	70	56	28534
1991	9443	5951	3135	2407	367	91	21394
1992	7880	7311	3639	997	261	19	20107
1993	5956	4915	2444	1233	172	84	14804
1994	6707	4733	3640	1041	305	158	16585
1995	5709	5474	3139	1465	220	210	16217
1996	7197	4641	4007	990	160	14	17008
1997	7558	5869	3091	1125	239	27	17909
1998	7842	6181	3475	753	176	3	18430
1999	9755	6386	4614	630	51	11	21446
2000	8849	7978	4559	1733	164	43	23325
2001	6428	7243	5528	1092	187	31	20509
2002	5264	5245	4722	1235	149	46	16661
2003	3905	4257	3212	1684	213	98	13370
2004	3947	3188	2713	751	320	99	11018
2005	5653	3220	2182	805	113	66	12040
2006	10185	4615	2191	665	143	92	17892
2007	3540	8332	3608	1200	198	51	16929
2008	7211	2886	6575	2295	615	142	19724

Table E11. Estimated fishing mortality rate at age.

Year	age 1	age 2	age 3	age 4	age 5	age 6+
1985	0.07	0.53	0.84	2.07	2.07	2.07
1986	0.02	0.72	0.76	0.78	0.78	0.78
1987	0.00	0.59	1.23	0.79	0.79	0.79
1988	0.02	0.55	1.45	2.60	2.60	2.60
1989	0.02	0.15	0.97	1.56	1.56	1.56
1990	0.01	0.60	1.49	0.79	0.79	0.79
1991	0.06	0.29	0.95	2.02	2.02	2.02
1992	0.27	0.90	0.88	1.56	1.56	1.56
1993	0.03	0.10	0.65	1.20	1.20	1.20
1994	0.00	0.21	0.71	1.36	1.36	1.36
1995	0.01	0.11	0.95	2.02	2.02	2.02
1996	0.00	0.21	1.07	1.22	1.22	1.22
1997	0.00	0.32	1.21	1.66	1.66	1.66
1998	0.01	0.09	1.51	2.50	2.50	2.50
1999	0.00	0.14	0.78	1.15	1.15	1.15
2000	0.00	0.17	1.23	2.03	2.03	2.03
2001	0.00	0.23	1.30	1.79	1.79	1.79
2002	0.01	0.29	0.83	1.56	1.56	1.56
2003	0.00	0.25	1.25	1.46	1.46	1.46
2004	0.00	0.18	1.02	1.70	1.70	1.70
2005	0.00	0.18	0.99	1.53	1.53	1.53
2006	0.00	0.05	0.40	1.01	1.01	1.01
2007	0.00	0.04	0.25	0.47	0.36	0.36

Table E12. Estimated spawning stock biomass (mt).

Year	age 1	age 2	age 3	age 4	age 5	age 6+	sum
1985	0	112	335	144	94	45	730
1986	0	261	384	213	39	11	908
1987	0	133	643	218	100	64	1157
1988	0	173	300	136	49	12	670
1989	0	739	622	124	23	8	1515
1990	0	217	1990	351	38	36	2633
1991	0	196	554	481	107	37	1375
1992	0	107	628	233	75	11	1054
1993	0	119	511	282	71	47	1029
1994	0	119	735	272	108	75	1308
1995	0	252	550	240	56	66	1164
1996	0	178	753	247	54	10	1242
1997	0	224	527	243	68	11	1073
1998	0	196	558	146	49	1	949
1999	0	326	1038	212	17	5	1599
2000	0	409	904	379	40	14	1746
2001	0	356	1016	266	62	12	1713
2002	0	265	1126	328	55	23	1797
2003	0	194	606	440	72	46	1359
2004	0	117	507	153	88	37	902
2005	0	122	409	197	38	30	796
2006	0	217	557	187	68	51	1080
2007	0	364	988	437	99	34	1922

Table E13a. Bootstrap estimates of uncertainty in 2007 F at age and spawning stock biomass.

	Point	10th%ile	90th%ile
F 2007			
age 1	0.004	0.003	0.007
age 2	0.037	0.027	0.051
age 3	0.252	0.193	0.338
age 4	0.468	0.330	0.682
age 5	0.360	0.285	0.482
age 6+	0.360	0.285	0.482
Avg F 4-5	0.414	0.312	0.578
SSB	1922	1592	2354

Table E13b. Mohn's rho adjusted estimates of F and spawning stock biomass in 2007.

F adj	0.427
SSB adj.	1701

Table E14. Values for partial recruitment, maturity, and weight at age (kg) used in yield per recruit calculations and age based projections.

Age	PR	Maturity	WAA
1	0.0024	0.000	0.074
2	0.1145	0.171	0.284
3	0.6420	0.833	0.389
4	1.0000	0.977	0.496
5	1.0000	1.000	0.677
6+	1.0000	1.000	0.896

Table E15. Biological reference points for Cape Cod-Gulf of Maine yellowtail flounder from GARM II, GARM III Reference Points meeting, and this assessment.

	GARM II	GARM III BRP	GARM III Final
Fmsy	0.17	0.238	0.239
SSBmsy (mt)	12600	8310	7790
MSY (mt)	2300	1820	1720

Table E16. Three projections for 2009 catch all of which assume catch in 2008 equal to catch in 2007: $F_{STATUS\ QUO}$ applied F2007 in 2009; F_{MSY} applies F_{MSY} in 2009; and $F_{REBUILD}$ is solved iteratively to produce 50% probability of SSB> SSB_{MSY} in 2023 when the F is applied every year from 2009 to 2023.

	2007	2008	2009		
			F st quo	Fmsy	$F_{REBUILD}$
C (mt)	627	627	1457	904	900
F (4-5)	0.4144	0.218	0.4144	0.239	0.238
SSB (mt)	1922	3407	3825	4076	4078

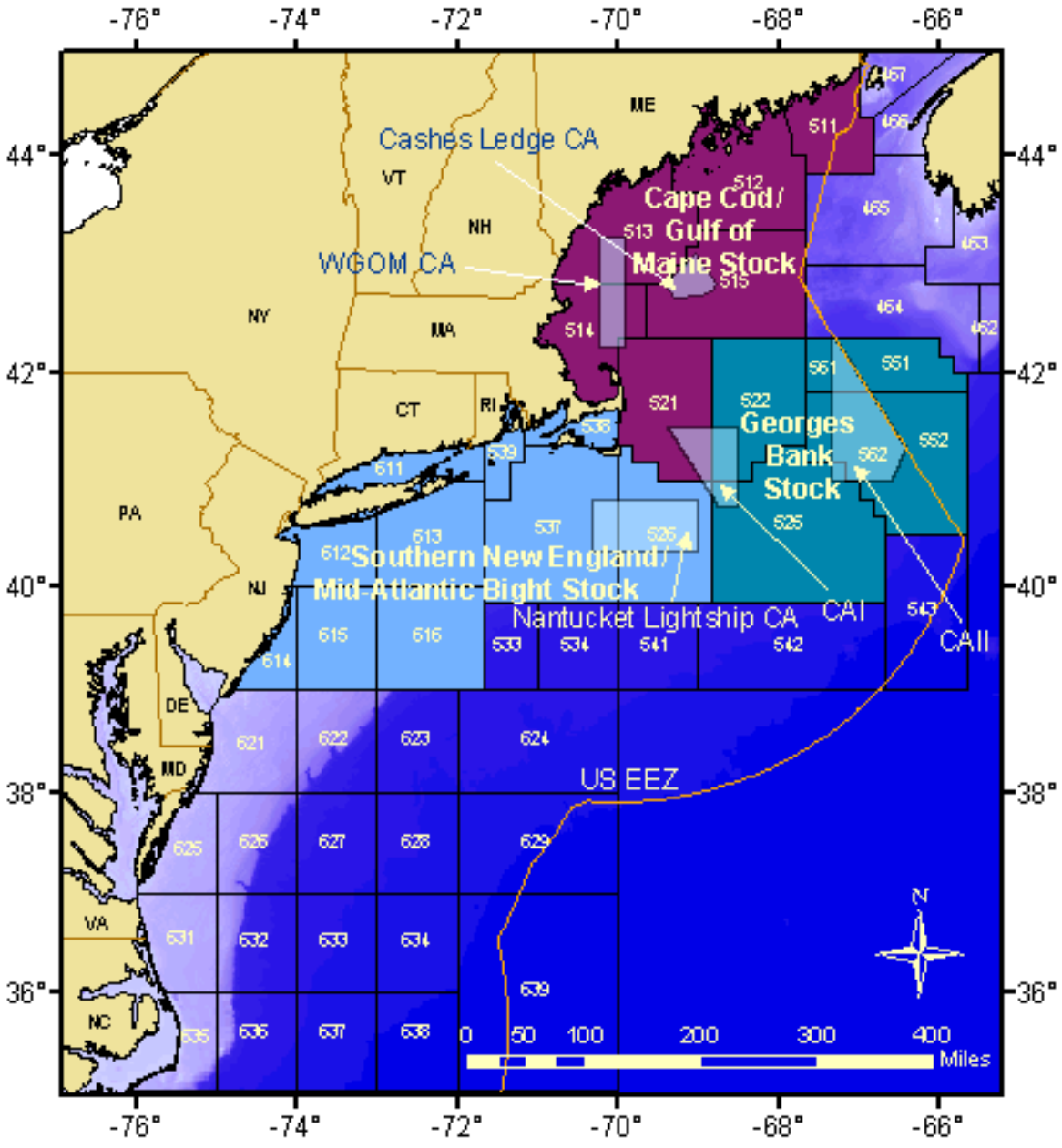


Figure E1. Stock area map for yellowtail flounder from Status of Stocks website (http://www.nefsc.noaa.gov/sos/).

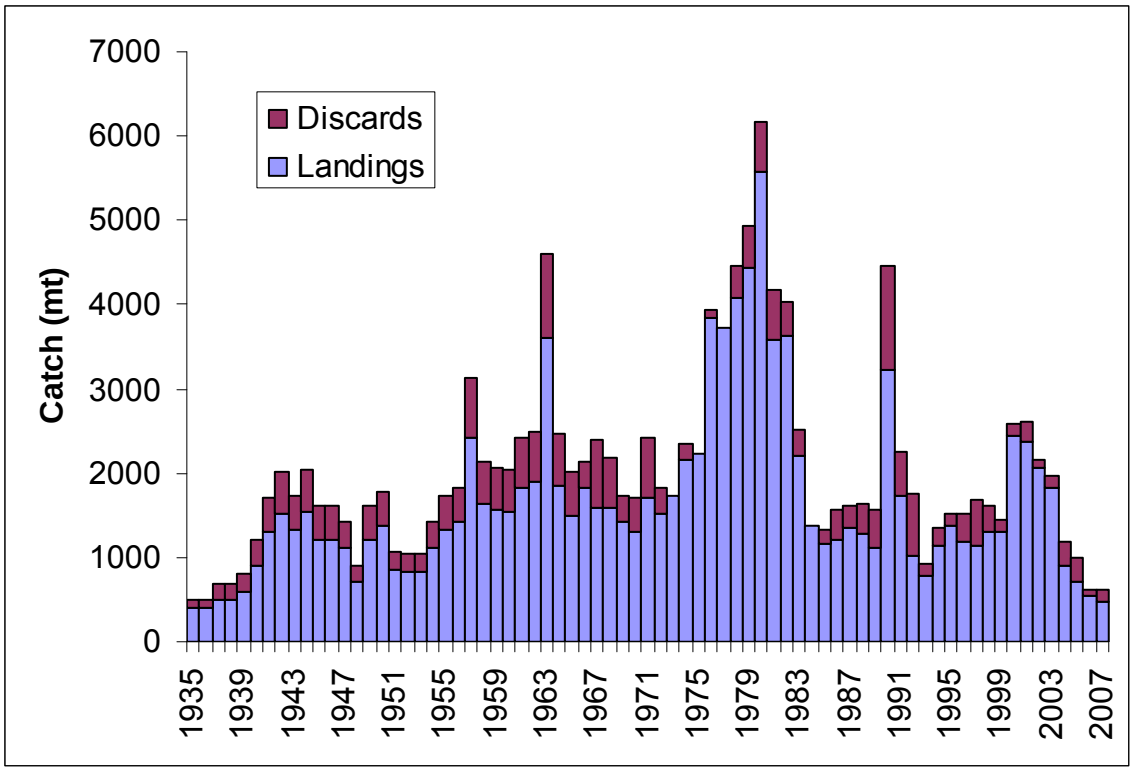


Figure E2. Catch (mt) of Cape Cod-Gulf of Maine yellowtail flounder.

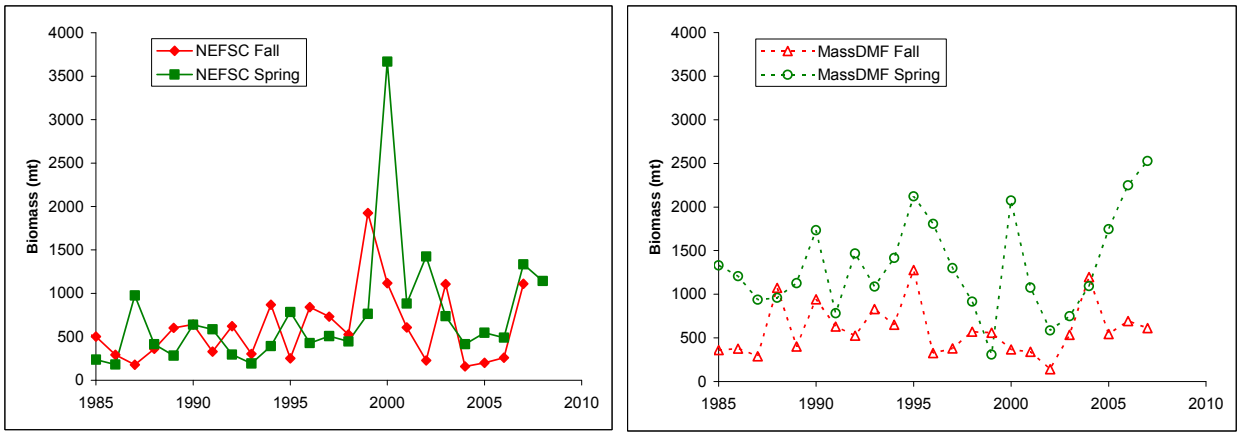
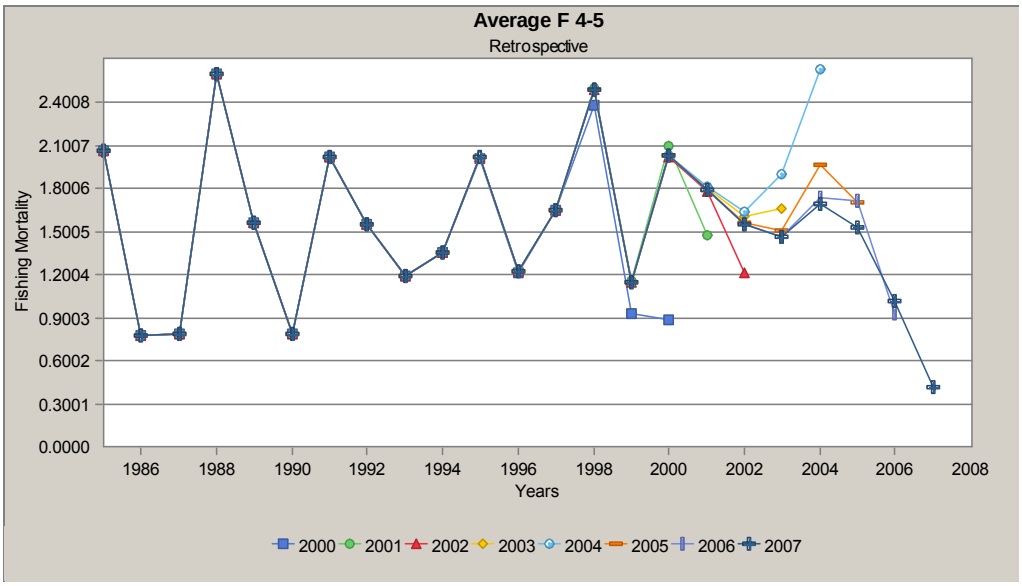


Figure E3. Trends in survey biomass for Cape Cod-Gulf of Maine yellowtail flounder.



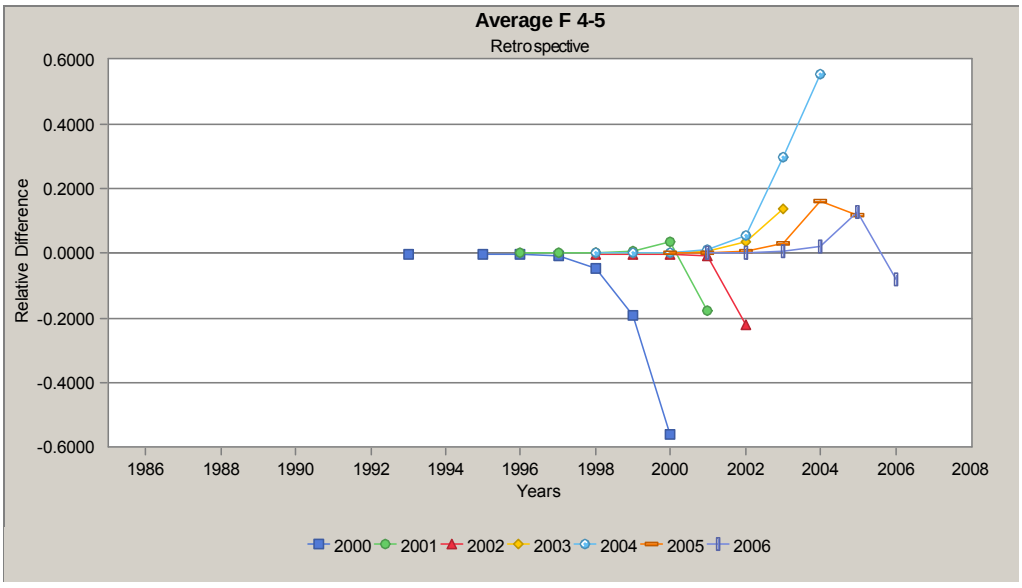
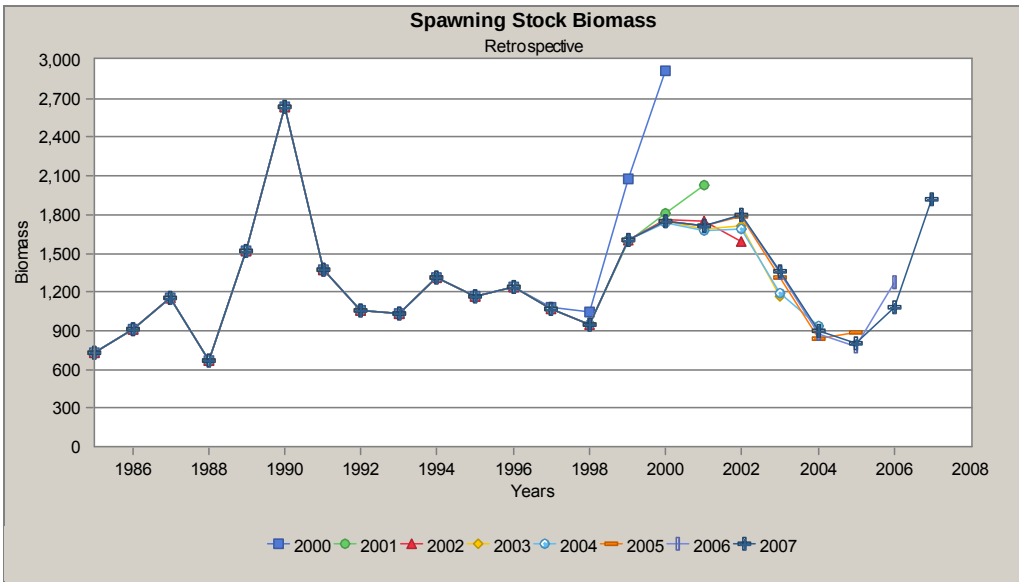


Figure E4. Retrospective plots of fully recruited fishing mortality rate (ages 4-5).



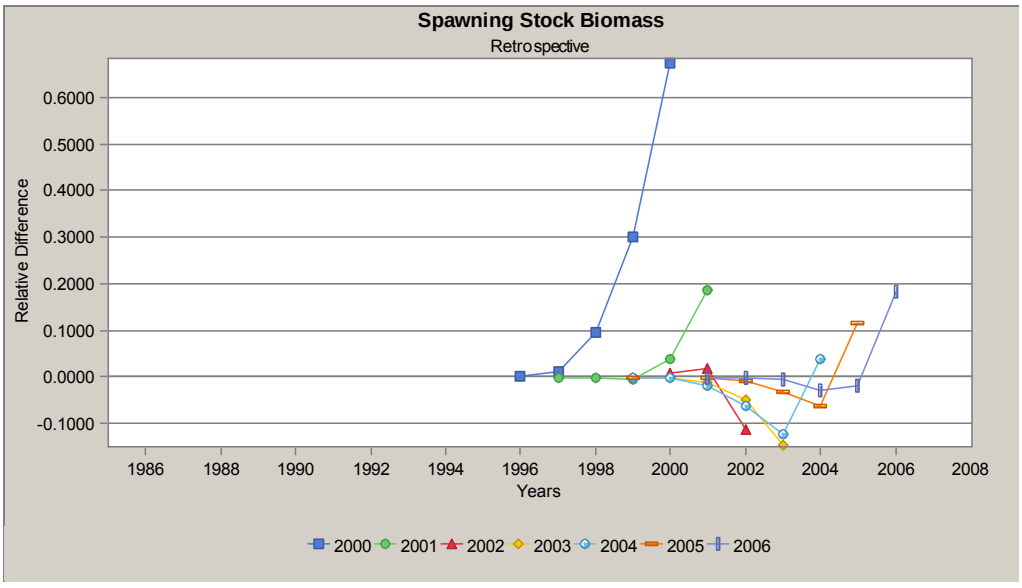
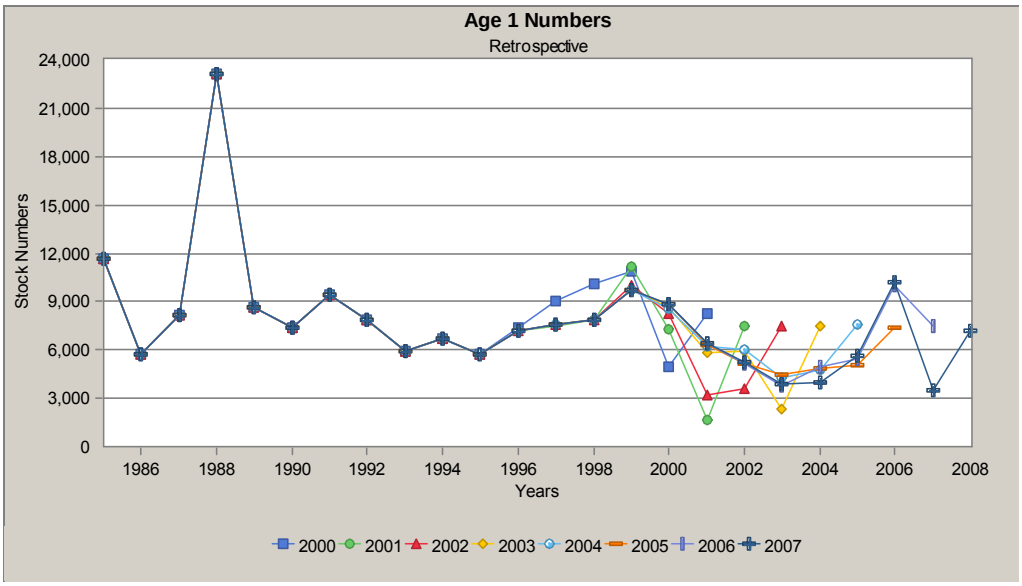


Figure E5. Retrospective plots of spawning stock biomass.



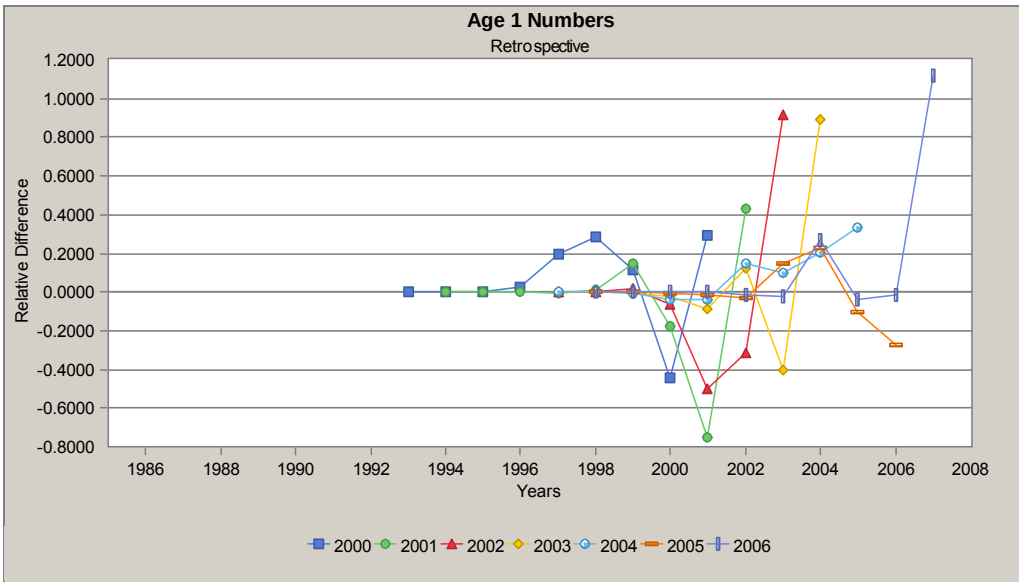


Figure E6. Retrospective plots of recruitment.

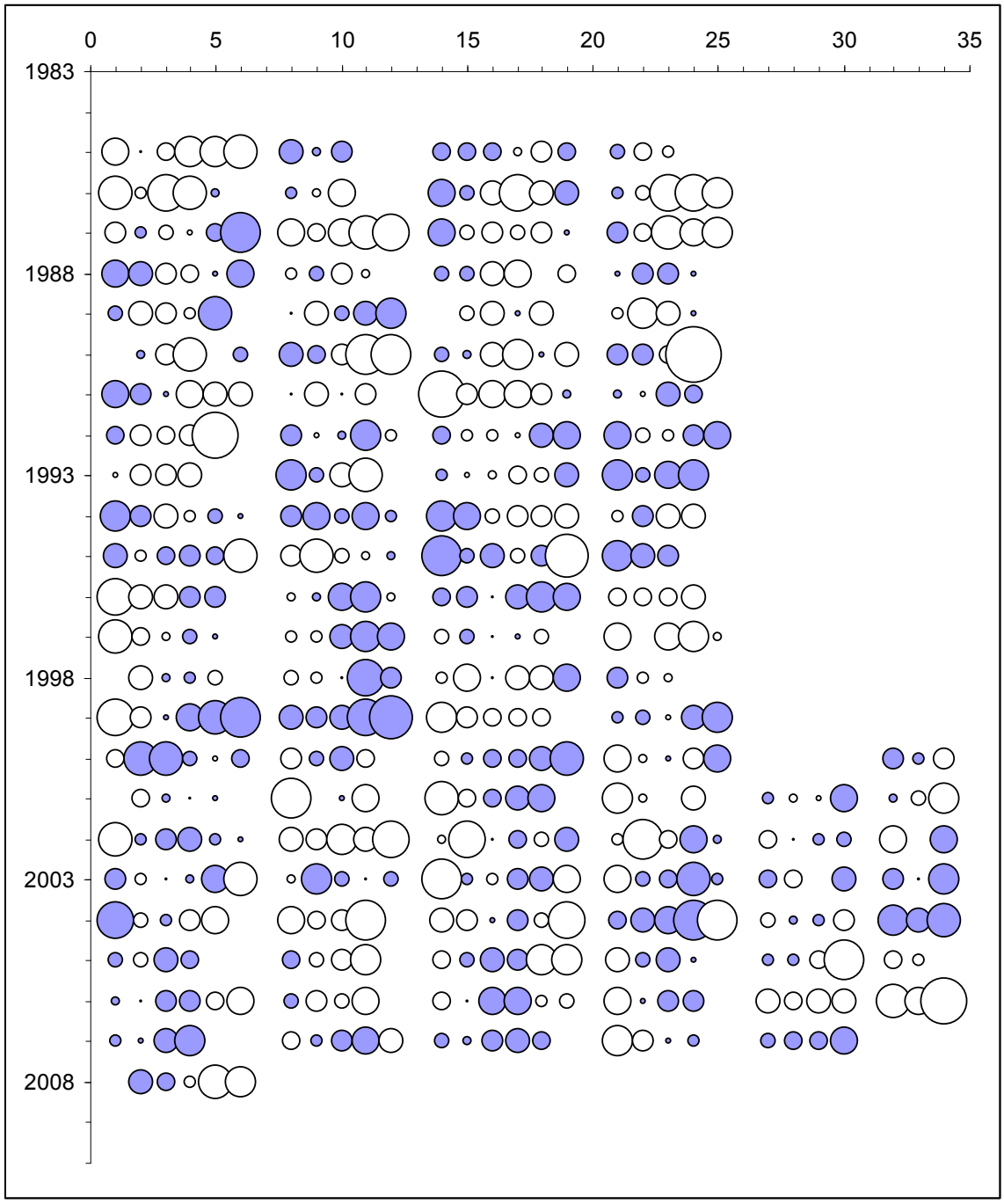


Figure E7. Residuals for indices of abundance in VPA grouped by survey: columns 1-6 are NEFSC Spring ages 1-6, columns 8-12 are NEFSC Fall ages 1-5, columns 14-19 are MADMF Spring ages 1-6, columns 21-25 are MADMF Fall ages 1-5, columns 27-30 are MENH Spring ages 2-5, and columns 32-34 are MENH Fall ages 2-4.

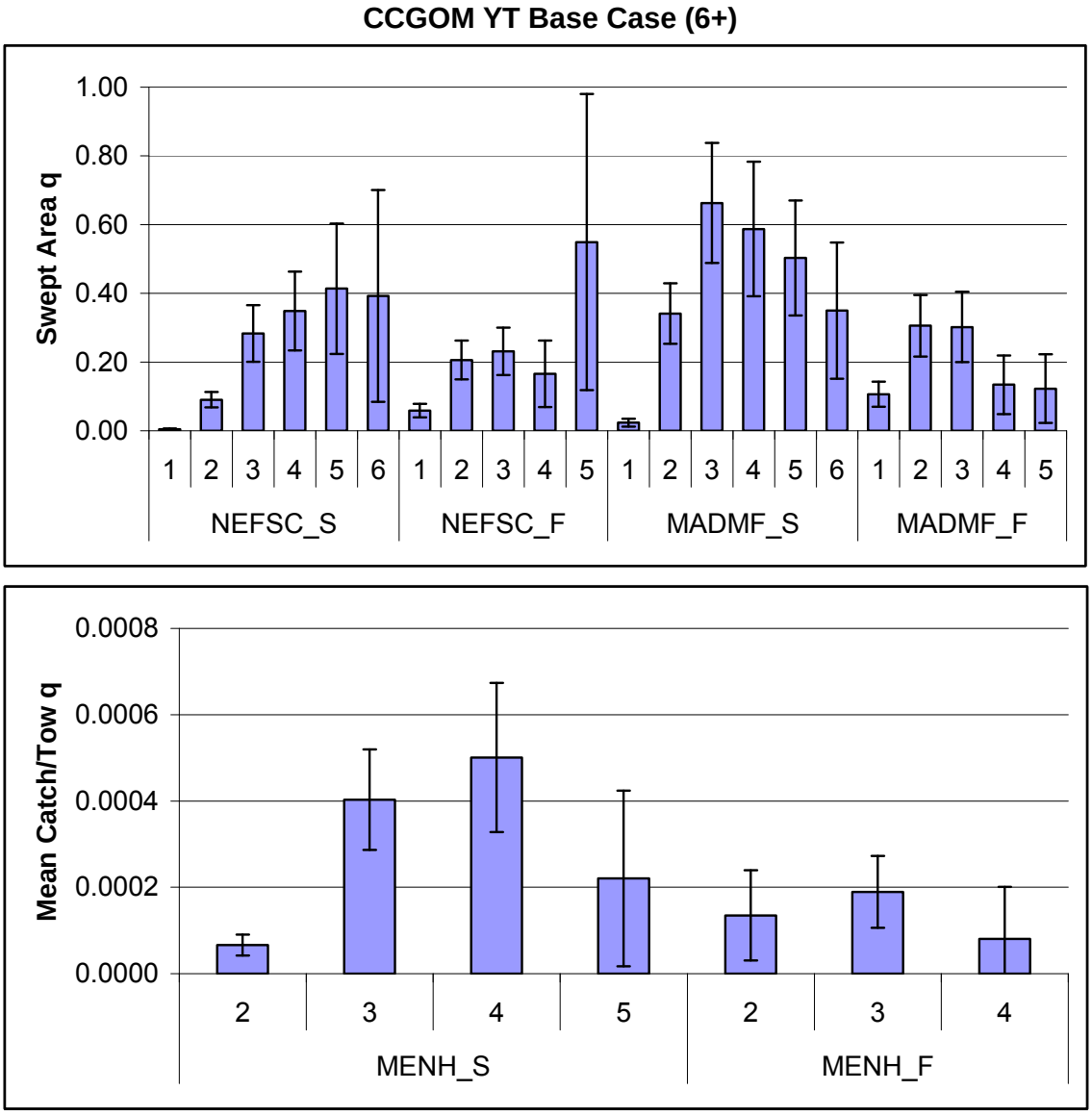


Figure E8. Catchability estimates with plus and minus two standard deviations for swept area indices (top panel, q is interpretable) and mean catch per tow (bottom panel, q is not directly interpretable).

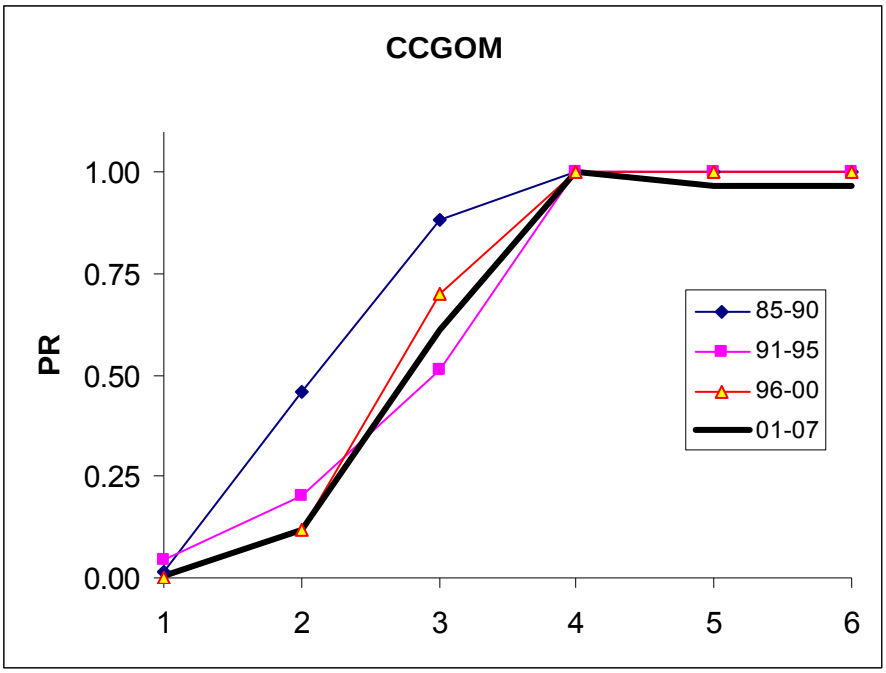


Figure E9. Average back-calculated partial recruitment from VPA showing age 3 PR is well below 1.0 in recent years.

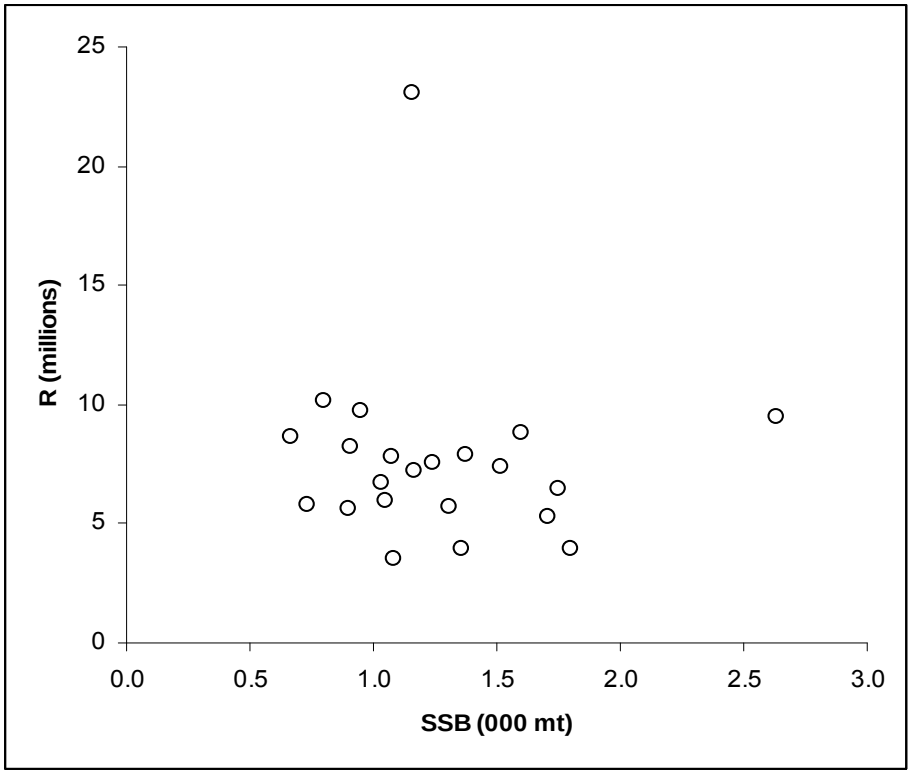


Figure E10. Stock recruitment relationship.

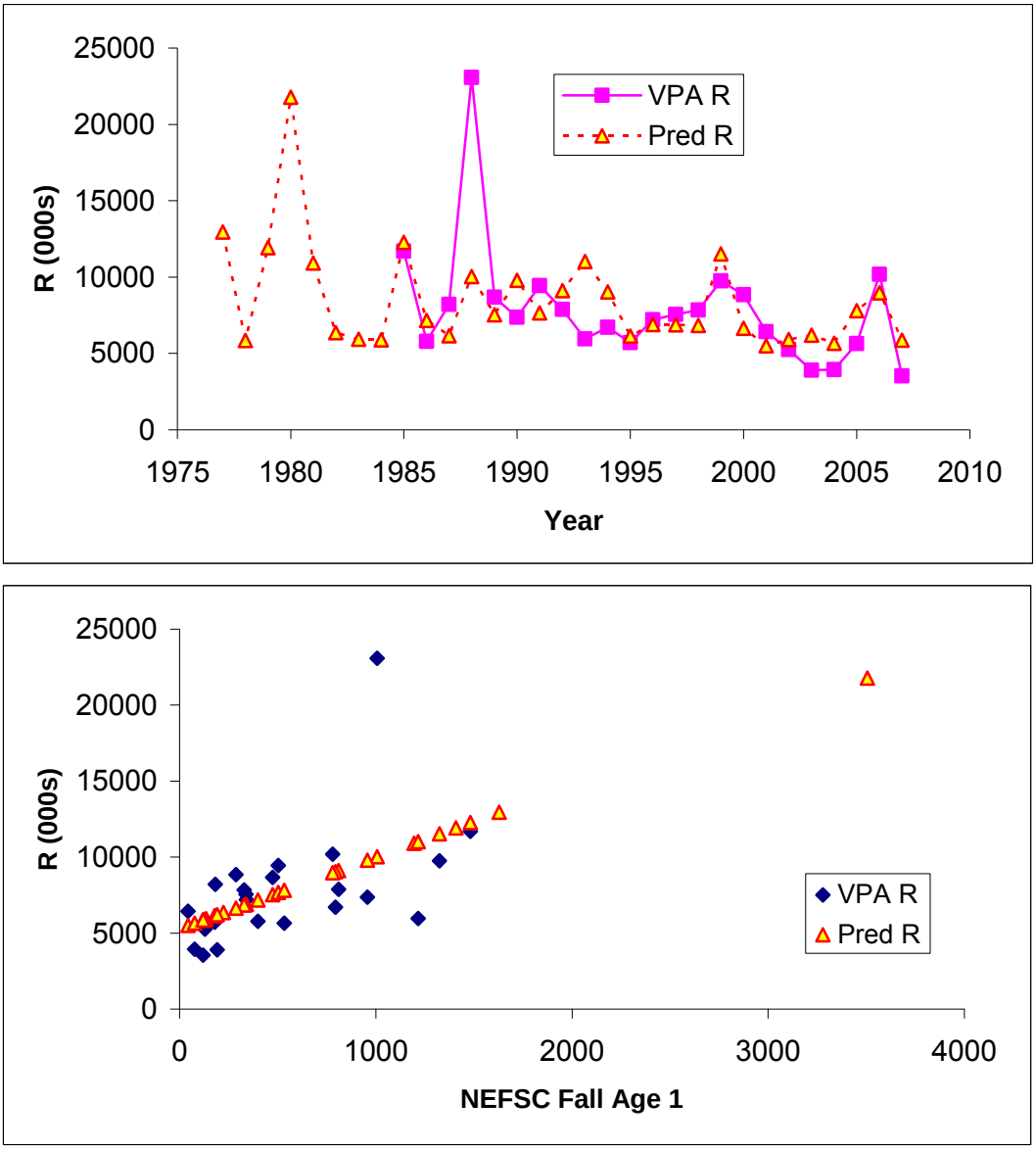


Figure E11. Hindcast estimates of recruitment using the NEFSC Fall survey at age 1.

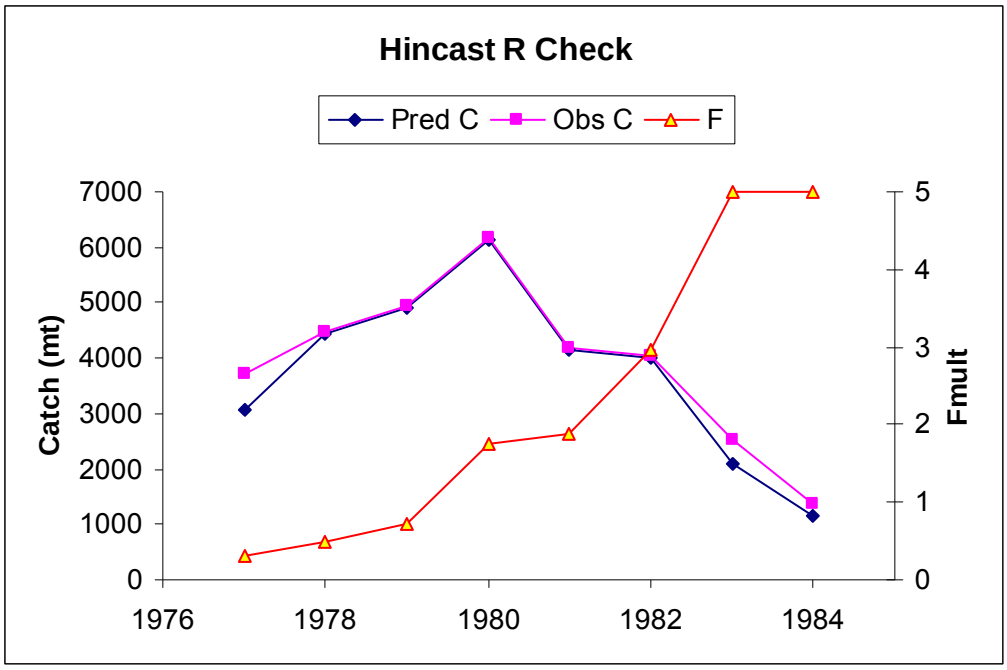


Figure E12. Comparison of observed and predicted catch using hindcast recruitment along with fishing mortality rate in each hindcast year

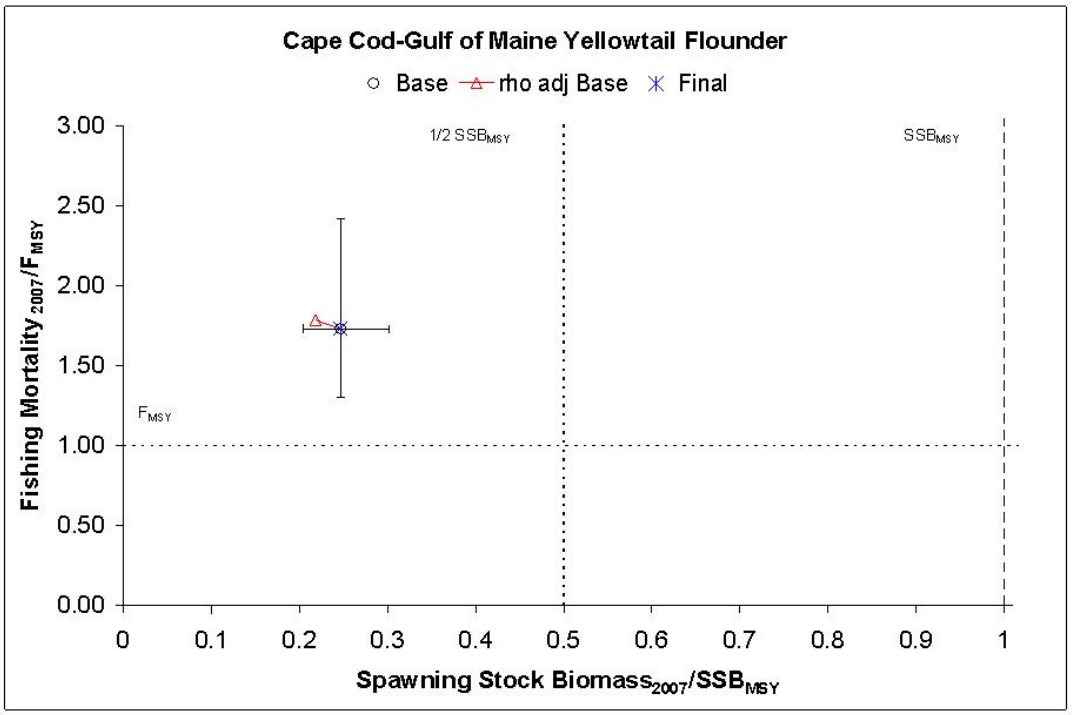


Figure E13. Current status of Cape Cod-Gulf of Maine yellowtail flounder.