Northeast Fisheries Science Center Reference Document 13-07

Bluefish 2012 Stock Assessment Update

by Anthony Wood

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EXECUTIVE SUMMARY

The updated stock assessment was completed by adding catch and indices through 2011 to the previous 1982-2010 assessment. Catch information consisted of commercial landings and length frequencies from Maine to Virginia collected by the Northeast Fisheries Science Center, North Carolina landings and length information collected by NC Division of Marine Fisheries, Florida landings and length information collected by FL Fish and Wildlife Research Institute, and recreational landings and discards from Maine to Florida collected in the NMFS recreational fisheries survey. The catch data were combined with fisheries-independent survey data from the Northeast Fisheries Science Center, DE DNR, NJ DEP, CT DEP, coast-wide recreational catch per angler, as well as juvenile indices from the SEAMAP program in the South Atlantic, in a forward projecting catch-at-age model (ASAP). Fishery-dependent and independent information was partitioned into ages using a 2011 age-length key developed by Old Dominion University supplemented with additional age information from MA DMF and NC DMF.

Results of the analyses show that bluefish are not overfished or experiencing overfishing. Fishing mortality in 2011 was 0.114, below the biological reference point (F_{MSY}) of 0.19. Fishing mortality steadily declined from 0.34 in 1987 to 0.12 in 1999 and has remained steady since 2000 with an average F=0.138. Recent total stock biomass estimates peaked in 1982 at 338.0 thousand MT, then declined to 77.7 thousand MT by 1996 before increasing steadily to the 136.4 thousand MT in 2010 and slightly declining again to 132.9 thousand MT in 2011. Recruitment estimated in the ASAP model has remained relatively constant since 2002 at around 20 million age-0 bluefish, with the exception of a relatively large 2006 cohort estimated as 35.1 million fish. However, the 2010 and 2011 recruitment estimates were well below average at 14.6 and 10.6 million fish, respectively. There was no significant retrospective bias in the results. A projection of the abundance through 2014, under five different fishing scenarios between F=0.10 and F=0.19, suggest that biomass will continue to decline due to poor incoming year classes. Changes in the NMFS survey, limited age information, discard size data and model configuration all contribute to the uncertainty in the assessment.

INTRODUCTION

The Atlantic coast stock of bluefish (*Pomatomus saltatrix*), distributed from Maine through eastern Florida, is jointly managed by the Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic Fishery Management Council (MAFMC). A total annual quota is established and allocations given to commercial and recreational fisheries. The management plan requires a distribution of 80% to recreational and 20% to commercial, with provisions to shift unused recreational quota to commercial fisheries.

A bluefish stock assessment was presented for peer-review at the Northeast Fisheries Science Center Stock Assessment Review Committee meeting (NEFSC SARC 41). The reviewers accepted the assessment for use in management decisions although there were some reservations about the modeling approach. Since the review, the bluefish stock assessment sub-committee (SASC) has produced annual updates while maintaining the basic model settings from the approved assessment. The current assessment is a continuation of the model update with the addition of 2011 catch at age and indices at age information.

LIFE HISTORY

Bluefish, *Pomatomus saltatrix*, is a coastal, pelagic species found in temperate and tropical marine waters throughout the world (Goodbred and Graves 1996; Juanes et al. 1996). Bluefish spawn in offshore waters (Kendall and Walford 1979; Kendall and Naplin 1981). Larvae develop into juveniles in continental shelf waters and eventually move to estuarine and nearshore shelf habitats (Marks and Conover 1993; Hare and Cowen 1994; Able and Fahay 1998; Able et al. 2003). Bluefish are highly migratory along the U.S. Atlantic coast and seasonally move between the U.S. south Atlantic and Middle-Atlantic, traveling as far north as Maine (Shepherd et al., 2006).

Several studies show bluefish to be a moderately long-lived fish with a maximum age of 14 years (Hamer 1959; Lassiter 1962; Richards 1976; Barger 1990; Chiarella and Conover 1990; Terceiro and Ross 1993; Austin et al. 1999; Salerno et al. 2001; Sipe and Chittenden 2002). Bluefish up to 88 centimeter (cm) fork length (FL) have been aged (Chiarella and Conover 1990; Salerno et al. 2001), although Terceiro and Ross (1993) noted considerable variation in mean bluefish size-at-age. Scale ages have been used to estimate von Bertalanffy growth parameters (Lassiter 1962; Barger 1990; Terceiro and Ross 1993; Salerno et al. 2001). The values for L_∞ from these studies (87-128 cm FL) match closely to the largest individuals in catch data and growth rates do not differ between sexes (Hamer 1959; Salerno et al. 2001).

Bluefish grow nearly one-third of their maximum length in their first year (Richards 1976, Wilk 1977). Variation in growth rates or sizes-at-age among young bluefish is evident from the appearance of intra-annual cohorts. Lassiter (1962) identified a spring-spawned cohort and a summer-spawned cohort from the bimodal appearance of size at Annulus I for fish aged from North Carolina and the seasonal cohorts can differ in age by two to three months. Summer-spawned larvae and juveniles grow faster than spring-spawned larvae and juveniles (McBride and Conover 1991) although size differences at annual age diminish greatly after three to four years (Lassiter 1962).

Spawning occurs offshore in the western North Atlantic Ocean, from approximately Massachusetts to Florida (Norcross et al. 1974; Kendall and Walford 1979; Kendall and Naplin 1981; Collins and Stender 1987). Bluefish are characterized as multiple spawners with indeterminate fecundity which spawn continuously during their spring migration (Robillard et al. 2008). In addition to distinctive spring and summer cohorts, Collins and Stender (1987) identified a fall-spawned cohort, demonstrating the potential of an extended bluefish spawning season.

Bluefish in the western North Atlantic are managed as a single stock (NEFSC 1997; Shepherd and Packer 2006). Genetic data support a unit stock hypothesis (Graves et al. 1992; Goodbred and Graves 1996; Davidson 2002). For management purposes, the ASMFC and MAFMC define the management unit as the portion of the stock occurring along the Atlantic Coast from Maine to the east coast of Florida.

FISHERIES DEPENDENT DATA

Annual catch information was developed for five components of the commercial fishery. Commercial landings from Maine to Virginia, North Carolina commercial landings, Florida commercial landings, coast-wide recreational landings and coast-wide recreational discards.

Commercial fisheries from Maine to Virginia were sampled as part of the NEFSC data collection program. Lengths were sampled from a variety of gears and market categories. Expansion of length data was completed by market category and quarter of the year, with the results merged into half year periods. In 2011 a total of 6,342 measurements were collected across all market categories from total landings of 1,482 mt (60% of all commercial landings; Table 1). Market category/quarter with inadequate length samples were filled with length information from adjacent quarters within the same market category or from NC samples if necessary.

North Carolina commercial landings were expanded using length samples collected by NC Division of Marine Fisheries. A total of 1,186 measurements were collected from landings of 862 mt (Table 1). Expansion of landings at length were done by quarter, market category and gear type then combined into half year totals. Length samples from Florida 2011 commercial landings were also available. A total of 237 lengths were used to expand commercial landings of 111 mt (Table 1). No landings were reported for South Carolina or Georgia. Total coast-wide commercial landings in 2011 were 2,455 mt, a decrease of 751 mt from 2010 (Figure 1).

Length frequencies from commercial fisheries are characterized by a multi-modal distribution (Figure 2). In 2011 the distribution was strongly bimodal with one peak at 38 cm and a second around 72 cm.

Recreational landings are sampled for length as part of the MRIP program. The 2011 recreational landings were 5,965 mt, a decrease from 8,184 mt in 2010 (Table 2, Figure 3). The MRIP 2011 length samples were used to expand recreational landings per half year. Recreational discards in 2011 were estimated at 16,860 mt, however after adjusting for a 15% mortality rate, the resulting discard loss was 2,529 mt. A recent publication (Fabrizio et al 2008) shows that mortality may be higher and the 15% should be reevaluated in the next benchmark assessment. Length sampling of bluefish tagged and released in the American Littoral Society tagging program (by definition B2 catches) were included in the length distribution (n=561). Length frequencies from the recreational catch and discards are characterized by a bimodal distribution, similar to the observed distribution of the commercial length frequency (Figure 4). Total combined (commercial and recreational) length frequencies are presented in Figure 5.

Age data were provided by Virginia Marine Resources Commission and Old Dominion University ageing lab (n = 481), MA DMF (n = 69), and NC DMF provided ages for fish over 50 cm (n = 45). Since the age key developed from these data was the only 2011 age information available, it was applied to both fishery dependent and independent length data.

The length frequencies by age were converted to weight for calculation of annual weights at age (Table 3 Figure 6). Length-weight equations from the spring and fall NEFSC bottom trawl survey were used for calculating weights at age. Due to low sample size in spring surveys, all years beginning with 1992 were used in the equation (n=248, a = -11.357, b = 3.003). Fall equations were estimated from combined 2004-2011 length-weight data (n = 3596, a = -11.610, b = 3.093).

The 2011 catch at age is presented in Table 4. As in previous bluefish assessments the ages are summarized in a plus category for ages 6 and above to reduce the effect of aging error.

FISHERIES INDEPENDENT DATA

Survey indices as used in the previous bluefish assessment were updated for 2011. These indices include SEAMAP juvenile (age 1) indices, Northeast Fisheries Science Center (NEFSC) bottom trawl survey indices for ages 0 to 6+, NJ bottom trawl survey indices of ages 0 to 2, DE bottom trawl survey indices for ages 0 to 2 and Marine Recreational Information Program (MRIP) recreational catch per angler trip (CPA) for ages 0 to 6+. The CT survey in 2008 and 2010 were not conducted during the month of September, therefore these indices were treated as missing data. The NEFSC survey in 2009 was modified by the replacement of the FV Albatross IV with the FSV Henry B. Bigelow. The consequence of the replacement was a change in the areas surveyed and the efficiency of the survey due to a change in net size and towing speed (as well as other intangibles associated with a different vessel). Beginning in 2009 only the outer third of the inshore strata set was sampled by the Bigelow. In addition, a conversion coefficient of 1.16 was used to convert Bigelow mean number per tow into equivalent Albatross units (Miller et al., 2010).

Among these survey indices, there were no consistent trends in total abundance. The total NEFSC index (ln re-transformed stratified mean number per tow) declined from 38.05 in 2006 to 6.66 in 2010, and slightly increased to 7.45 in 2011 (Table 5). The series arithmetic average index equaled 25.9 (geometric mean of 13.6). The 2011 Delaware survey index of ages 0 to 2 was 0.2 fish per tow, and below the time series average (0.51 per tow; Table 6). New Jersey trawl survey indices of ages 0 to 2 for 2010 (14.37 fish/tow) was well above the time series average of 6.6 per tow (Table 6). In the 2010 bluefish update assessment there was an error in the NJ index resulting from an incorrect tally of the raw survey data. This error has been corrected for both 2010 and 2011 data for this update. Connecticut DEP survey data were unavailable for 2010 but the index for 2011 was 12.93, lower than the mean of 32.8 (Table 7). Recreational catch per angler trip showed a small increase to 0.401 fish per angler trip in 2011, an increase from 0.361 in 2010 (Table 8). The recreational catch per angler was modeled in a generalized linear model using a negative binomial error structure. The year coefficient partitioned into ages (assuming the same proportion as the recreational catch) was used in the ASAP model as a relative index of abundance.

ASAP MODEL

The ASAP model (version 2.0.20) was run as an update of previous 1982-2010 input file, updated for 2011 total catch, catch at age, weight at age and indices at age. The fishery was modeled as a single fleet with selectivity fixed as a bimodal pattern with full recruitment at age 1 (coded age 2). Model weighting factors remained the same as previous assessments with the model heavily weighted towards the fishery total catch rather than survey indices. Natural mortality was fixed at 0.2 and maturity at age was held constant with full maturity at age 3. The updated model was run using the same parameter settings while substituting the updated catch and weight at age matrices.

The results of the updated ASAP model showed a decrease in total abundance since 2006, declining from 94.4 million to 66.3 million fish (Table 9, Figure 7). The decline is primarily the result of poor 2009, 2010, and 2011 year classes. Prior to 2009 recruitment had remained relatively constant since 2000 at 21.4 million age-0 bluefish, with the exception of a large 2006 cohort estimated as 37.3 million fish. The 2009 recruitment estimate was below average at 12.5 million fish compared to the series average of 22.8 million, and low recruitment persisted for 2010 and 2011 (Table 9, Figure 8). Estimated recruitment in 2011 was the lowest in the time series at 10.6 million. However among other age groups, the estimate of age 6-plus bluefish continued to be large at 12.8 million, the highest since 1990. Total mean biomass in 2011 equaled 132,890 mt, a slight decrease from the 2010 estimate of 136,371 mt (Table 10, Figure 9). Corresponding spawning stock biomass (SSB) in 2011 was 123,107 mt, also a slight decrease from the 2010 estimate of 124,601 mt (Figure 9).

Fishing mortality estimates in ASAP are based on a separability assumption with F at age the product of F_{MULT} and selectivity. Full selectivity is fixed at age 1. The 2011 F_{MULT} value equals 0.114 (Figure 7). Fishing mortality steadily declined from 0.34 in 1987 to 0.12 in 1999 and has remained steady since 2000 with an average F=0.14.

Retrospective bias for the final model was examined for F, total abundance, recruitment (age 0) and total biomass. The analysis shows little evidence of bias in the estimates (Figure 10). The variation in the final model results for F and SSB was determined using a Monte Carlo Markov chain with 1000 iterations and a thinning factor of 100. The MCMC results of variation around F ranged from 0.096 to 0.134, with the 80% CI between 0.106 and 0.123. Estimates for SSB ranged from 101,800 to 143,400 mt, with an 80% CI between 115,632 mt and 133,207 mt. (Figure 11).

PROJECTIONS

Bluefish abundance and biomass through 2014 were examined for a range of fishing scenarios with a stochastic projection in AGEPRO software. Weight-at-age in 2012-2014 was assumed equal to 2011, recruitment was derived from a random draw of 28 empirical estimates of age 0 abundance since 1982 and initial population size was drawn from the output of the MCMC run. Fishing quota for 2012 was set equal to the ACL of 14,535 mt. Five projection scenarios were examined: F =0.10, F=status quo (0.114), F_{target} (0.17) which equals 90% of F_{MSY} as defined in FMP, $F_{0.1}$ (0.16) from the yield per recruit, and F_{MSY} (0.19)

Results of the projections show a decrease in mean biomass and SSB for each scenario including a reduced F (F=0.10) (Table 11). However, abundance continued to increase in all 5 cases. Yield through 2014 would be projected as lower for F scenarios of status quo or less. Under status quo F (0.114), projected 2013 yield would decrease to 10,840 mt, which includes commercial and recreational landings as well as recreational discards losses.

BIOLOGICAL REFERENCE POINTS

The current biological reference points for bluefish, determined in SARC 41 are F_{MSY} (0.19) and B_{MSY} (147,052 mt). The basis for the reference points was the Sissenwine-Shepherd method using the Beverton-Holt stock recruitment parameters and SSB per recruit results generated by the SARC 41 ASAP model results. B_{MSY} was calculated using mean weights at age and is therefore comparable to mean biomass in year *t*. The 2011 estimate of mean total biomass is 132,890 mt ($\pm$1 std. dev. of 7,433 mt), is slightly below B_{MSY} but well above ½ B_{MSY} of 73,526 mt. The 2011 estimate of fishing mortality (0.114) remains below $F_{MSY.}$

MODEL UNCERTAINTY

Model uncertainty can be characterized using Markov Chain Monte Carlo (MCMC) simulations to produce a distribution of possible outcomes given the model input parameters. However, these results do not capture the uncertainty from variations in the model input parameters. Forward projecting catch at age models are extremely flexible in applying weighting factors to emphasize either catch data or survey data. To illustrate the impact of changes to these weightings, as well as other factors, an ASAP model was run with changes to the effective sample size, and changes to index lambdas and CVs to force the model to fit closer to the annual indices (Table 12). The resulting fishing mortality in 2011 was 0.14 with an SSB estimate of 101,533 mt, slightly outside the 80% confidence interval associated with the MCMC simulation for the base model.

CONCLUSION

The conclusion of the updated assessment is that the Atlantic coast bluefish stock continues below B_{MSY} while remaining below F_{MSY} and is not considered overfished or experiencing overfishing. The estimates of the model show little variation or significant retrospective patterns. The lack of variation is due in part to the fixed parameters for selectivity. Nevertheless, uncertainty remains in several aspects of the assessment input data. Age data continue to be limited to one age key built from a limited set of samples. The assumption that this age information is applicable to all areas remains untested. Length samples from recreational discards are limited and contribute to the uncertainty as does the lack of commercial discard estimates. Changes in the NEFSC inshore survey series, from both vessel changes and sample area adjustments, significantly alter indices. Strata inshore of 15 fathoms are currently sampled as part of the NEMAP survey, but the time series is not yet adequate to provide a tuning index.

The highly migratory nature of bluefish populations and the recruitment dynamics of the species create a unique modeling situation. Migration creates seasonal fisheries with unique selectivity patterns resulting in a bimodal partial recruitment pattern. This pattern has been identified in previous assessments as a source of uncertainty in the results and has been held constant in the model. The migratory pattern in bluefish also results in several recruitment events. A spring cohort, originating south of Cape Hatteras, NC during spring migrations, and a summer cohort originating in the offshore Mid-Atlantic Bight result in a bimodal age-0 size distribution. It has been hypothesized that the success of the spring cohort controls the abundance of adult bluefish. Future assessments should include any additional information that could index seasonal abundance of incoming recruitment.

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Table 1. Commercial landings (mt) by state groupings used in length expansions.

Year	State			**Total**
	ME - VA	NC	SC-FL	
1982	4137	1946	914	**6997**
1983	3421	3061	685	**7166**
1984	3046	1615	720	**5380**
1985	4199	1634	289	**6122**
1986	4559	1562	531	**6651**
1987	3805	2069	705	**6578**
1988	4277	2286	599	**7161**
1989	2793	1493	455	**4740**
1990	3684	2076	489	**6250**
1991	3709	1778	673	**6160**
1992	3423	1288	495	**5205**
1993	3039	1226	543	**4808**
1994	3071	809	424	**4304**
1995	2034	1365	229	**3628**
1996	2654	1496	62	**4212**
1997	2165	1815	129	**4109**
1998	2257	1327	155	**3739**
1999	1921	1252	157	**3330**
2000	2057	1525	64	**3647**
2001	2038	1844	63	**3945**
2002	2025	1054	37	**3116**
2003	1739	1574	45	**3358**
2004	1885	1707	56	**3647**
2005	1844	1122	71	**3037**
2006	1851	1146	45	**3042**
2007	2282	909	76	**3267**
2008	1766	762	57	**2585**
2009	1959	1096	97	**3151**
2010	1601	1463	143	**3206**
2011	1482	862	111	**2455**

Table 2. Commerical landings, recreational landings, recreational discard loss, and total catch for bluefish from Maine to Florida.

Year	Commercial Landings (mt)	Commercial Landings (000 lbs)	Recreational Landings (mt)	Recreational Discard (mt)	Recreational Catch (mt)	Total Landings (mt)	Total Catch (mt) (w/o comm. discards)
1974	4538	10005					
1975	4402	9705		**assumes same**			
1976	4546	10022		**mean wt**			
1977	4802	10587		**as landings**			
1978	4986	10992					
1979	5693	12551					
1980	6857	15117					
1981	7465	16457	43222	*2001*	*45223*		52688
1982	6997	15426	37651	*832*	*38483*	44648	45480
1983	7166	15798	40425	*1280*	*41705*	47591	48871
1984	5380	11861	30597	*1260*	*31857*	35977	37237
1985	6122	13497	23821	*599*	*24420*	29943	30542
1986	6651	14663	42133	*1544*	*43677*	48784	50328
1987	6578	14502	34769	*1615*	*36384*	41347	42962
1988	7161	15787	21873	*1146*	*23019*	29034	30180
1989	4740	10450	17808	*989*	*18797*	22548	23537
1990	6250	13778	13860	*929*	*14789*	20110	21039
1991	6160	13580	14967	*1194*	*16161*	21127	22320
1992	5205	11475	11011	*979*	*11990*	16216	17195
1993	4808	10600	9204	*1013*	*10217*	14012	15025
1994	4304	9488	7049	*1128*	*8177*	11353	12481
1995	3628	7998	6489	*1003*	*7492*	10117	11120
1996	4113	9066	5328	*1010*	*6338*	9441	10451
1997	4064	8960	6487	*1287*	*7774*	10551	11838
1998	3739	8242	5595	*999*	*6594*	9334	10333
1999	3330	7341	3744	*1191*	*4935*	7074	8264
2000	3647	8040	4811	*1675*	*6486*	8458	10132
2001	3945	8697	6001	*1857*	*7858*	9946	11803
2002	3116	6869	5158	*1448*	*6606*	8274	9721
2003	3358	7403	5958	*1331*	*7289*	9316	10647
2004	3647	8041	7179	*1761*	*8940*	10826	12587
2005	3187	7026	8225	*1915*	*10140*	11412	13327
2006	2926	6450	7663	*1860*	*9523*	10589	12449
2007	3267	7182	9608	*2653*	*12261*	12874	15527
2008	2585	5655	8573	*2443*	*11016*	11158	13601
2009	3151	6990	6161	*960*	*7121*	9312	10273
2010	3206	7069	8184	*2409*	*10593*	11390	13799
2011	2455	5413	5965	*2529*	*8494*	8420	10949

Table 3. Bluefish mean catch weight at age (kg) from 1982 to 2011.

Year	Age						
	0	1	2	3	4	5	6+
1982	0.140	0.490	1.520	2.050	3.200	4.232	4.958
1983	0.100	0.420	0.990	2.150	3.160	4.417	5.577
1984	0.100	0.410	0.930	1.830	2.910	4.483	5.650
1985	0.100	0.400	0.970	1.930	2.820	3.991	5.053
1986	0.120	0.490	1.200	2.320	3.150	4.303	4.848
1987	0.120	0.300	1.180	2.020	2.960	3.927	4.984
1988	0.170	0.400	1.000	2.050	2.840	3.564	4.623
1989	0.130	0.300	1.060	2.120	3.640	4.106	4.720
1990	0.210	0.500	0.880	1.730	3.240	4.177	4.474
1991	0.140	0.330	0.700	1.730	2.810	3.963	4.965
1992	0.160	0.390	1.040	1.890	2.800	3.303	5.107
1993	0.180	0.590	0.950	2.460	2.730	3.237	4.880
1994	0.120	0.400	0.900	1.880	3.040	3.757	4.093
1995	0.170	0.440	0.980	1.730	2.850	4.058	4.696
1996	0.170	0.440	0.980	1.730	2.850	4.058	4.696
1997	0.113	0.483	1.048	2.360	3.301	4.411	6.005
1998	0.173	0.570	0.891	2.314	3.387	4.079	5.906
1999	0.133	0.511	0.890	2.111	3.577	4.168	5.960
2000	0.160	0.430	0.959	2.692	3.508	3.659	5.851
2001	0.134	0.383	0.830	2.339	3.608	3.846	4.926
2002	0.143	0.495	1.119	2.284	2.922	3.872	5.158
2003	0.101	0.556	1.007	2.308	2.774	4.170	5.011
2004	0.069	0.371	1.049	1.949	2.779	3.639	4.488
2005	0.135	0.564	0.980	2.316	3.434	4.310	5.529
2006	0.160	0.525	1.125	2.081	3.379	3.664	5.317
2007	0.066	0.421	1.168	2.408	3.018	3.476	5.006
2008	0.151	0.407	1.263	2.359	3.169	3.747	4.756
2009	0.081	0.450	1.270	2.394	3.444	3.690	4.880
2010	0.098	0.384	0.975	1.580	3.470	4.017	4.979
2011	0.086	0.342	0.833	1.416	2.609	4.377	5.397

Table 4. Bluefish catch at age (000s) from Maine to Florida, 1982 to 2011.

Year	Age							Total
	0	1	2	3	4	5	6+	
1982	11164.1	9747.9	2850.8	2439.3	795.3	1213.5	3736.3	**31947.2**
1983	4778.4	7666.7	8686.1	3022.0	970.6	1325.3	4778.4	**31227.5**
1984	7121.3	6807.3	6718.5	2039.9	895.1	744.7	3176.7	**27503.5**
1985	4676.7	6468.8	5773.3	2925.5	1328.5	520.0	2377.1	**24069.9**
1986	5169.3	8070.7	8728.0	2801.7	1056.4	1703.1	4465.0	**31994.2**
1987	3127.1	5419.5	5177.8	5757.4	2009.3	1083.0	3948.2	**26522.3**
1988	1709.8	2083.6	2524.0	1588.6	1984.1	1598.6	2740.4	**14229.1**
1989	3473.6	5672.6	3221.1	992.1	395.9	1168.5	2409.8	**17333.6**
1990	2726.7	7185.8	1840.7	687.2	381.8	431.6	2478.6	**15732.4**
1991	3694.6	5292.6	7391.9	1590.7	310.9	224.7	2136.5	**20641.9**
1992	2131.3	9633.3	1709.8	2352.9	583.4	479.2	967.2	**17857.1**
1993	1194.1	2081.6	1566.9	593.0	1040.8	669.0	1178.9	**8324.3**
1994	1970.8	3144.3	1313.3	368.1	296.7	849.5	1073.1	**9015.8**
1995	1822.8	3371.4	735.7	137.7	214.1	695.7	1057.8	**8035.2**
1996	1701.5	2145.1	631.5	202.2	207.2	545.0	1411.8	**6844.3**
1997	1634.1	4299.3	1496.2	510.5	196.6	93.4	1212.3	**9442.4**
1998	683.5	2754.1	2786.1	861.3	261.0	308.0	458.8	**8112.8**
1999	1638.5	1946.1	2096.7	572.8	174.7	352.5	482.8	**7264.1**
2000	667.4	4396.5	2693.3	717.7	96.9	536.0	155.9	**9263.7**
2001	1414.3	4466.7	3466.2	1151.9	198.3	608.0	243.5	**11548.9**
2002	587.1	5145.6	1661.6	542.6	340.3	236.8	415.9	**8929.9**
2003	819.3	2646.0	3975.0	774.6	377.9	319.8	644.0	**9556.6**
2004	420.9	4445.2	2683.8	1276.9	429.5	507.0	816.4	**10579.8**
2005	2756.1	2139.9	3953.0	1907.3	563.0	629.7	576.5	**12525.4**
2006	1291.6	3212.1	2554.9	1844.1	1392.2	419.2	845.7	**11559.8**
2007	639.0	5181.4	4255.6	1529.3	927.1	300.3	679.1	**13511.7**
2008	839.8	4242.2	3327.5	878.9	762.1	424.3	523.0	**10997.9**
2009	94.5	2858.7	2783.3	682.3	490.3	320.1	633.2	**7862.4**
2010	254.5	2925.0	3924.7	631.5	640.5	377.9	836.2	**9590.2**
2011	342.0	3282.2	2207.8	782.1	296.6	500.6	902.5	**8313.7**

Table 5. NEFSC bluefish indices by age using fall inshore strata and retransformed $\log_e$ stratified mean number per tow.

Year	Age 0	1	2	3	4	5	6+	Total
1982	18.768	10.788	0.064	0.053	0.011		0.023	**29.71**
1983	8.189	16.695	0.845	0.034	0.004	0.017	0.068	**25.85**
1984	81.356	40.869	1.257	0.201	0.120	0.052	0.147	**124.00**
1985	17.473	9.703	0.925	0.428	0.096	0.036	0.088	**28.75**
1986	21.055	0.923	0.042	0.060	0.024	0.028	0.033	**22.17**
1987	7.589	1.768	0.167	0.238	0.098	0.049	0.158	**10.07**
1988	9.493	0.067	0.009	0.010	0.028	0.006	0.023	**9.64**
1989	237.573	1.254	0.113	0.130		0.014	0.119	**239.20**
1990	6.186	3.637	0.006	0.016	0.016		0.084	**9.95**
1991	7.878	0.154	0.050	0.026	0.001		0.001	**8.11**
1992	6.625	0.637	0.016	0.022	0.002	0.002	0.008	**7.31**
1993	1.109	0.123	0.044	0.003	0.034	0.023		**1.34**
1994	6.580	0.760	0.010	0.019	0.030	0.021	0.006	**7.43**
1995	9.222	4.122	0.115	0.015	0.015	0.025	0.062	**13.58**
1996	9.643	1.638	0.211	0.144	0.027	0.021	0.019	**11.70**
1997	4.179	0.482	0.217	0.107	0.002	0.007	0.013	**5.01**
1998	4.793	0.387	0.074	0.045	0.017			**5.32**
1999	15.266	1.528	0.061	0.051	0.018	0.002	0.008	**16.93**
2000	2.485	1.517	0.157	0.017	0.015	0.006		**4.20**
2001	8.819	0.754	0.148	0.020	0.002	0.001	0.003	**9.75**
2002	7.815	1.210	0.042	0.037				**9.10**
2003	48.332	3.085	0.277	0.019	0.006	0.022	0.043	**51.78**
2004	7.048	5.307	0.372	0.079	0.008	0.012	0.031	**12.86**
2005	24.086	0.705	0.107	0.098	0.031	0.030	0.012	**25.07**
2006	36.300	1.017	0.714	0.016				**38.05**
2007	8.837	7.064	0.583	0.082	0.012	0.004	0.009	**16.59**
2008	7.444	4.543	0.797	0.012	0.010	0.009	0.026	**12.84**
2009*	1.050	5.385	0.503	0.013	0.011	0.000	0.037	**7.00**
2010*	2.559	3.352	0.527	0.029	0.069	0.028	0.093	**6.66**
2011*	2.641	4.357	0.299	0.036	0.045	0.030	0.039	**7.450**

*indices adjusted with conversion factor = 1.16 (Miller et al., 2010)

Table 6. Bluefish survey indices by age (stratified geometric mean number per tow) from the Delaware and New Jersey trawl surveys.

	Delaware				New Jersey			
Year	Age 0	Age 1	Age 2	**Total**	Age 0	Age 1	Age 2	**Total**
1982	0.025							
1983	0.024							
1984	0.039							
1985	0.022							
1986	0.081							
1987	0.073							
1988	0.114				26.066	0.411	0.002	**26.48**
1989	0.267				7.041	0.544	0.026	**7.61**
1990	0.082	0.683	0.015	**0.780**	5.947	0.299	0.005	**6.25**
1991	0.132	0.209	0.004	**0.345**	3.652	0.009	0.020	**3.68**
1992	0.071	0.211	0.003	**0.285**	3.747	0.582	0.040	**4.37**
1993	0.063	0.220	0.013	**0.296**	2.483	0.085	0.109	**2.68**
1994	0.103	0.295	0.004	**0.401**	11.179	0.231	0.017	**11.43**
1995	0.093	0.376	0.031	**0.500**	5.055	0.238	0.050	**5.34**
1996	0.081	0.426	0.017	**0.524**	2.483	0.096	0.015	**2.59**
1997	0.147	0.317	0.023	**0.486**	3.930	0.075	0.034	**4.04**
1998	0.080	0.581	0.107	**0.768**	1.719	0.243	0.154	**2.12**
1999	0.097	0.439	0.034	**0.570**	1.710	0.350	0.035	**2.10**
2000	0.113	0.365	0.047	**0.525**	1.410	0.395	0.102	**1.91**
2001	0.290	0.555	0.107	**0.952**	0.400	0.068	0.090	**0.56**
2002	0.159	1.210	0.047	**1.416**	7.924	3.469	0.077	**11.47**
2003	0.038	0.224	0.012	**0.274**	6.793	0.196	0.077	**7.06**
2004	0.074	0.836	0.030	**0.940**	2.019	0.684	0.318	**3.02**
2005	0.060	0.127	0.009	**0.195**	6.141	0.235	0.168	**6.54**
2006	0.039	0.070	0.020	**0.129**	6.573	0.126	0.061	**6.76**
2007	0.093	0.321	0.021	**0.436**	6.136	6.718	0.342	**13.20**
2008	0.087	0.172	0.016	**0.275**	9.041	0.843	0.028	**9.91**
2009	0.031	0.282	0.029	**0.342**	3.013	0.187	0.010	**3.21**
2010	0.031	0.383	0.066	**0.481**	1.934	0.136	0.020	**2.09**
2011	0.050	0.140	0.010	**0.200**	7.364	6.989	0.017	**14.37**

Table 7. Bluefish survey indices by age (stratified geometric mean number per tow) from the Conneticut DEP trawl survey.

Year	Age							Total
	0	1	2	3	4	5	6+	
1984	52.101	0.800	0.760	0.298	0.054	0.014	0.041	**54.068**
1985	36.368	1.573	1.075	0.498	0.244	0.044	0.131	**39.933**
1986	8.727	0.547	0.352	0.083	0.053	0.028	0.018	**9.808**
1987	14.357	2.229	0.951	0.279	0.213	0.131	0.070	**18.230**
1988	13.122	0.851	0.567	0.358	0.234	0.173	0.106	**15.411**
1989	47.873	1.900	0.732	0.205	0.347	0.282	0.072	**51.411**
1990	28.027	3.499	0.742	0.106	0.141	0.200	0.024	**32.739**
1991	36.482	5.233	2.078	0.194	0.135	0.164	0.075	**44.361**
1992	24.585	3.359	1.750	0.172	0.152	0.283	0.005	**30.306**
1993	25.810	1.241	2.161	0.877	0.385	0.107		**30.581**
1994	30.018	1.410	0.752	0.512	0.386	0.251	0.010	**33.339**
1995	26.588	6.967	1.313	0.303	0.168	0.202	0.034	**35.575**
1996	42.334	0.491	1.031	0.360	0.060	0.036	0.159	**44.471**
1997	40.413	0.586	0.536	0.140	0.051	0.022	0.058	**41.806**
1998	34.831	1.453	0.512	0.130	0.058	0.011	0.025	**37.020**
1999	44.950	5.617	0.287	0.188	0.046	0.049	0.079	**51.216**
2000	22.593	3.652	1.408	0.178	0.021	0.016	0.029	**27.897**
2001	34.050	2.294	2.180	0.283	0.026	0.021	0.042	**38.896**
2002	12.419	4.926	0.578	0.135	0.045	0.048	0.063	**18.214**
2003	27.307	0.357	0.655	0.104	0.024	0.034	0.044	**28.525**
2004	20.134	3.944	3.315	1.336	0.071	0.160	0.171	**29.131**
2005	29.687	0.047	0.243	0.099	0.037	0.021	0.007	**30.141**
2006	14.353	0.719	0.558	0.030				**15.660**
2007	25.680	16.460	0.940	0.260	0.040	0.010	0.040	**43.430**
2008	no september sampling							
2009	30.217	1.702	0.733	0.107	0.067	0.006	0.029	**32.860**
2010	mechanical failure							
2011	12.237	0.306	0.190	0.081	0.014	0.034	0.069	**12.930**

Table 8. Recreational catch per angler trip by age for bluefish from Maine to Florida, 1982 to 2011. Index was predicted from a Genearlized Linear Model with a negative bionomial transformation.

Year	Age							**Total**
	0	1	2	3	4	5	6+	
1982	0.110	0.100	0.027	0.022	0.010	0.016	0.048	**0.332**
1983	0.040	0.058	0.063	0.025	0.008	0.011	0.042	**0.246**
1984	0.087	0.069	0.056	0.025	0.011	0.008	0.041	**0.297**
1985	0.080	0.097	0.097	0.050	0.018	0.008	0.040	**0.390**
1986	0.055	0.068	0.084	0.035	0.013	0.019	0.054	**0.327**
1987	0.036	0.067	0.065	0.068	0.024	0.015	0.054	**0.329**
1988	0.022	0.027	0.031	0.023	0.028	0.022	0.042	**0.195**
1989	0.059	0.090	0.046	0.017	0.005	0.015	0.040	**0.271**
1990	0.038	0.114	0.033	0.012	0.006	0.005	0.029	**0.236**
1991	0.044	0.056	0.057	0.027	0.005	0.003	0.027	**0.217**
1992	0.016	0.049	0.033	0.054	0.013	0.004	0.024	**0.193**
1993	0.021	0.047	0.023	0.012	0.024	0.016	0.015	**0.158**
1994	0.042	0.063	0.029	0.010	0.006	0.012	0.018	**0.180**
1995	0.026	0.081	0.015	0.004	0.006	0.015	0.013	**0.158**
1996	0.055	0.062	0.017	0.007	0.007	0.008	0.023	**0.179**
1997	0.050	0.101	0.035	0.011	0.004	0.002	0.029	**0.231**
1998	0.031	0.077	0.066	0.029	0.010	0.007	0.018	**0.237**
1999	0.106	0.090	0.065	0.026	0.007	0.008	0.015	**0.318**
2000	0.034	0.180	0.088	0.028	0.003	0.011	0.007	**0.352**
2001	0.060	0.157	0.094	0.035	0.006	0.012	0.008	**0.373**
2002	0.029	0.210	0.064	0.019	0.005	0.006	0.015	**0.348**
2003	0.034	0.092	0.129	0.024	0.007	0.010	0.019	**0.316**
2004	0.018	0.157	0.088	0.051	0.013	0.016	0.024	**0.368**
2005	0.101	0.071	0.106	0.036	0.009	0.014	0.012	**0.349**
2006	0.194	0.151	0.146	0.031	0.012	0.006	0.027	**0.568**
2007	0.022	0.086	0.148	0.042	0.024	0.018	0.038	**0.377**
2008	0.036	0.147	0.137	0.014	0.016	0.006	0.012	**0.367**
2009	0.008	0.133	0.119	0.019	0.014	0.006	0.020	**0.319**
2010	0.012	0.120	0.143	0.022	0.021	0.013	0.029	**0.361**
2011	0.017	0.170	0.097	0.030	0.016	0.026	0.045	**0.401**

Table 9. Abundance at age (000s) for bluefish from the ASAP model.

Year	Age							Total
	0	1	2	3	4	5	6+	
1982	44851	43553	13193	7009	6861	12841	45377	**173685**
1983	34582	34553	29781	9116	5267	5281	40791	**159371**
1984	45082	26390	22975	20043	6760	4015	31355	**156620**
1985	25019	34589	17829	15696	14975	5182	24413	**137703**
1986	21416	19181	23314	12154	11714	11470	20440	**119689**
1987	14868	15649	11218	13904	8478	8546	19740	**92403**
1988	20911	10798	8987	6576	9615	6146	17157	**80190**
1989	46011	15363	6416	5440	4622	7053	14509	**99414**
1990	19267	34394	9609	4076	3919	3450	14078	**88793**
1991	23637	14482	21867	6200	2959	2942	11518	**83605**
1992	11657	17396	8650	13302	4368	2174	9004	**66551**
1993	12768	8725	10921	5515	9598	3265	7264	**58056**
1994	18477	9583	5523	7018	3995	7195	6937	**58728**
1995	16706	13983	6217	3632	5143	3020	9604	**58305**
1996	16038	12840	9495	4268	2720	3949	8798	**58108**
1997	14652	12373	8818	6588	3214	2097	8996	**56738**
1998	19804	11325	8543	6149	4973	2482	7829	**61105**
1999	23218	15370	7915	6026	4669	3857	7367	**68422**
2000	15582	18243	11143	5779	4656	3666	8299	**67368**
2001	26781	12175	13009	8010	4430	3636	8716	**76757**
2002	20816	20665	8365	9029	6033	3415	8715	**77038**
2003	23366	16305	14843	6054	6946	4722	8884	**81120**
2004	16461	18275	11661	10699	4648	5429	9948	**77121**
2005	23511	12728	12632	8140	8081	3591	10929	**79612**
2006	35148	18303	8976	8986	6207	6286	10458	**94364**
2007	22143	27452	13035	6444	6885	4845	12209	**93013**
2008	22928	17123	18983	9102	4869	5319	12094	**90418**
2009	12484	17899	12177	13611	6969	3798	12655	**79593**
2010	14602	9867	13200	9035	10603	5505	12309	**75121**
2011	10598	11362	6951	9380	6886	8244	12844	**66265**

Table 10. Biomass at age (mt) for bluefish as estimated from the ASAP model results.

Year	Age							Total
	0	1	2	3	4	5	6+	
1982	3624	15013	16861	11573	18687	47255	224979	**337992**
1983	1708	8379	20742	16480	13406	19854	227491	**308061**
1984	2254	5344	14359	26978	16909	15112	177156	**258112**
1985	1131	6918	11243	21028	34019	17660	123359	**215357**
1986	1625	4247	16152	18232	28883	39956	99093	**208188**
1987	977	2969	8530	21647	22217	30057	98384	**184781**
1988	2677	2366	4922	10228	23030	19962	79317	**142501**
1989	3051	3469	4178	7921	12626	24085	68482	**123811**
1990	3227	8770	4937	5520	10271	13453	62985	**109163**
1991	1983	3812	12937	7650	6524	10542	57187	**100634**
1992	971	4065	5067	15300	9614	6623	45983	**87624**
1993	1541	2680	6648	8821	21802	9830	35448	**86770**
1994	1159	2571	4025	9379	10925	23043	28393	**79494**
1995	1766	3213	3892	4532	11905	10607	45100	**81016**
1996	1618	3512	6235	5557	6040	13430	41315	**77708**
1997	737	3545	5988	10019	7680	7435	54021	**89426**
1998	1994	2874	5604	9576	14060	9107	46238	**89454**
1999	1718	4570	5637	8265	13433	14492	43907	**92021**
2000	1611	4362	7800	8945	12670	13263	48557	**97209**
2001	1867	3013	7772	11997	13806	13355	42935	**94745**
2002	1509	5321	5477	12432	15772	12764	44952	**98227**
2003	1231	4598	10479	9729	17484	16483	44518	**104523**
2004	397	3538	8906	14988	11772	17249	44647	**101496**
2005	1611	2511	7617	12688	20906	12428	60426	**118188**
2006	3466	4872	7150	12833	17364	22297	55605	**123587**
2007	589	7124	10208	10606	17254	16605	61118	**123504**
2008	2006	2806	13842	15108	13450	17887	57519	**122619**
2009	464	4666	8755	23668	19864	12988	61756	**132162**
2010	767	1741	8744	12798	30560	20476	61287	**136371**
2011	428	2080	3931	11022	13981	32129	69319	**132890**

Table 11. Projection results for bluefish through 2014 under various fishing scenarios. A quota for 2012 and F values for 2013 and 2014 were used to project forward.

		Quota (000s mt)	F	Jan 1 Abundance (000s)	Mean Biomass (000s mt)	SSB (000s mt)	Yield (000s mt)
F low	2012	14.54		71299.60	127.58	121.21	14.54
	2013		0.10	73900.40	120.82	112.90	9.56
	2014		0.10	77388.80	119.64	109.87	9.68

		Quota (000s mt)	F	Jan 1 Abundance (000s)	Mean Biomass (000s mt)	SSB (000s mt)	Yield (000s mt)
F status quo	2012	14.54		71299.60	127.58	121.21	14.54
	2013		0.114	73900.40	120.18	112.27	10.84
	2014		0.114	76850.60	117.75	108.07	10.85

		Quota (000s mt)	F	Jan 1 Abundance (000s)	Mean Biomass (000s mt)	SSB (000s mt)	Yield (000s mt)
F0.1	2012	14.54		71299.60	127.58	121.21	14.54
	2013		0.16	73900.40	118.13	110.26	14.93
	2014		0.16	75124.00	111.78	102.38	14.42

		Quota (000s mt)	F	Jan 1 Abundance (000s)	Mean Biomass (000s mt)	SSB (000s mt)	Yield (000s mt)
Ftarget	2012	14.54		71299.60	127.58	121.21	14.54
	2013		0.17	73900.40	117.69	109.82	15.80
	2014		0.17	74757.20	110.53	101.19	15.14

		Quota (000s mt)	F	Jan 1 Abundance (000s)	Mean Biomass (000s mt)	SSB (000s mt)	Yield (000s mt)
Fmsy	2012	14.54		71299.60	127.58	121.21	14.54
	2013		0.19	73900.40	116.82	108.96	17.52
	2014		0.19	74032.00	108.07	98.84	16.52

Table 12. Results of alternative model configuration which includes variable ESS, changes in index lambdas and changes in index CVs.

Year	Unweighted F	SSB	N	Observed Recruits (000s)
1982	0.24	208212	162640	50579
1983	0.28	189184	153235	40639
1984	0.26	166949	153637	51345
1985	0.25	151032	134846	28510
1986	0.42	152877	115128	22502
1987	0.45	124533	86536	15782
1988	0.41	95135	74242	21852
1989	0.35	84189	92571	45549
1990	0.32	67925	82554	20343
1991	0.42	60162	77177	23992
1992	0.35	60471	59458	11910
1993	0.35	58350	50752	12623
1994	0.32	52313	50660	17334
1995	0.26	51104	50518	16352
1996	0.24	48760	51500	16628
1997	0.24	58934	50536	14792
1998	0.22	58139	53445	18261
1999	0.17	61355	60218	22182
2000	0.19	67308	59921	15557
2001	0.23	65715	68407	25324
2002	0.17	71010	67998	19537
2003	0.17	75271	72404	22634
2004	0.21	73790	69208	16259
2005	0.19	91149	71859	22989
2006	0.17	88489	84236	32041
2007	0.21	88453	83855	21892
2008	0.17	93819	81817	22552
2009	0.13	104656	72524	13053
2010	0.18	102689	68813	14500
2011	0.14	101533	60081	10120

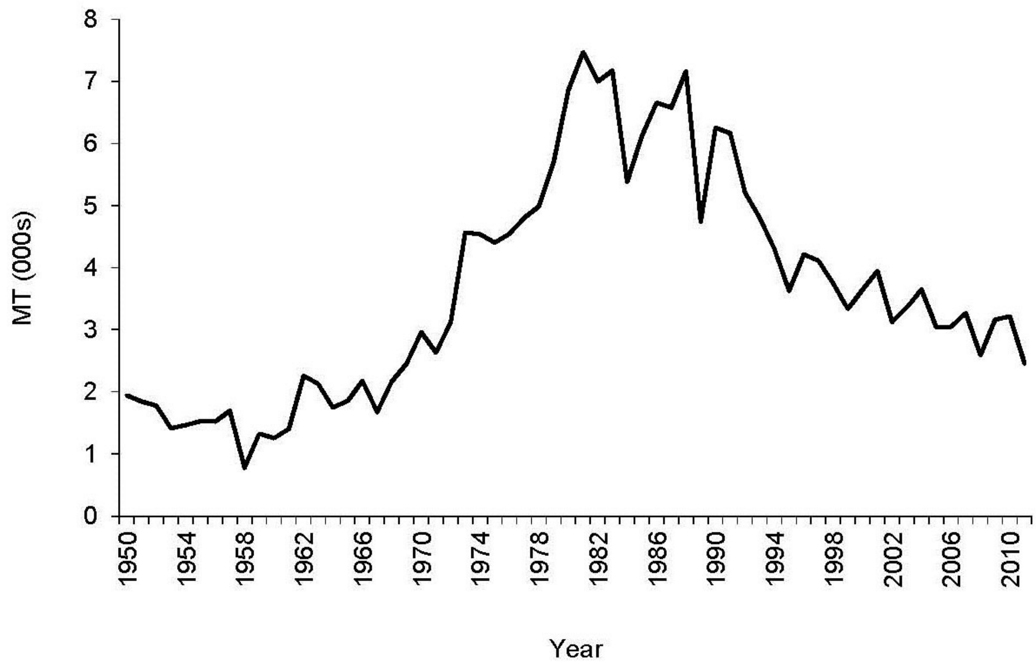

Figure 1. Times series of bluefish commercial landings (mt) along the Atlantic coast from 1950 to 2011.

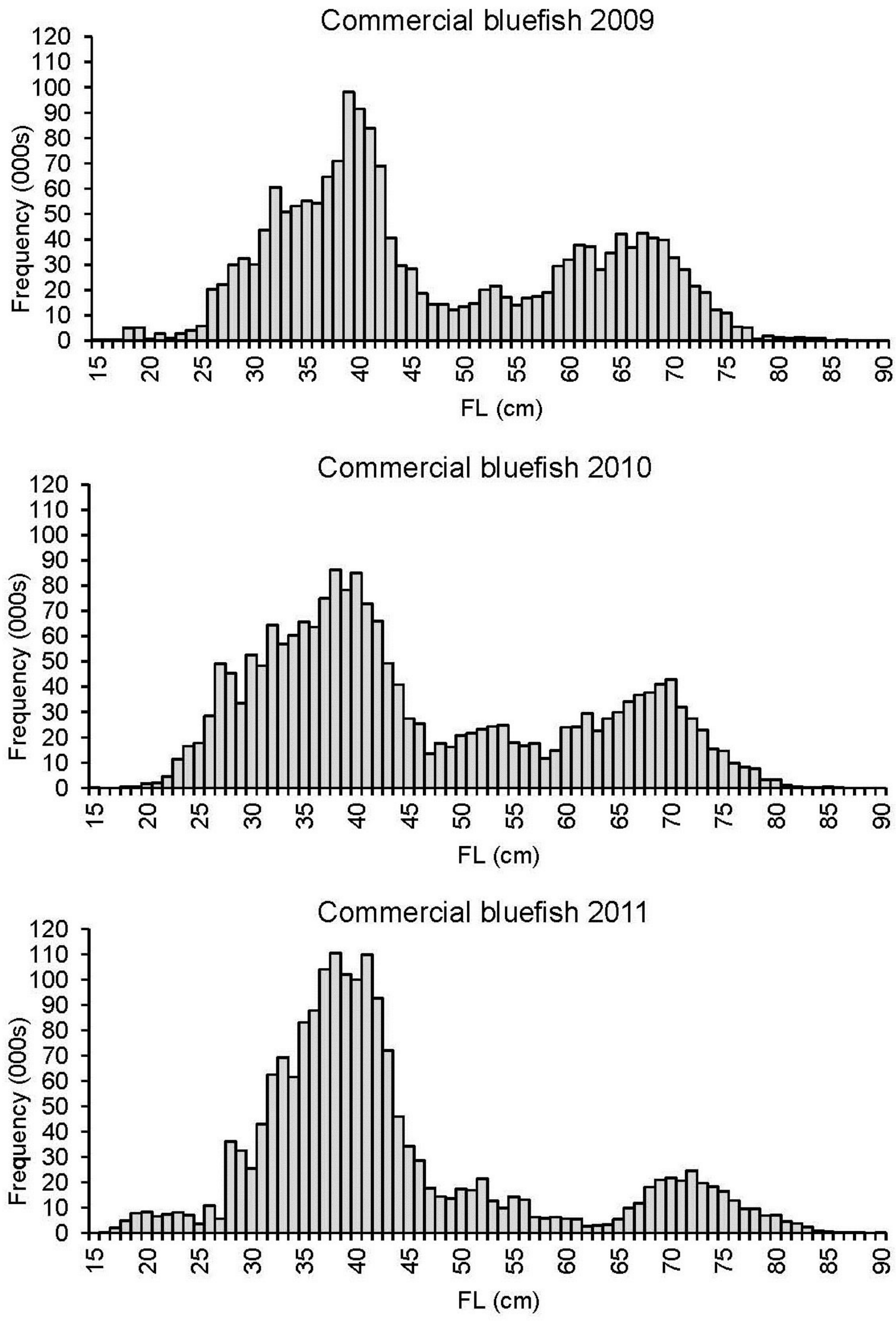

Figure 2. Length frequency distribution of commercial bluefish landings from Maine to Florida, 2009 to 2011.

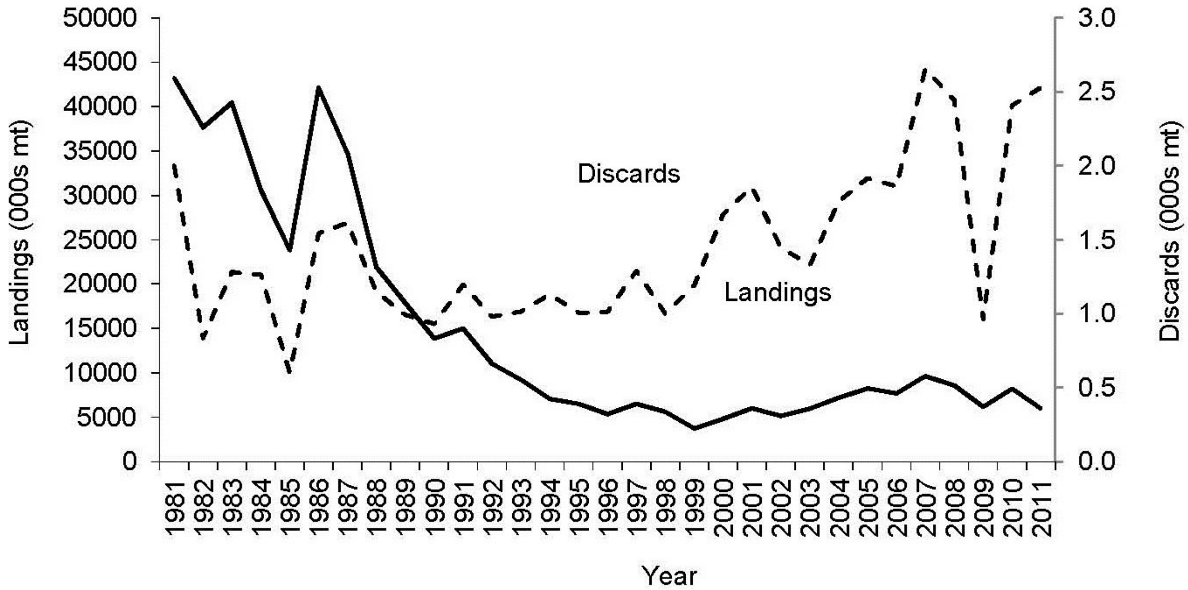

Figure 3. Recreational landings (mt) and recreational discard losses (MRIP B2 estimates*0.15) from Maine to Florida, 1981 to 2011.

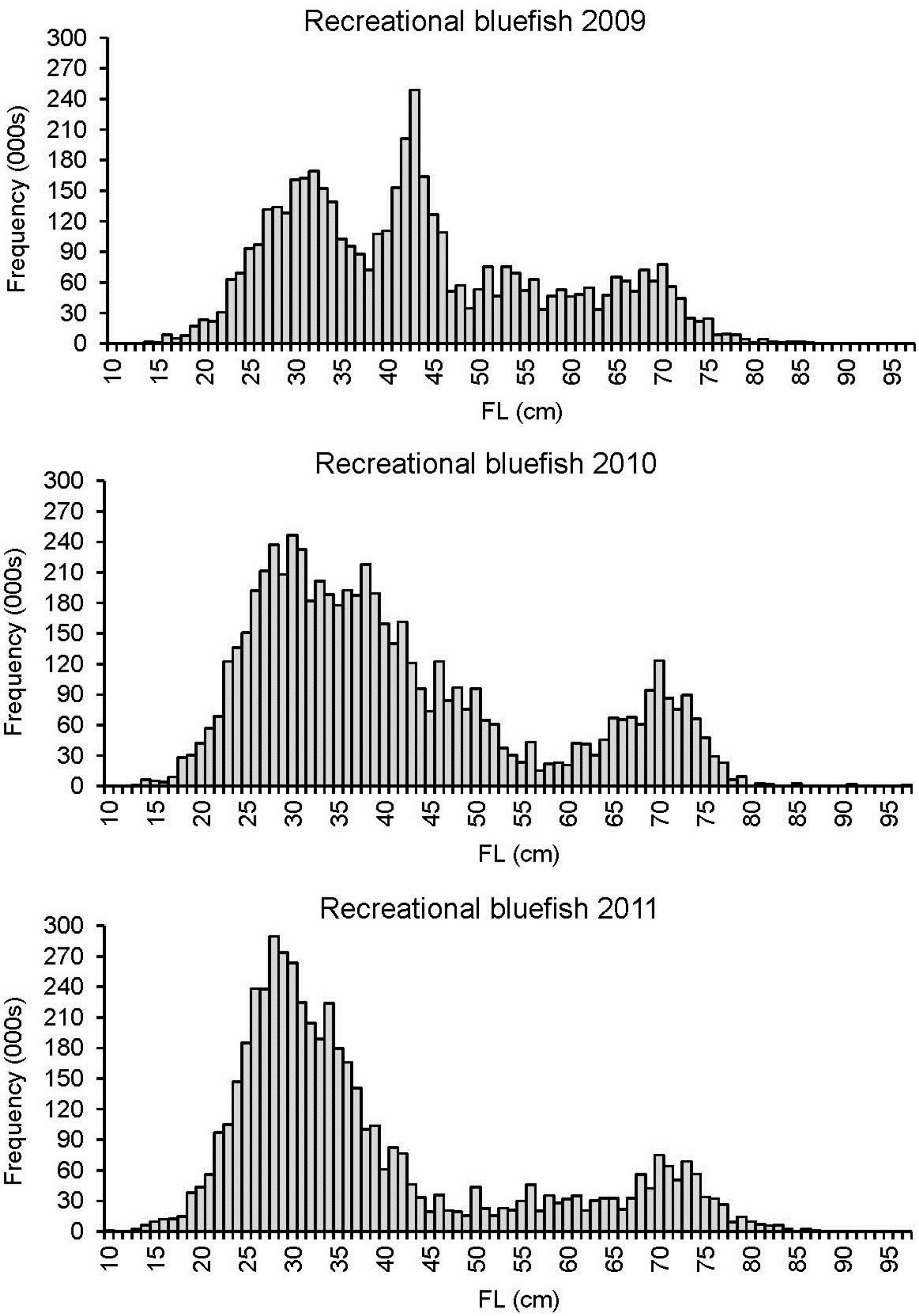

Figure 4. Length frequency distribution of recreational bluefish landings from Maine to Florida, 2009 to 2011

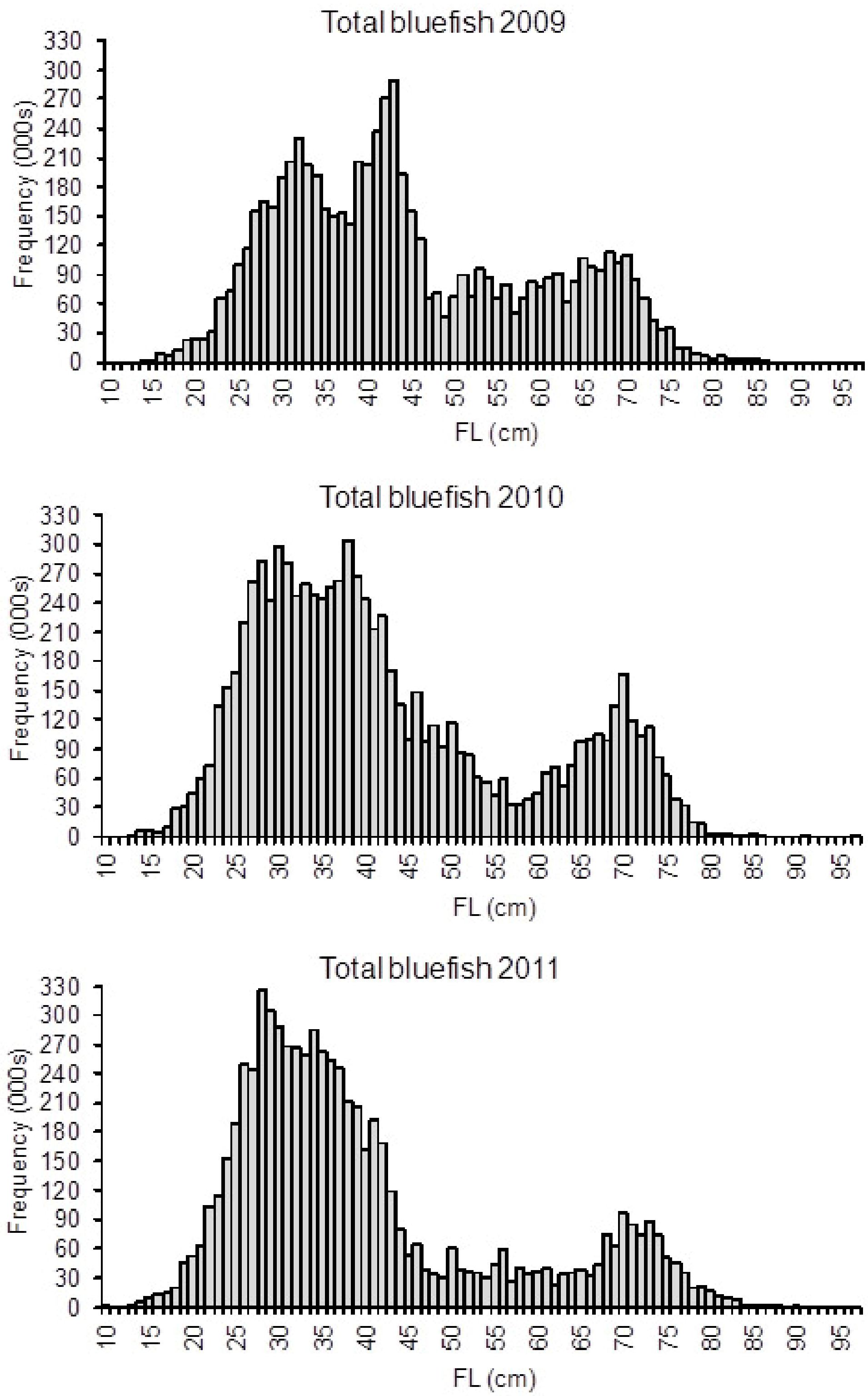

Figure 5. Length frequency distribution of total bluefish landings from Maine to Florida, 2009 to 2011.

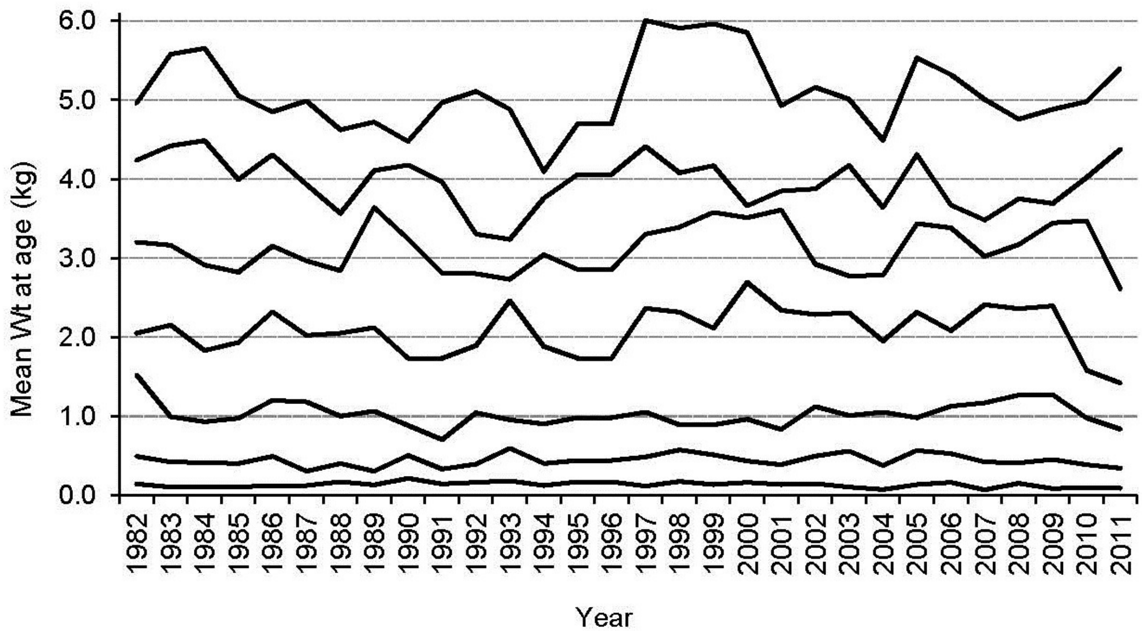

Figure 6. Bluefish mean weights (kg) ages 0 to 6+ from 1982 to 2011.

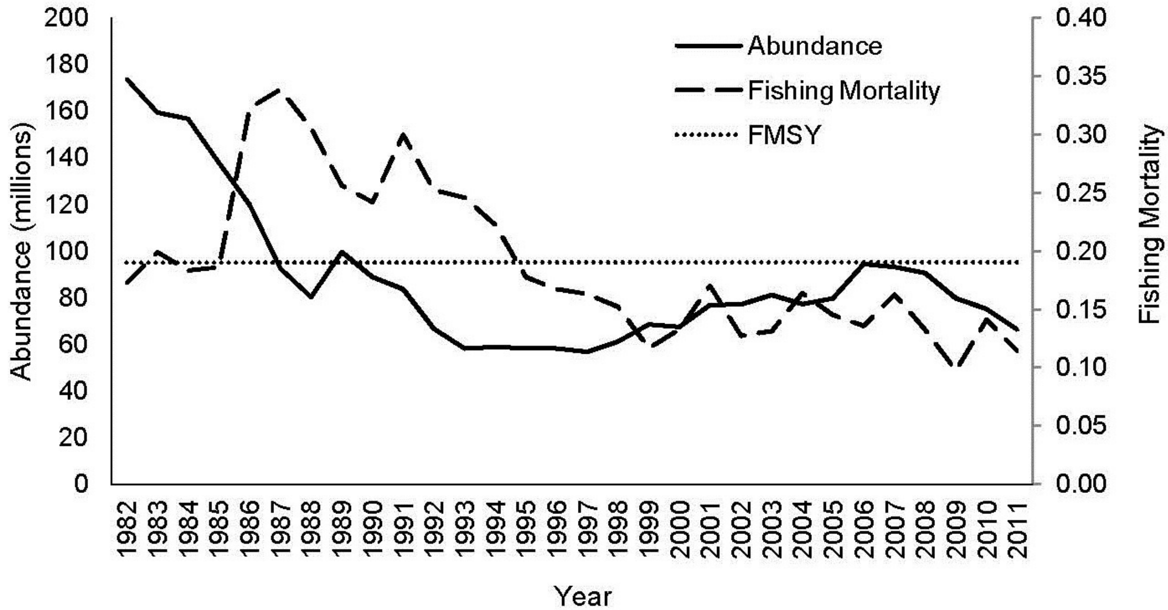

Figure 7. Total bluefish abundance and fishing mortality as estimated in ASAP model F_{MSY} indicated by dotted horizontal line.

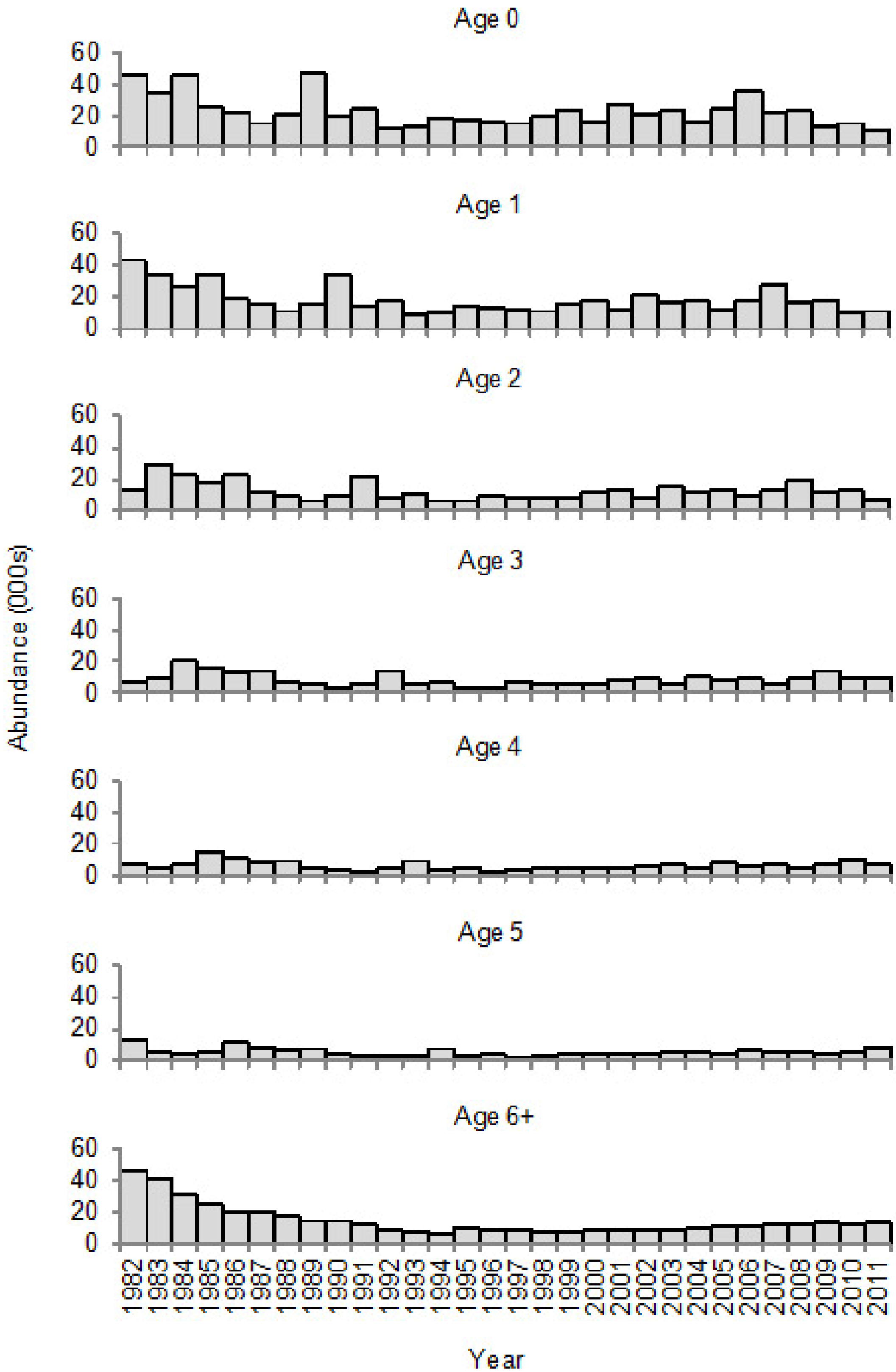

Figure 8. Total bluefish abundance (000s) at age from ASAP model results.

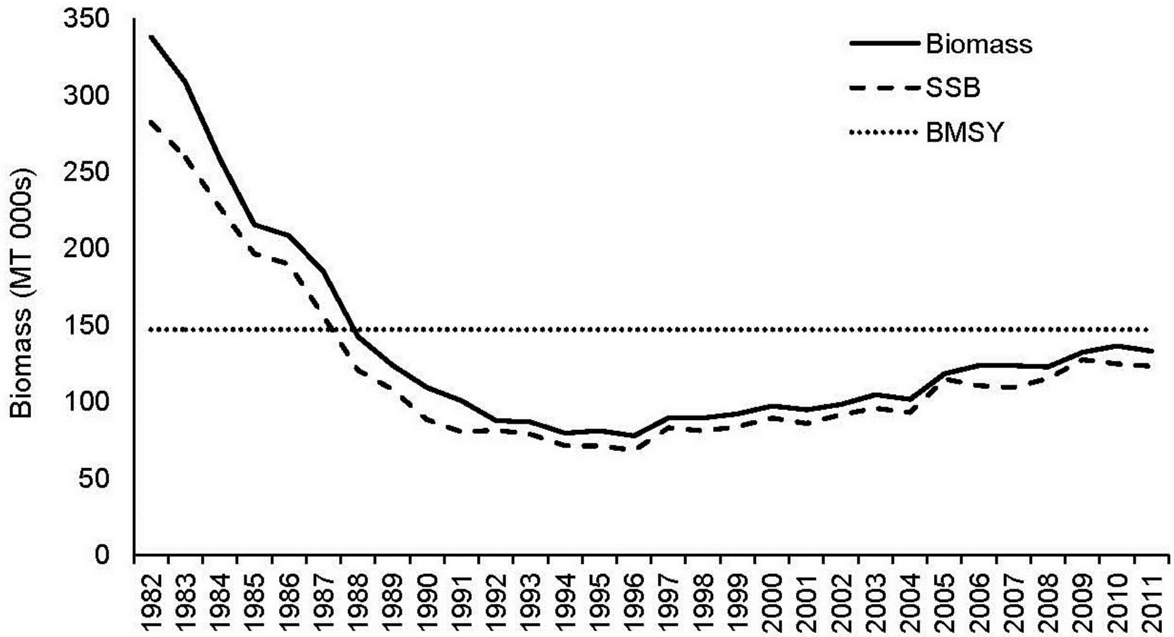

Figure 9. Time series of bluefish total mean biomass (000s mt) and spawning stock biomass (000s mt).

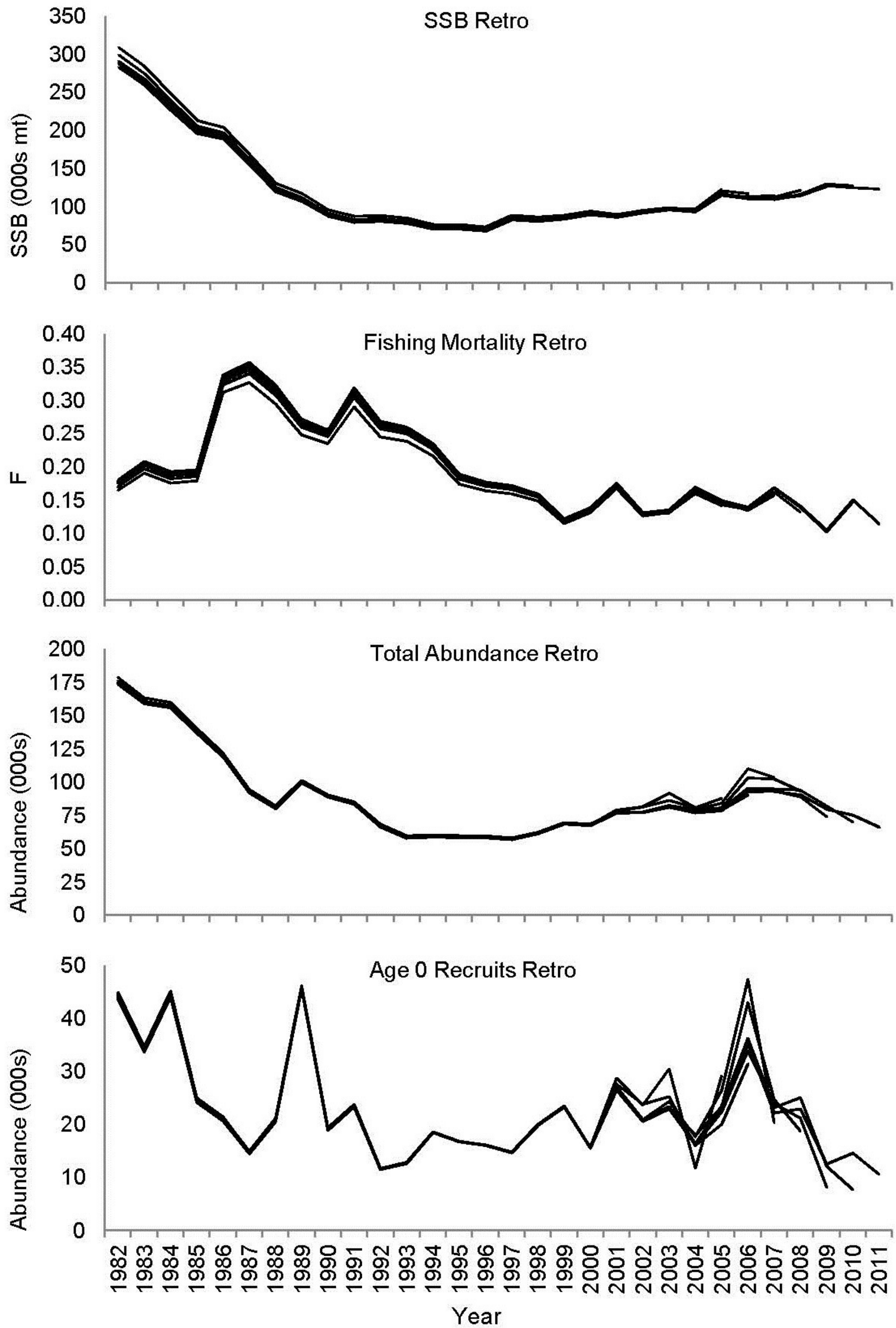

Figure 10. Retrospective bias in bluefish estimates from ASAP model.

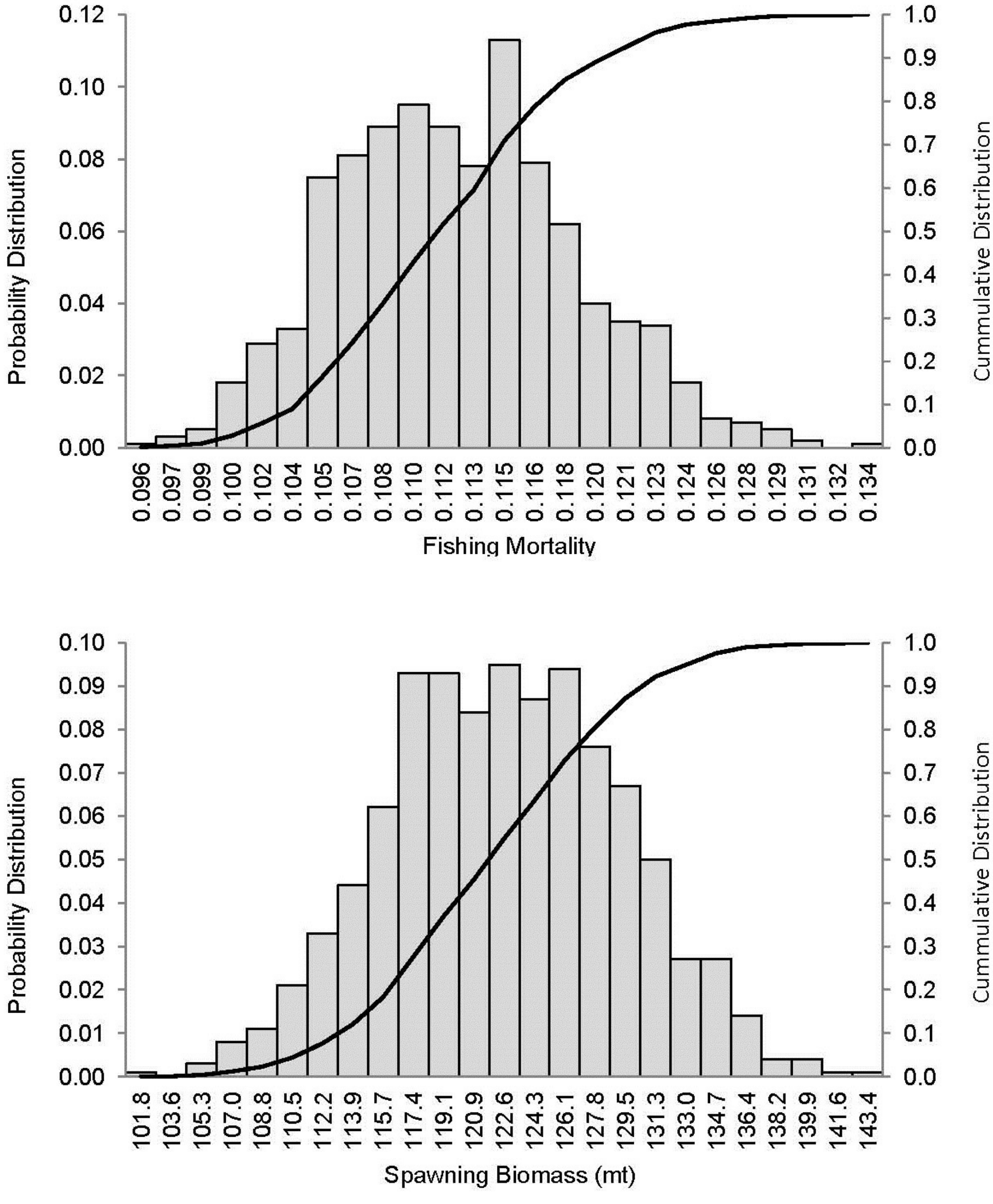

Figure 11. Distribution of bluefish mortality and spawning stock biomass resulting from 1000 MCMC iterations in ASAP model.

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