Projected landings and stock biomass under
different fishing mortality scenarios for Atlantic Herring.

Prepared for the Herring PDT
By

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Herring PDT
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At the request of the NEFMC's Statistical and Science Committee (SSC), I have run six projections for six fishing mortality scenarios. The projections were run using the NFT AGEPRO version 3.3.8. The PDT set F=0.16 for 2009 for all projections, corresponding to the median projected F from using an [1]assumed 90,029 mt of landings. For projections with retrospective adjustments, assumed landings of 90,029 metric tons were assumed for 2009. From 2010 through 2038, the six scenarios for fishing mortality were (FMSY (0.27), Frebuild (0.153), Fstatus quo (0.14), 75% status quo (.105), 50% status quo (0.07) and F=0. Projected biomass and the 5th and 95th percentiles are shown in Figure 1.

Note that under a Fmsy strategy, long-term biomass stays below Bmsy, and long-term landings remains below MSY. Clearly an inconsistency between the reference points derived in the Fox surplus production model and long-term projections at Fmsy exists. Under Frebuild, projected biomass reaches Bmsy, but long-term landings remain below MSY.

Projected landings
The median and 5th and 95th percentiles from the distribution of projected landings for five mortality scenarios are shown in Figure 2. A range of percentiles for 2010-2012 for projected landings are shown in Table 1.

Retrospective adjusted projected landings.
The SSC recommended that the average retrospective adjustments be applied to the projected landings. Restrospective adjustment values were derived from retrospective peels of the ASAP terminal year value back to 2001. Retrospective January 1 number at age were converted to stock biomass using mean weights at age provided in the Final ASAP model. Results from retrospective analysis of 2+ stock biomass and abundance at age for 2-6+ are shown in Appendix Figure 1 (ratio of retrospective year: base) and Appendix Figure 2 (actual values) for 2001-2008.

The retrospective adjustments to the terminal year estimates were used as input to the AGEPRO projection model. The age specific retrospective adjustment was calculated based on the ratio of the January 1 numbers at age for 2008 (base) to the tips of terminal retrospective years 2007 through 2001. For example, age 2 in 2001 retrospective peel was estimated at 1849 compared to the 2008 terminal year estimate of 1033, giving an adjustment ratio of 0.55 for that peel compared with the terminal year 2008. The average ratio's for all retrospective peels (2001-2007) for age 2 was 0.72, with a range (0.32 to 1.09). The retrospective correction factors are shown in Table 2. The average ratio was applied to the retrospective adjusted projected landings for the Fmsy and Frebuild runs presented in Table 3.

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[1] Status quo refers to the fishing mortality rate in 2008

Retrospective adjustments were not applied to the Fstatus quo, 75% Fstatus quo or 50% F status quo projections. The use of these fishing mortality streams was considered as an alternate method to retrospective adjustment for accounting for scientific uncertainty and further adjustments could be considered excessively precautionary.

Additional corrections for other sources of uncertainty
The retrospective pattern in the herring assessment is the largest source of uncertainty, swamping the uncertainty from model formulation and distribution of uncertainty around terminal year estimates. Despite the retrospective pattern, fishing mortality has remained below F_{msy}. Overfishing has not occurred since 1989 and age 2^+ stock biomass has remained above B_{msy} since 1996 (Appendix Figure 3). The terminal 2008 year point estimate is at 97% of B_{msy}. Despite the retrospective pattern and model formulation uncertainty, the view of stock status has not changed: biomass has remain relatively stable at a high biomass since the mid-1990's and fishing mortality rates have been below F_{msy} (Appendix Figure 4). Fishing mortality has averaged 0.17 since 1998, approximately 63% of F_{msy}, and 85% of the natural mortality rate assumed in the assessment (0.20). A retrospective adjusted 2008 F is at 95% of Fmsy and the 2008 January 1st 2^+ biomass is at 62% of B_{msy}.

Causes for the retrospective pattern are unknown in the case of Atlantic herring, but general causes can include misspecification of catch, ageing problems, changes in M, changes in survey catchability, differences in fishery selectivity, difference among stock components or across time, etc. The range of uncertainty in the retrospective analysis in the final model encompasses the range of uncertainty found in the various model formulations. The PDT concludes that the retrospective adjustment should provide adequate precaution for these scientific uncertainties.

The Atlantic herring stock is a complex composed of several spawning components, which mix at different rates during the year. Annual catch limits are set for four management areas (1A, 1B, 2, and 3). The risk of these ACL to the inshore component of the stock will be analyzed by the Plan Development Team during the ACL setting process.
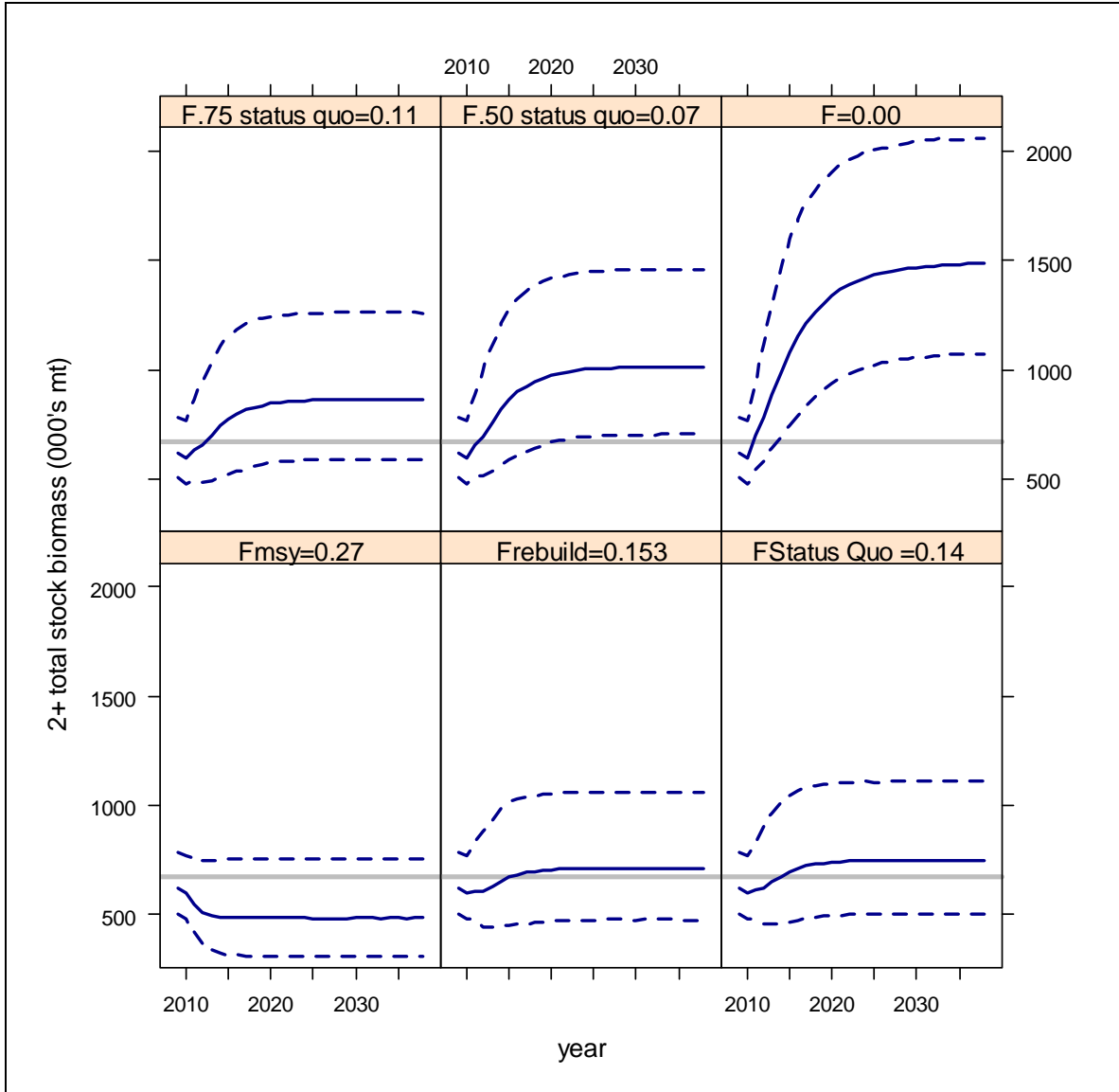
Figure 1. Projected Atlantic Herring total 2$^+$ median biomass under six fishing mortality scenarios. F in 2009 was set at 0.16 for all projections. Gray line is Bmsy estimate (670.6 thousand metric tons) from 2009 TRAC assessment.
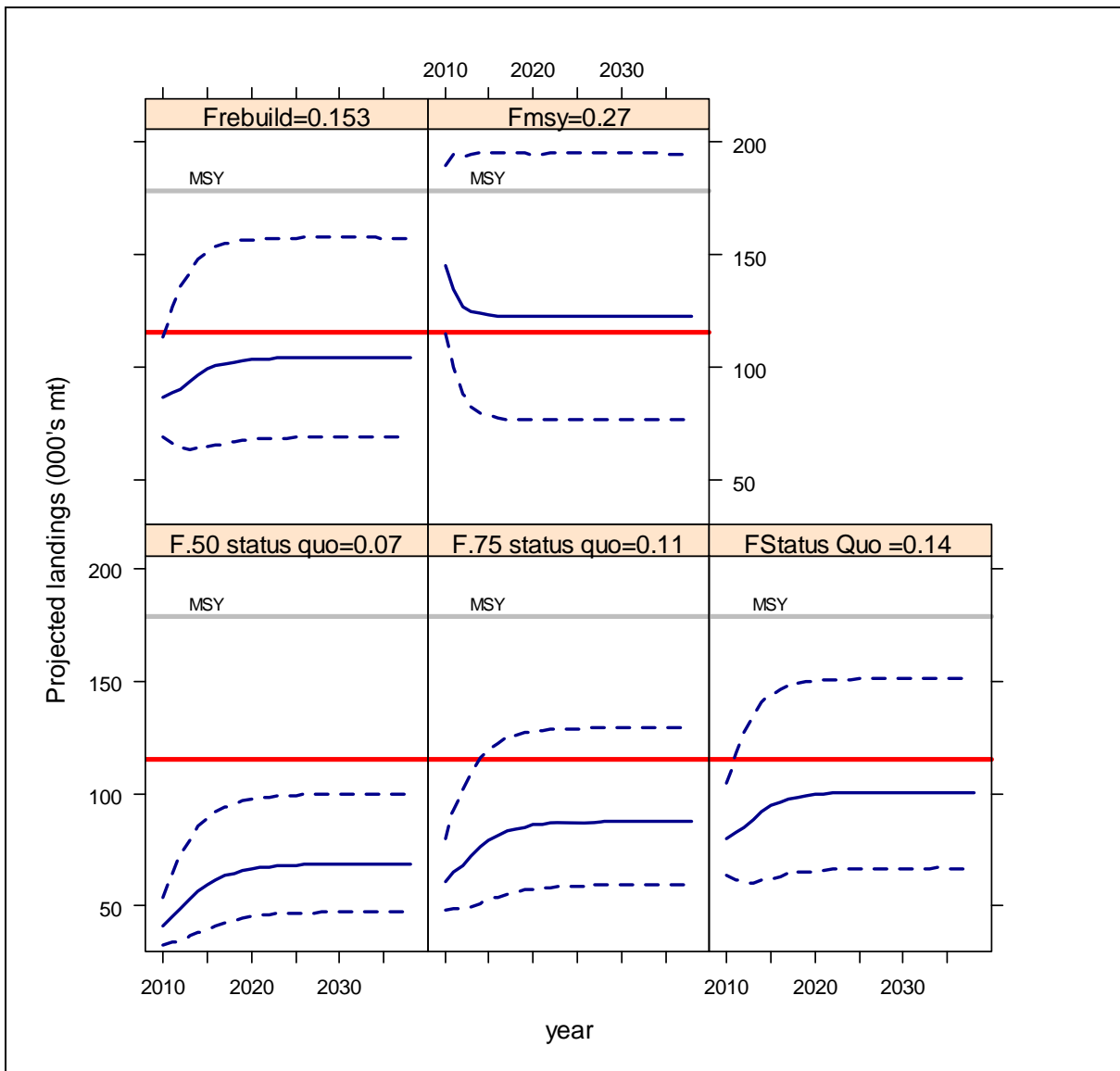
Figure 2. Projected landings under five fishing mortality scenarios for 2010-2038. Solid blue line is median, dashed lines are 5th and 95th percentiles of the distribution of projected landings. Gray line is MSY (178.374 thousand metric tons). Solid red line is average total landings from 1998 to 2008 (115.5 thousand metric tons).

Table 1. Percentiles of projected landings distribution for five fishing mortality scenarios for Atlantic sea herring . Landings are in thousands of metric tons. Landings are not adjusted for retrospective pattern in January 1 stock biomass. All mortality scenarios use F=0.16 for 2009.

Run	YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%	F
F_{msy}	2010	105.477	115.066	120.727	131.296	144.996	160.488	176.931	189.598	221.021	0.27
	2011	89.868	99.955	106.437	118.597	134.493	153.115	175.320	194.622	226.376	0.27
	2012	76.543	88.241	95.355	109.068	126.966	148.563	175.386	193.975	226.817	0.27
$F_{rebuild}$	2010	63.118	68.856	72.244	78.568	86.767	96.037	105.877	113.457	132.260	0.15
	2011	59.803	66.443	70.663	78.522	88.833	100.856	115.014	127.174	148.682	0.15
	2012	55.894	63.877	68.796	78.135	90.389	105.006	123.082	135.953	158.141	0.15
$F_{status\ quo}$	2010	58.110	63.393	66.512	72.334	79.882	88.417	97.476	104.455	121.766	0.14
	2011	55.727	61.899	65.808	73.114	82.692	93.862	107.006	118.236	138.351	0.14
	2012	52.604	60.073	64.691	73.412	84.878	98.532	115.343	127.401	148.275	0.14
75% $F_{status\ quo}$	2010	44.310	48.339	50.717	55.157	60.912	67.420	74.328	79.649	92.850	0.105
	2011	43.898	48.718	51.765	57.476	64.968	73.695	83.900	92.566	108.666	0.105
	2012	42.571	48.530	52.186	59.141	68.288	79.127	92.425	102.038	118.646	0.105
50% $F_{status\ quo}$	2010	30.037	32.767	34.379	37.389	41.290	45.702	50.384	53.992	62.940	0.07
	2011	30.739	34.094	36.210	40.182	45.383	51.456	58.516	64.487	75.853	0.07
	2012	30.655	34.866	37.470	42.382	48.859	56.533	65.892	72.718	84.441	0.07

Percentiles of projected landings distribution

Table 2. Retrospective adjustment ratio's for January 1st 2$^+$ total stock biomass and for January 1 abundance at age.

Retrospective peel year	F	Retro adjustment 2+ biomass	Retrospective adjustment for January 1 numbers at age				
			age 2	age 3	age 4	age 5	age 6+
2001	1.96	0.60	0.55	0.60	0.82	0.55	0.47
2002	2.28	0.48	0.32	0.48	0.49	0.57	0.46
2003	1.99	0.45	0.70	0.45	0.55	0.51	0.49
2004	2.04	0.50	0.49	0.50	0.56	0.61	0.50
2005	1.61	0.59	1.09	0.59	0.66	0.68	0.60
2006	1.41	0.73	1.08	0.73	0.68	0.73	0.70
2007	1.17	1.05	0.79	1.05	0.84	0.88	0.87
2008					Terminal year of assessment		
mean	1.78	0.63	0.72	0.63	0.66	0.65	0.58

Table3. Percentiles of projected landings distribution for five fishing mortality scenarios for Atlantic sea herring. Landings are in thousands of metric tons. Landings are adjusted for retrospective pattern in January 1 numbers at age for 2008-2001. All projection runs used assumed landings of 90,029 tons for 2009.

		Retrospective- adjusted Percentiles of projected landings distribution									
Run	YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%	F
F_{msy}	2010	59.239	66.918	71.535	80.311	92.135	105.645	120.093	132.393	165.291	0.27
	2011	56.086	65.178	71.098	82.436	97.690	115.401	137.256	157.285	188.825	0.27
	2012	53.830	64.954	71.842	85.318	102.943	124.288	151.123	169.699	202.095	0.27
$F_{rebuild}$	2010	35.449	40.044	42.807	48.059	55.134	63.219	71.864	79.225	98.911	0.15
	2011	37.209	43.089	46.931	54.232	64.062	75.535	89.446	101.803	123.18	0.15
	2012	38.754	46.286	51.086	60.182	72.209	86.628	104.745	117.591	139.513	0.15

Appendix 1. Additional tables and figures.

Data sources for projections:
Projections were run by Gary Shepherd on 8.31.2009 using the original input files (FMSYLONGTERM2.in) and bootstrap input files (final2009amcmc.bsn). Agepro 3.3.8 was used to run the projections.

Projected recruitment was drawn from the 42 year timeseries of age 2 recruits in the assessments using an empirical model in the projections. .

Terminal year January 1 abundance at age estimates for 2009. January 2009 age 2 recruits are drawn from empirical distribution of recruits from ASAP model.

 Mean weights (January 1, catch weights, spawner weights) were based on average of 2006-2008.

Appendix Table 1.

	Age 2	Age 3	Age 4	Age 5	Age 6+
Jan 1 weights	0.034	0.067	0.102	0.133	0.177
Catch weights	0.049	0.090	0.121	0.147	0.177
Spawner weights	0.049	0.090	0.121	0.147	0.177
Maturity	0.21	0.86	0.93	0.98	1
Natural mortality	0.2	0.2	0.2	0.2	0.2
Fishery selectivity	1	1	1	1	1

Appendix Figures and Tables.
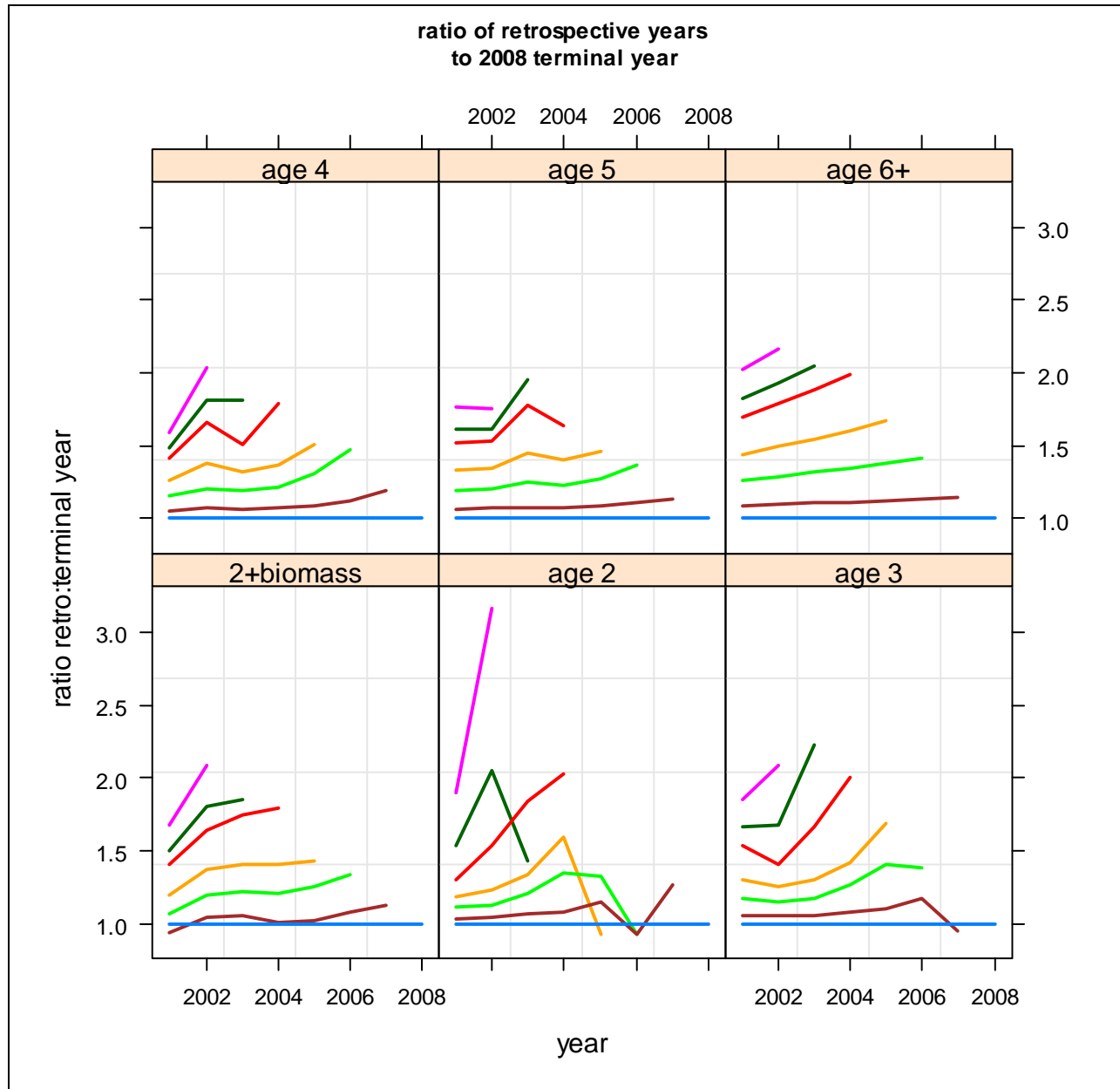
Appendix Figure 1. Result of retrospective analysis using years 2001-2008 for 2+ biomass and abundances for ages 2 through 6+. Retrospective measured as ratio of retrospective year to terminal year.
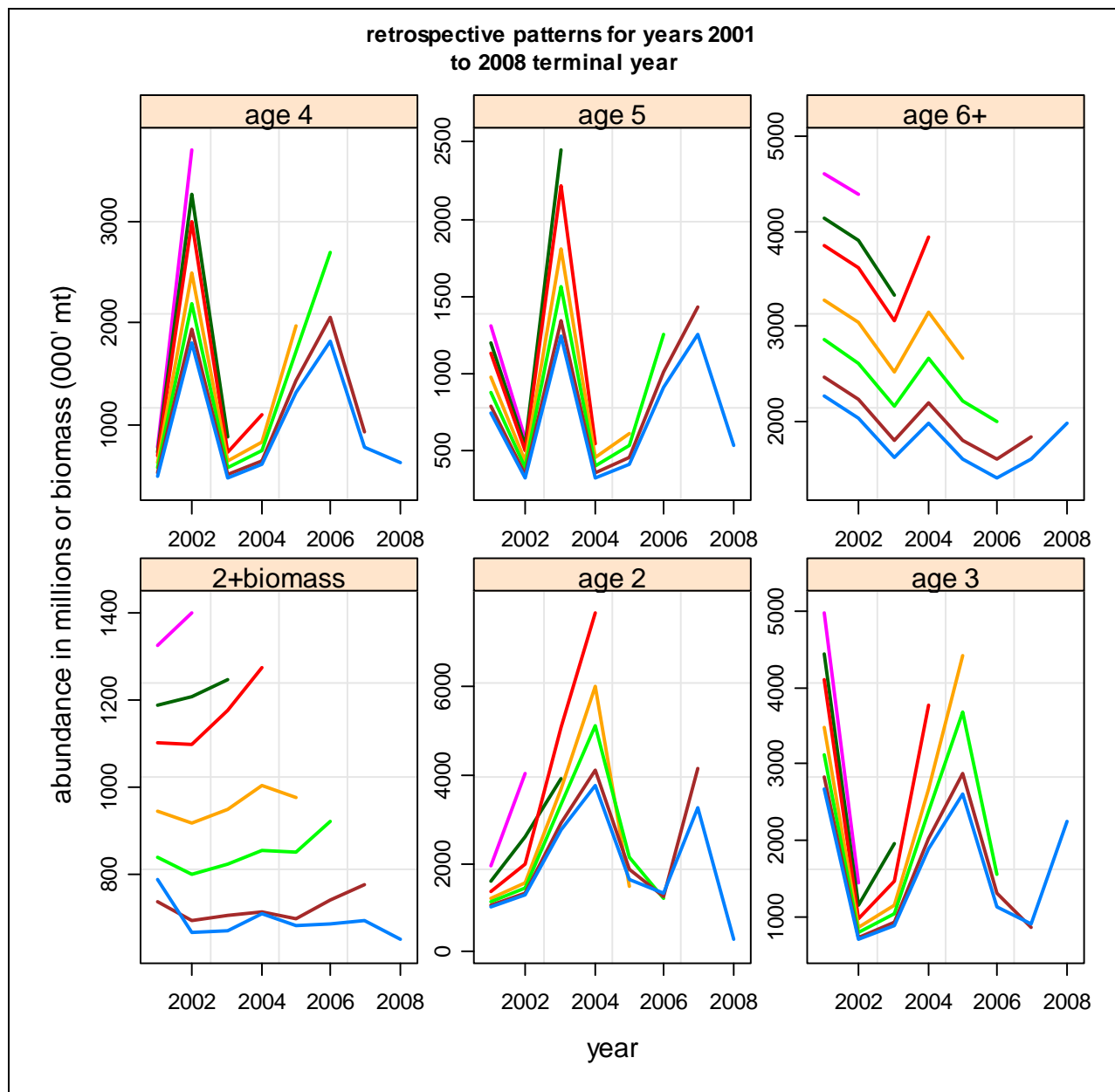
Appendix Figure 2. Retrospective pattern for either 2+ January 1 biomass (000's mt) or abundance at age (millions)

The following tables are provided in case the PDT would wish to use the F_{2009} as the status quo rather than F_{2008}. In addition, a run that uses the 2008 catch (90,029 mt) as a constant catch strategy for 2010-2012.Projection began with F=0.16 in 2009.

Appendix Table 2. Percentiles of projected landings based on F_{2009}, 75% of $F2_{009}$ and 50% of F_{2009}. Not adjusted for retrospective.

					Percentiles of projected landings distribution						
Run	YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%	F
F_{2009}	2010	65.789	71.770	75.301	81.893	90.438	100.101	110.357	118.258	137.857	0.16
	2011	61.929	68.820	73.196	81.353	92.050	104.507	119.207	131.899	154.126	0.16
	2012	57.559	65.830	70.899	80.550	93.216	108.344	127.028	140.377	163.294	0.16
75% F_{2009}	2010	50.282	54.853	57.551	62.589	69.121	76.506	84.344	90.383	105.362	0.12
	2011	49.124	54.539	57.964	64.372	72.778	82.582	94.072	103.881	121.696	0.12
	2012	47.1	53.722	57.804	65.553	75.734	87.797	102.642	113.361	131.877	0.12
50% F_{2009}	2010	34.164	37.270	39.103	42.527	46.964	51.982	57.308	61.411	71.589	0.08
	2011	34.639	38.427	40.815	45.305	51.179	58.031	66.000	72.776	85.562	0.08
	2012	34.270	39.003	41.931	47.444	54.721	63.342	73.850	81.523	94.720	0.08

Appendix Table 3. Distribution of F under constant catch strategy based on F=0.16 in 2009 and catch$_{2008}$ =90,029 mt thereafter. Not adjusted for retrospective bias.

					Percentiles of projected F distribution						
Run	YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%	Catch
Constant catch	2010	0.102	0.119	0.128	0.143	0.159	0.177	0.194	0.205	0.226	90.029
	2011	0.086	0.103	0.115	0.134	0.156	0.180	0.206	0.222	0.255	90.029
	2012	0.078	0.093	0.105	0.127	0.153	0.184	0.219	0.242	0.294	90.029
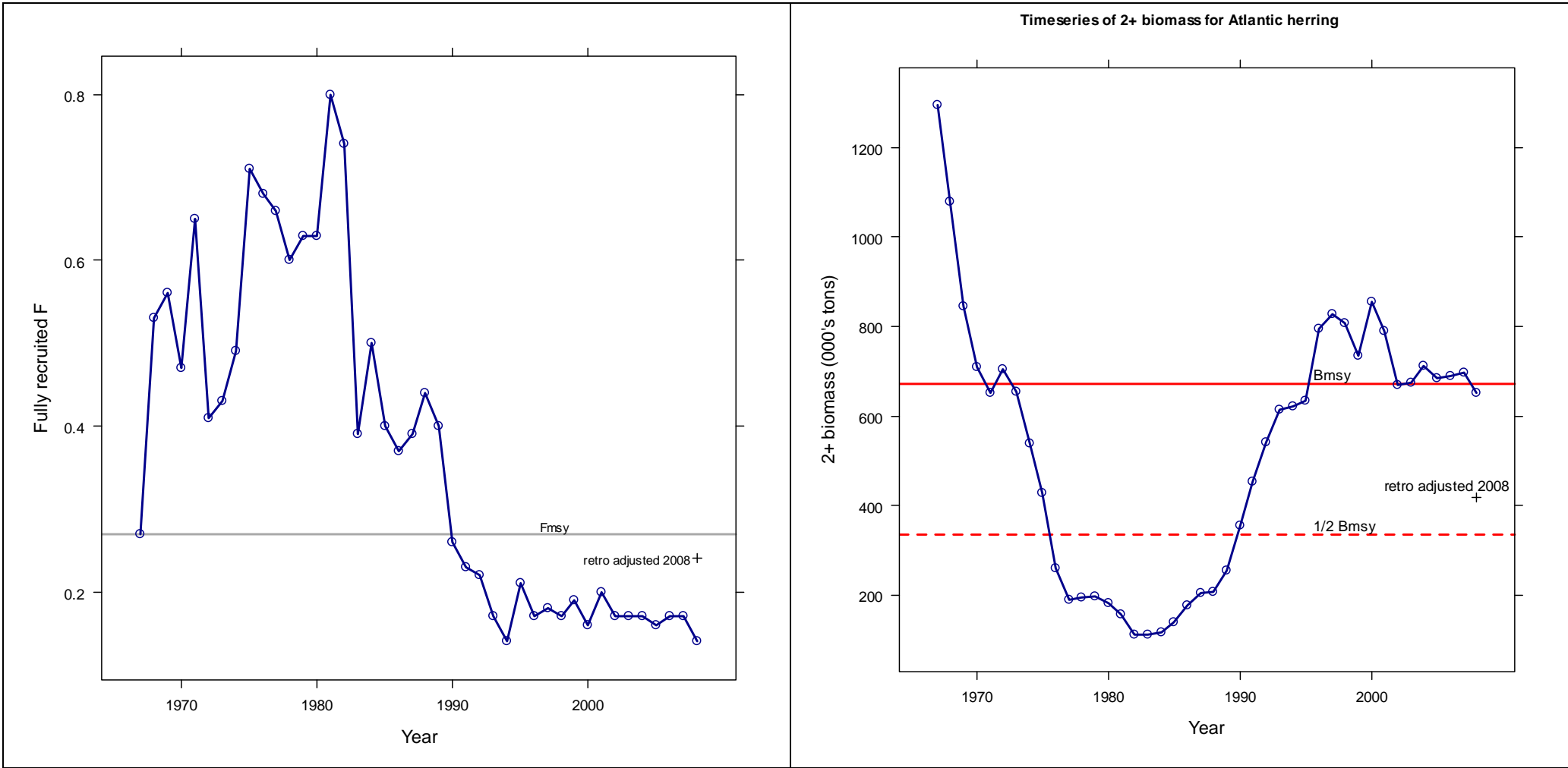
Appendix Figure 3. Left panel: Timeseries of fully recruited F from TRAC 2009 assessment. Gray line is updated Fmsy (0.27). Right panel: Timeseries of January 1st 2_+ biomass. Solid red line is B_{msy}. Broken red line is Biomass threshold (1/2 B_{msy}). + indicates retrospective adjusted 2008 value based on average of 7 retrospective peels. For 2007-2009, quota was set on a target fishing mortality rate=0.31, representing the Fmsy estimate at the time).
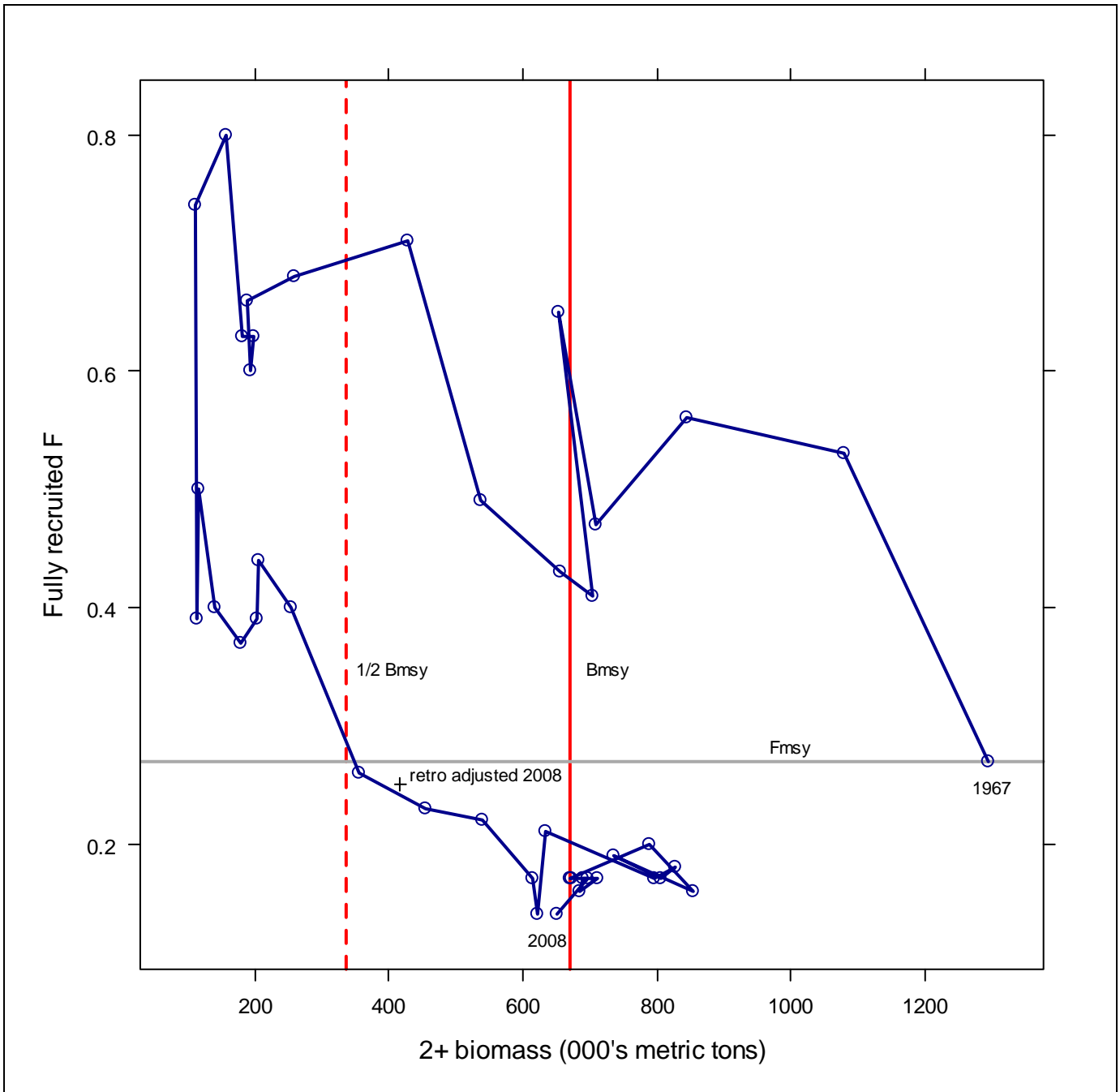
Appendix Figure 4.   Phase plot of 2^+ January 1 biomass against fully recruited F for Atlantic herring in the 2009 TRAC assessment. Gray solid line is Fmsy. Red solid line is Bmsy. Broken red line is ½ Bmsy. Plus sign is retrospective adjusted 2008 values for biomass and fishing mortality based on 7 year retrospective peels.
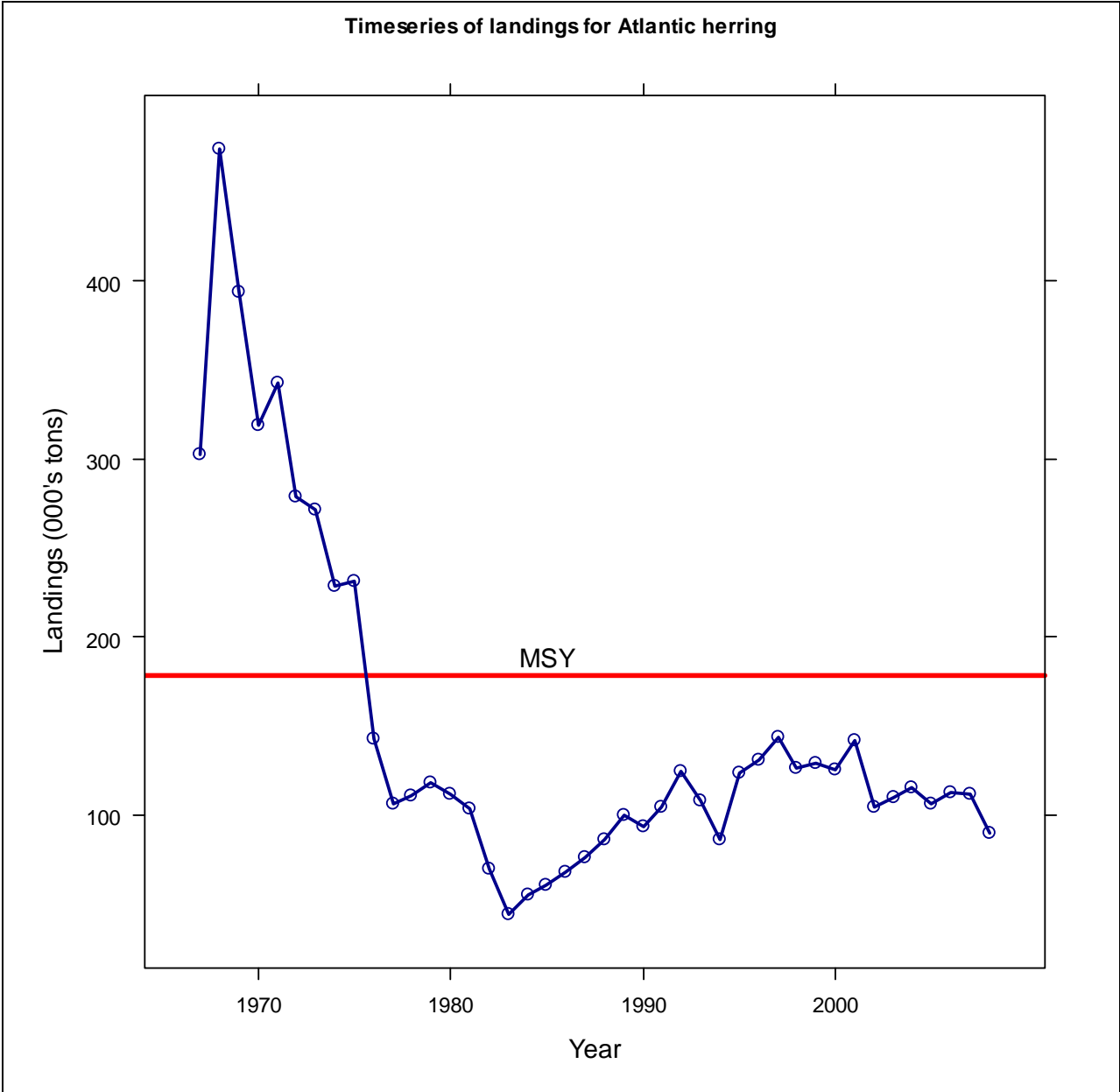
Appendix Figure 5. Timeseries of Atlantic herring landings 1967-2008. Solid red line is MSY estimate from TRAC 2009.