Bluefish 2013 Stock Assessment Update

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Executive Summary

The updated stock assessment was completed by adding catch and independent indices through 2012 to the previous 1982-2011 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 DEEP, 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 2012 age-length key developed by Old Dominion University.

The result of the analysis shows that bluefish is not overfished or experiencing overfishing. Fishing mortality in 2012 was 0.097, 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=0.135. Total stock biomass estimates peaked in 1982 at 357 thousand MT, then declined to 79.8 thousand MT by 1996 before increasing steadily to the 130.6 thousand MT in 2010 and slightly declining again to 125.8 thousand MT in 2012. 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 33.2 million fish. However, beginning in 2009 recruitment dropped to 13.6 million and the 2010 and 2011 recruitment estimates were also below average at 16.4 and 16.7 million fish, respectively. Current recruitment is at an all time low with a model estimate of 9.8 million fish. However, the total catch at age shows a much higher number of age-0 fish than in recent years. Low estimates of recruitment coming from the model may be due to retrospective bias resulting in the model underestimating recruitment by upwards of 50% near the end of the time series. A projection of the abundance through 2015, under seven different fishing scenarios between F=0.097 and F=0.19, suggest that biomass will continue to decline due to poor

incoming year classes. Changes in the NMFS survey (no longer sampling inshore strata), 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 in 2005 (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 2012 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 iteroparous spawners with indeterminate fecundity and 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 2012 a total of 8,037 measurements were collected across all market categories from total landings of 1,809 MT (81% 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 1,016 measurements were collected from landings of 347 MT (Table 1). Expansion of landings at length were done by quarter, market category and gear type and then combined into half year totals. Length samples from Florida 2011 commercial landings were also available. A total of 603 lengths were used to expand commercial landings of 81 MT (Table 1). No landings were reported for South Carolina or Georgia. Total coast-wide commercial landings in 2012 were 2,236 MT, a decrease of 219 MT from 2011 (Figure 1).

Length frequencies from commercial fisheries are characterized by a multi-modal distribution. In 2012 the distribution had a strong peak at 36 cm and lacked the definitive second peak at around 70 cm seen in previous years (Figure 2).

Recreational landings are sampled for length as part of the MRIP program. The 2012 recreational landings were 4,846 MT, a decrease from 5,965 MT in 2011 (Table 2, Figure 3). The MRIP 2012 length samples were used to expand recreational landings per half year. Recreational discards in 2012 were estimated at 15,887 MT and after adjusting for a 15% mortality rate the resulting discard loss was 2,383 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=707). Length frequencies from the recreational catch and discards show a similar trend to the commercial length frequency. While previous years were characterized by a bimodal distribution, the 2012 length frequency is a skewed distribution, with a main peak around 28 cm and a flat/slightly-decreasing distribution out to 90 cm (Figure 4). Total combined (commercial and recreational) length frequencies are presented in Figure 5.

Recreational landings are also used to develop a recreational catch per angler trip index. In 2012 this CPA index showed a small decrease to 0.38 fish per angler trip from 0.40 in 2011 (Table 3). 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.

Age data were provided by Virginia Marine Resources Commission and Old Dominion University ageing lab (n = 531). Since the age key developed from these data was the only 2012 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 4, 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=257, a = -11.357, b = 3.004). Fall equations were estimated from combined 2004-2012 length-weight data (n = 3788, a = -11.607, b = 3.091).

The 2012 catch at age (includes commercial landings, recreational landings and recreational discards) is presented in table 5. 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 2012. These indices include SEAMAP juvenile (age 0) indices, Northeast Fisheries Science Center (NEFSC) bottom trawl survey indices for ages 0 to 6+, CT DEEP bottom trawl

survey for ages 0-6+, NJ bottom trawl survey indices of ages 0 to 2, and DE bottom trawl survey indices for ages 0 to 2. The CT DEEP bottom trawl 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, increased to 7.45 in 2011, and dropped to 5.27 in 2012 (Table 6). The series arithmetic average index equaled 25.2 (geometric mean of 13.0). The 2012 Delaware survey index of ages 0 to 2 was 0.2 fish per tow, and below the time series average (0.49 per tow; Table 7). New Jersey trawl survey indices of ages 0 to 2 for 2012 (10.57 fish/tow) was above the time series average of 6.6 per tow (Table 7). The Connecticut DEP survey index for 2012 was 25.19, lower than the mean of 32.3, but almost double the 2011 estimate (Table 8).

ASAP Model

The ASAP model was run as an update of previous 1982-2011 input file, updated for 2012 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 91.4 million to 64.2 million fish (Table 9, Figure 7). Poor

recruitment began in 2009 with a below average estimate of 13.6 million fish compared to the series average of 22.8 million. Low recruitment persisted for 2010 and 2011, and estimated recruitment in 2012 was the lowest in the time series at 9.8 million fish (Table 9, Figure 8). However among other age groups, the estimate of age 6-plus bluefish continued to be large at 14.9 million, the highest since 1990. Total mean biomass in 2012 equaled 125,808 MT, a slight decrease from the 2011 estimate of 127,129 MT (Table 10, Figure 9). Corresponding spawning stock biomass (SSB) in 2012 was 119,857 MT, a slight increase from the 2011 estimate of 116,615 MT (Figure 9, Table 11).

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 2012 F_{MULT} value equals 0.097 (Figure 7, Table 11). Fishing mortality steadily declined from 0.34 in 1987 to 0.12 in 1999 and has remained relatively steady since 2000, with a slight declining trend in recent years.

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 of SSB, F, and total abundance. There does appear to be a retrospective bias showing up in the recruitment estimates going back to 2009 (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 0.086 to 0.117, with the 80% CI between 0.091 and 0.105. Estimates for SSB ranged from 102,200 to 136,400 MT, with an 80% CI between 111,236 MT and 127,549 MT. (Figure 11).

Projections

Bluefish abundance and biomass through 2015 were examined for a range of fishing scenarios with a stochastic projection in AGEPRO software. Weight at age in 2013-2015 was assumed equal to 2012, recruitment was derived from a random draw of 31 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 12,461 MT. Five standard projection scenarios were examined: F =0.10, F=status quo (0.097), 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). Two additional projection scenarios were also conducted: F = 0.132 (from 2013 P* = 0.341) and at F that resulted in the 2014 ACL (12,273 MT) being taken (F = 0.1384).

Results of the projections show a decrease in mean biomass and SSB for each scenario (Table 12). However, abundance continued to increase in all cases. Yield through 2015 would be projected as lower for F scenarios of F_{low} or F_{sq} or less. Under status quo F (0.097), projected 2014 yield would decrease to 8,750 MT, which includes commercial and recreational landings as well as recreational discards losses.

Biological Reference Points

The current biological reference points for bluefish were determined in SARC 41 and 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 2012 estimate of mean total biomass is 125,808 MT, which is below B_{MSY} but well above ½ B_{MSY} of 73,526 MT. The 2012 estimate of fishing mortality (0.097) remains well below F_{MSY}.

Model Uncertainty

Model uncertainty can be characterized using the 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. It should be noted that the current model is heavily weighted toward the catch. Sensitivity analyses exploring changes in effective sample size and changes to index lambdas and CVs will be explored in the upcoming benchmark.

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, however a retrospective bias is starting to show up in estimates of recruitment. The overall 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 continues 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.

It is anticipated that specific modeling and data uncertainties will be explored extensively during the benchmark assessment in 2014.

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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**
2012	1809	347	81	**2236**

Table 2. Commercial 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): 0.15 * B2	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	*2856*	*8821*	8420	11276
2012	2236	4930	4846	*2383*	*7229*	7082	9465

Table 3. Recreational catch per angler trip by age for bluefish from Maine to Florida, 1982 to 2011. Index was predicted from a Generalized Linear Model with a negative binomial 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**
2012	0.064	0.131	0.090	0.038	0.023	0.008	0.022	**0.376**

Table 4. 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
2012	0.084	0.366	0.844	1.396	3.148	3.896	5.541

Table 5. 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**
2012	1145.9	2746.2	2357.4	919.5	493.0	188.1	507.1	**8357.2**

Table 6. NEFSC bluefish indices by age using fall inshore strata and re-transformed $\log_e$ stratified mean number per tow.

Year	Age							Total
	0	1	2	3	4	5	6+	
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**
2012*	1.746	2.763	0.587	0.123	0.043	0.004	0.008	**5.270**

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

Table 7. Bluefish survey indices by age from the Delaware (stratified geometric mean number per tow) and New Jersey (stratified mean number per tow) trawl surveys.

	Delaware				New Jersey			
Year	Age			**Total**	Age			**Total**
	0	1	2		0	1	2	
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**
2012	0.020	0.160	0.016	**0.196**	7.959	2.535	0.081	**10.57**

Table 8. Bluefish survey indices by age (stratifed 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**
2012	22.346	2.563	0.165	0.066	0.024	0.008	0.017	**25.190**

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

Year	Age							Total
	0	1	2	3	4	5	6+	
1982	44204	42413	12957	6936	6802	12300	49729	**175340**
1983	34061	34173	29303	9041	5238	5254	43815	**160885**
1984	44552	26091	22976	19928	6739	4008	33714	**158008**
1985	24649	34299	17806	15846	14961	5184	26263	**139008**
1986	20965	18955	23330	12242	11878	11495	21883	**120746**
1987	14524	15387	11229	14083	8592	8703	20848	**93367**
1988	20524	10599	8964	6673	9806	6260	18134	**80961**
1989	45620	15147	6384	5496	4720	7226	15355	**99948**
1990	18984	34231	9581	4099	3980	3537	14877	**89289**
1991	23383	14314	21966	6236	2988	2997	12195	**84079**
1992	11516	17283	8659	13523	4420	2205	9560	**67167**
1993	12636	8649	10962	5574	9805	3316	7711	**58652**
1994	18405	9513	5525	7104	4055	7373	7317	**59291**
1995	16650	13965	6219	3659	5225	3073	10040	**58830**
1996	15967	12821	9538	4292	2748	4020	9184	**58570**
1997	14564	12339	8850	6649	3240	2122	9356	**57120**
1998	19764	11275	8560	6198	5031	2506	8132	**61465**
1999	23102	15358	7910	6060	4715	3906	7625	**68677**
2000	15461	18169	11163	5790	4688	3706	8544	**67520**
2001	26384	12091	12987	8043	4444	3664	8941	**76553**
2002	20556	20376	8328	9035	6065	3429	8910	**76698**
2003	22951	16108	14654	6035	6955	4749	9046	**80498**
2004	16137	17956	11529	10570	4634	5437	10092	**76356**
2005	22801	12479	12417	8051	7986	3581	11040	**78354**
2006	33215	17749	8800	8832	6139	6212	10529	**91476**
2007	18911	25934	12629	6312	6764	4790	12196	**87535**
2008	22714	14610	17883	8795	4762	5221	12016	**86002**
2009	13639	17704	10342	12766	6719	3709	12477	**77357**
2010	16359	10762	12997	7640	9923	5299	12062	**75042**
2011	16675	12707	7542	9190	5809	7702	12461	**72088**
2012	9768	13101	9210	5505	7100	4561	14921	**64167**

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	3572	14620	16559	11452	18528	45265	246554	**356549**
1983	1683	8287	20410	16344	13331	19754	244354	**324163**
1984	2228	5283	14360	26823	16857	15086	190482	**271120**
1985	1114	6860	11228	21229	33988	17666	132707	**224792**
1986	1591	4197	16163	18364	29288	40041	106086	**215730**
1987	954	2919	8539	21926	22516	30611	103907	**191372**
1988	2627	2322	4910	10378	23488	20332	83834	**147892**
1989	3025	3420	4157	8002	12894	24676	72477	**128652**
1990	3180	8729	4923	5551	10430	13793	66561	**113167**
1991	1962	3767	12995	7694	6589	10740	60547	**104294**
1992	959	4039	5072	15554	9729	6719	48825	**90898**
1993	1525	2657	6673	8916	22272	9982	37629	**89654**
1994	1154	2552	4026	9494	11090	23612	29949	**81876**
1995	1760	3209	3893	4566	12095	10794	47147	**83465**
1996	1611	3507	6263	5589	6102	13672	43127	**79871**
1997	733	3535	6010	10111	7742	7524	56184	**91838**
1998	1990	2862	5615	9652	14222	9195	48029	**91566**
1999	1710	4566	5634	8311	13565	14677	45445	**93908**
2000	1599	4344	7814	8962	12757	13407	49990	**98873**
2001	1839	2993	7759	12046	13848	13457	44041	**95982**
2002	1490	5247	5452	12441	15855	12815	45960	**99260**
2003	1210	4543	10346	9698	17506	16579	45328	**105209**
2004	389	3476	8805	14808	11737	17276	45291	**101782**
2005	1562	2462	7487	12549	20660	12393	61040	**118153**
2006	3275	4725	7010	12613	17175	22034	55982	**122813**
2007	503	6730	9889	10389	16951	16417	61052	**121931**
2008	1987	2395	13040	14600	13156	17557	57149	**119884**
2009	507	4615	7436	22199	19152	12685	60888	**127483**
2010	859	1898	8609	10823	28601	19710	60054	**130554**
2011	674	2327	4266	10799	11794	30018	67253	**127129**
2012	389	2324	4948	5937	14991	14542	82677	**125808**

Table 11. Annual SSB (MT), recruitment (000s), total abundance (000s), and F from the ASAP model.

Year	SSB	Recruitment	Total Abundance	F
1982	298990	44204	175340	0.170
1983	273824	34061	160885	0.197
1984	238175	44552	158008	0.182
1985	204907	24649	139008	0.185
1986	196723	20965	120746	0.324
1987	161951	14524	93367	0.340
1988	125571	20524	80961	0.307
1989	112593	45620	99948	0.258
1990	91941	18984	89289	0.244
1991	83648	23383	84079	0.303
1992	84590	11516	67167	0.255
1993	81522	12636	58652	0.248
1994	73620	18405	59291	0.225
1995	73481	16650	58830	0.181
1996	70364	15967	58570	0.171
1997	85242	14564	57120	0.166
1998	82947	19764	61465	0.154
1999	85473	23102	68677	0.119
2000	90876	15461	67520	0.136
2001	86953	26384	76553	0.173
2002	92554	20556	76698	0.130
2003	96232	22951	80498	0.134
2004	93191	16137	76356	0.169
2005	114491	22801	78354	0.149
2006	109783	33215	91476	0.140
2007	107904	18911	87535	0.172
2008	112232	22714	86002	0.145
2009	122009	13639	77357	0.109
2010	118579	16359	75042	0.156
2011	116615	16675	72088	0.122
2012	119857	9768	64167	0.097

Table 12. Projection results for bluefish through 2015 under various fishing scenarios.

		Quota (000s mt)	F	Jan 1 Abundance (000s)	Mean Biomass (000s mt)	SSB (000s mt)	Yield (000s mt)
F	**2013**	12.46		69111.60	119.31	112.99	12.46
status quo	**2014**		0.097	71616.70	115.90	108.34	8.75
	2015		0.097	74650.70	115.73	106.38	8.85
F	**2013**	12.46		69111.60	119.31	112.99	12.46
low	**2014**		0.10	71616.70	115.77	108.22	9.01
	2015		0.10	74539.60	115.35	106.02	9.09
F0.1	**2013**	12.46		69111.60	119.31	112.99	12.46
	2014		0.16	71616.70	113.24	105.73	14.07
	2015		0.16	72376.20	107.97	98.99	13.55
Ftarget	**2013**	12.46		69111.60	119.31	112.99	12.46
	2014		0.17	71616.70	112.83	105.32	14.89
	2015		0.17	72025.70	106.79	97.87	14.23
Fmsy	**2013**	12.46		69111.60	119.31	112.99	12.46
	2014		0.19	71616.70	112.00	104.51	16.51
	2015		0.19	71332.30	104.48	95.67	15.54
F	**2013**	12.46		69111.60	119.31	112.99	12.46
from 2013	**2014**		0.132	71616.70	114.41	106.88	11.74
P* = 0.341	**2015**		0.132	73372.20	111.34	102.21	11.55
F	**2013**	12.46		69111.60	119.31	112.99	12.46
resulting in	**2014**		0.1384	71616.70	114.14	106.62	12.27
2014 ABC	**2015**		0.1384	73142.60	110.56	101.46	12.02

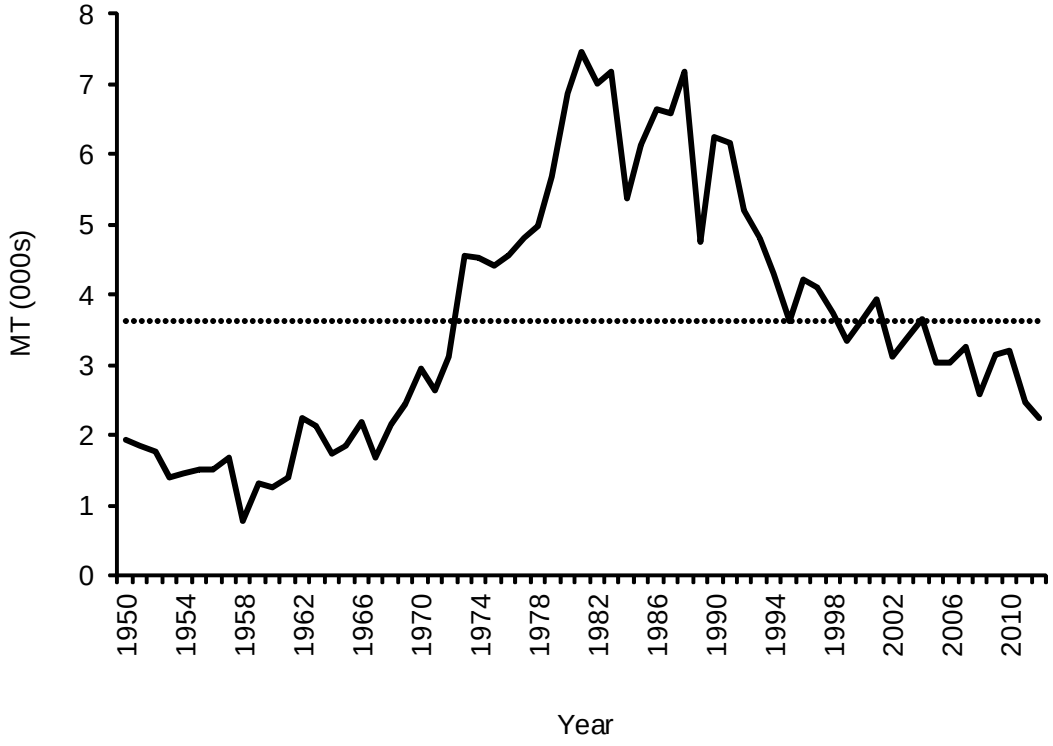

Figure 1. Times series of bluefish commercial landings (mt) along the Atlantic coast from 1950 to 2012.

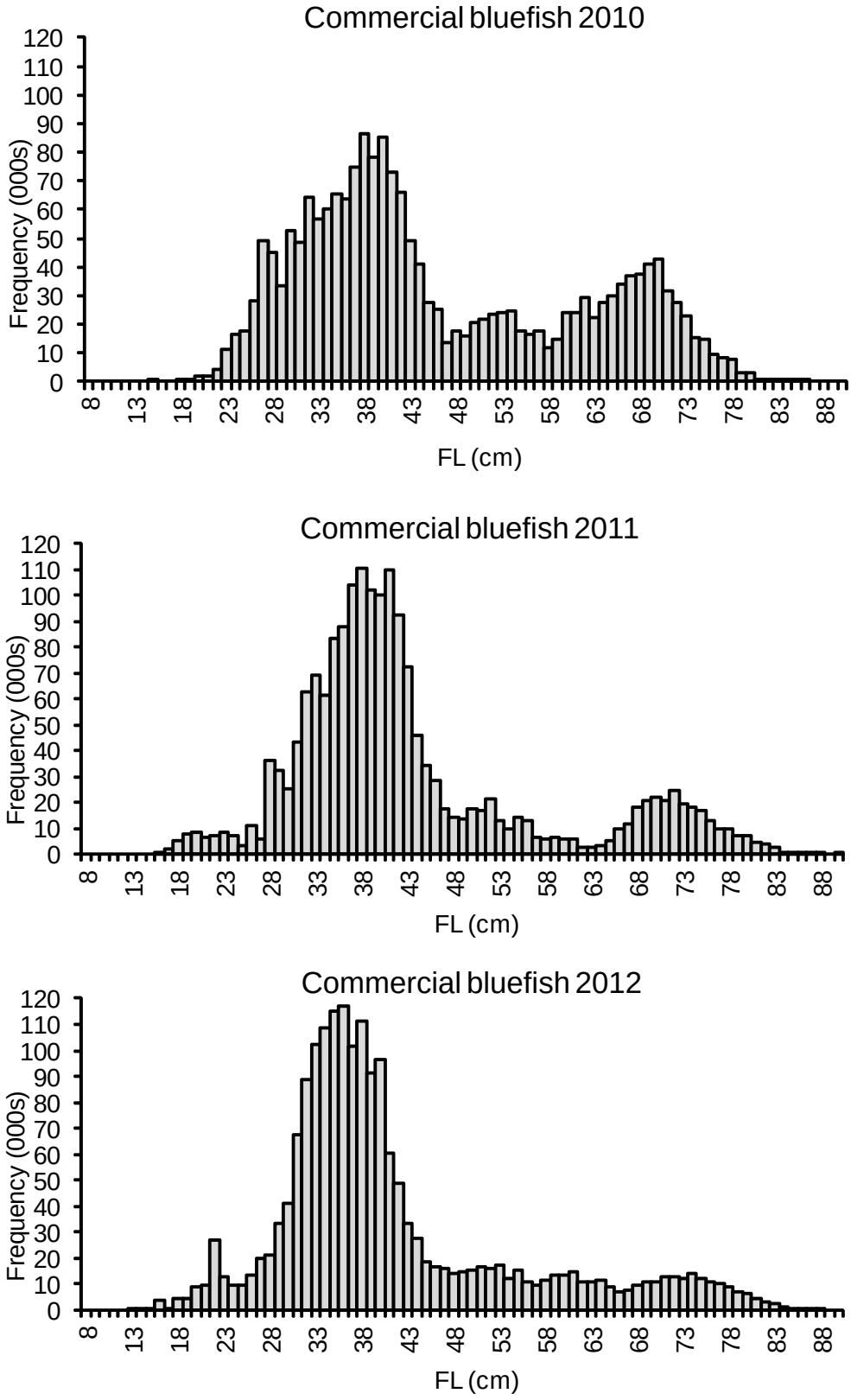

Figure 2. Length frequency distribution of commercial bluefish landings from Maine to Florida, 2010 to 2012

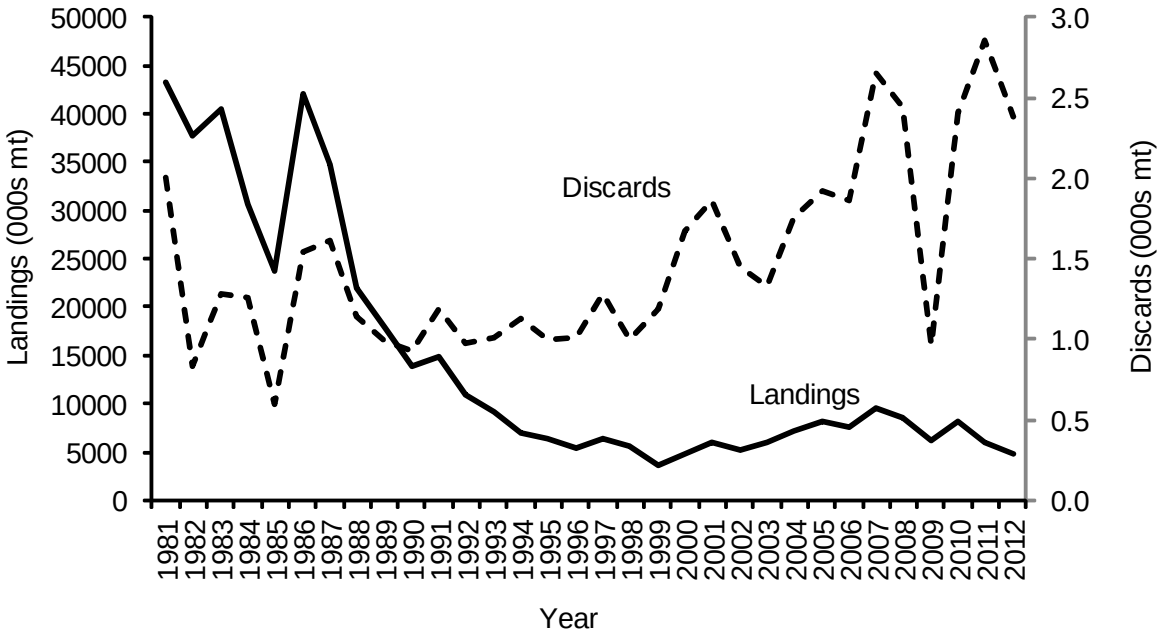

Figure 3. Recreational landings (mt) and recreational discard losses (MRIP B2 estimates*0.15) from Maine to Florida, 1981 to 2012.

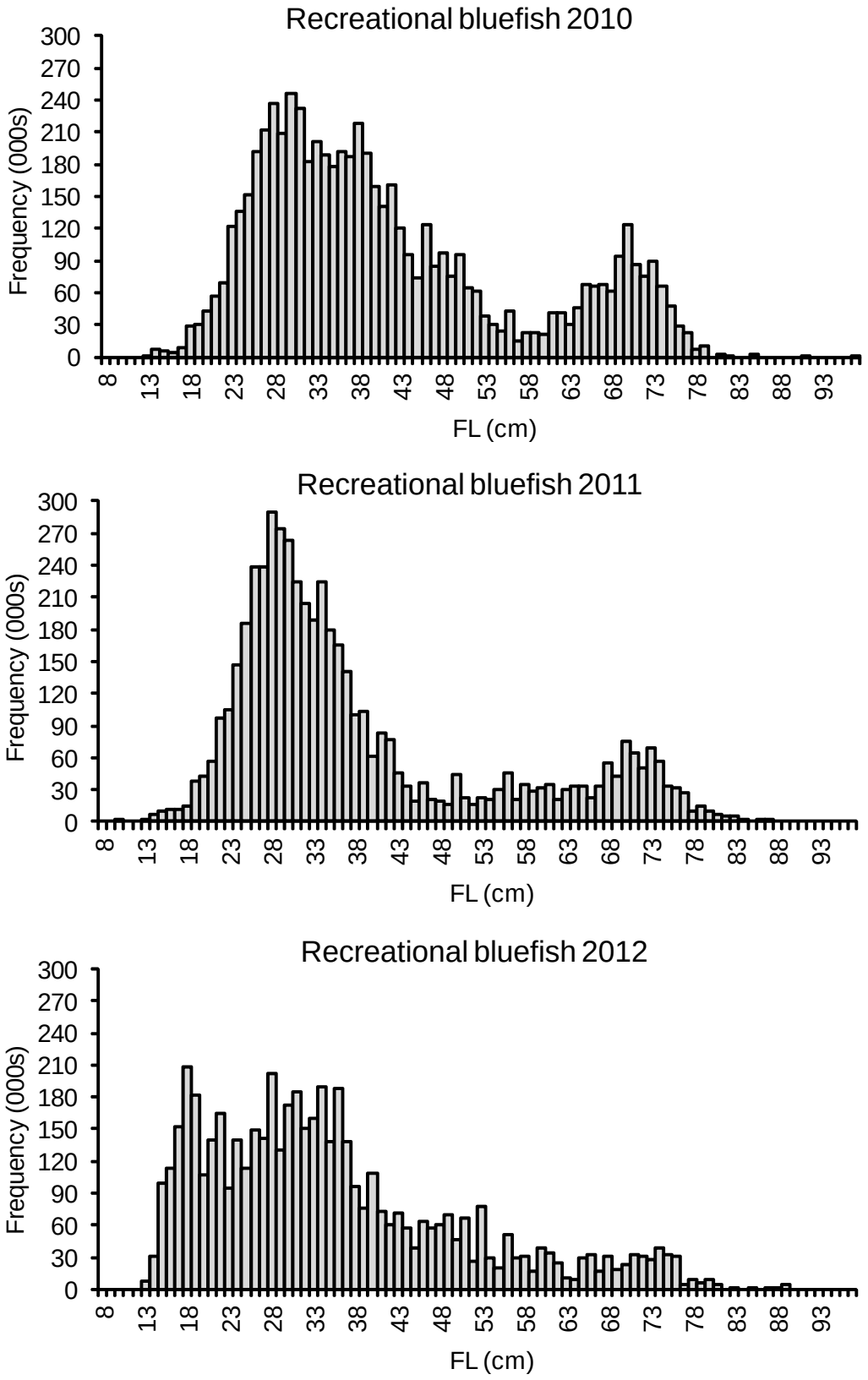

Figure 4. Length frequency distribution of recreational bluefish landings from Maine to Florida, 2010 to 2012.

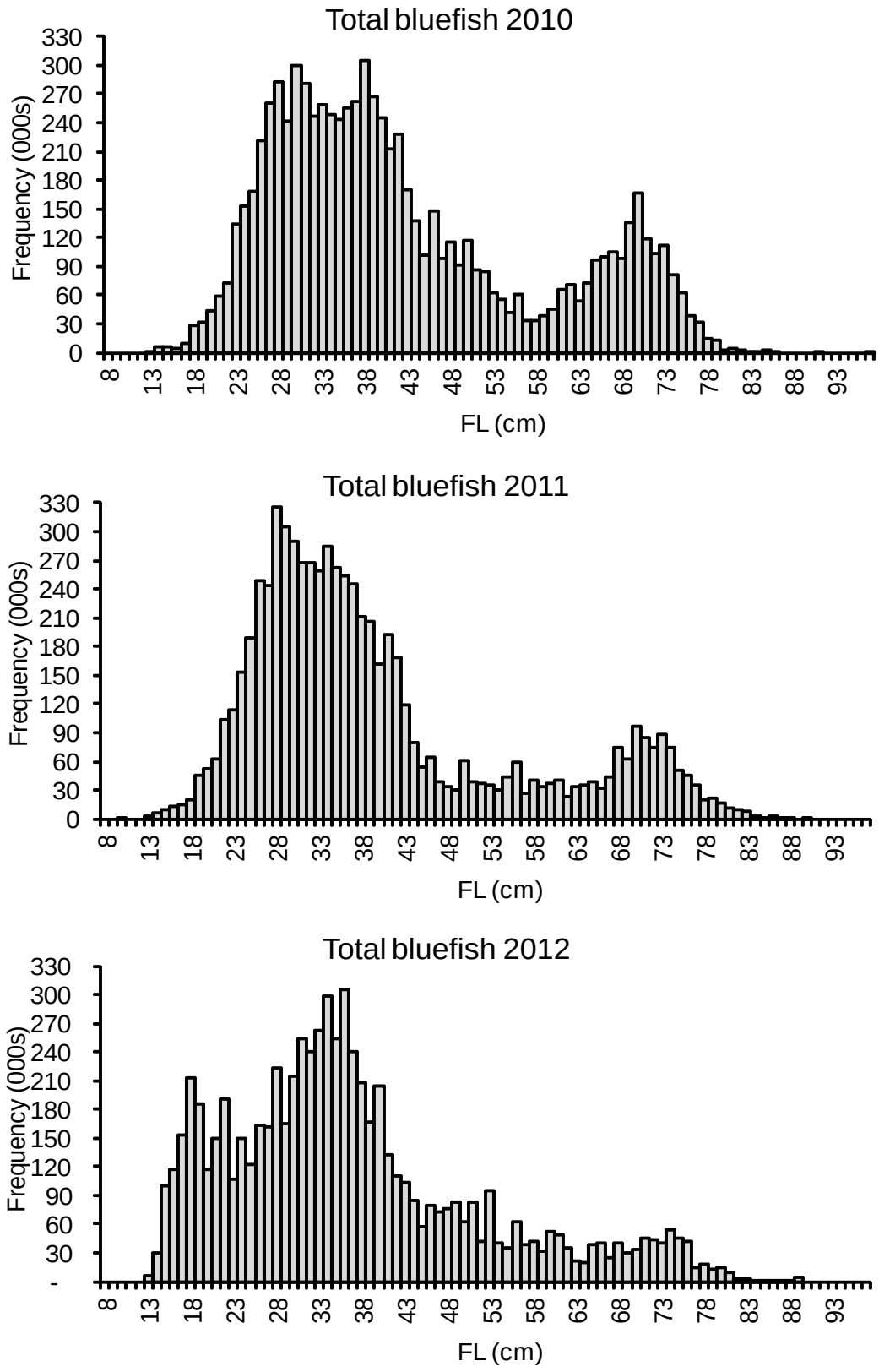

Figure 5. Length frequency distribution of total bluefish landings from Maine to Florida, 2010 to 2012.

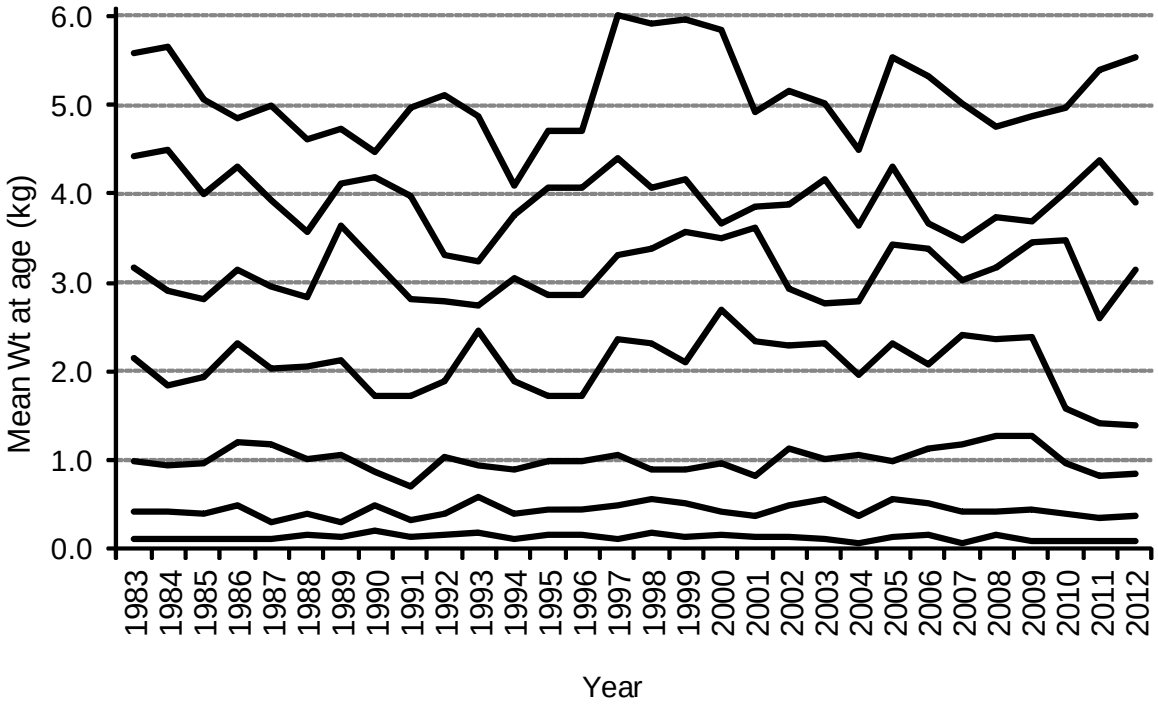

Figure 6. Bluefish mean weights (kg) at ages 0 to 6+ from 1982 to 2012.

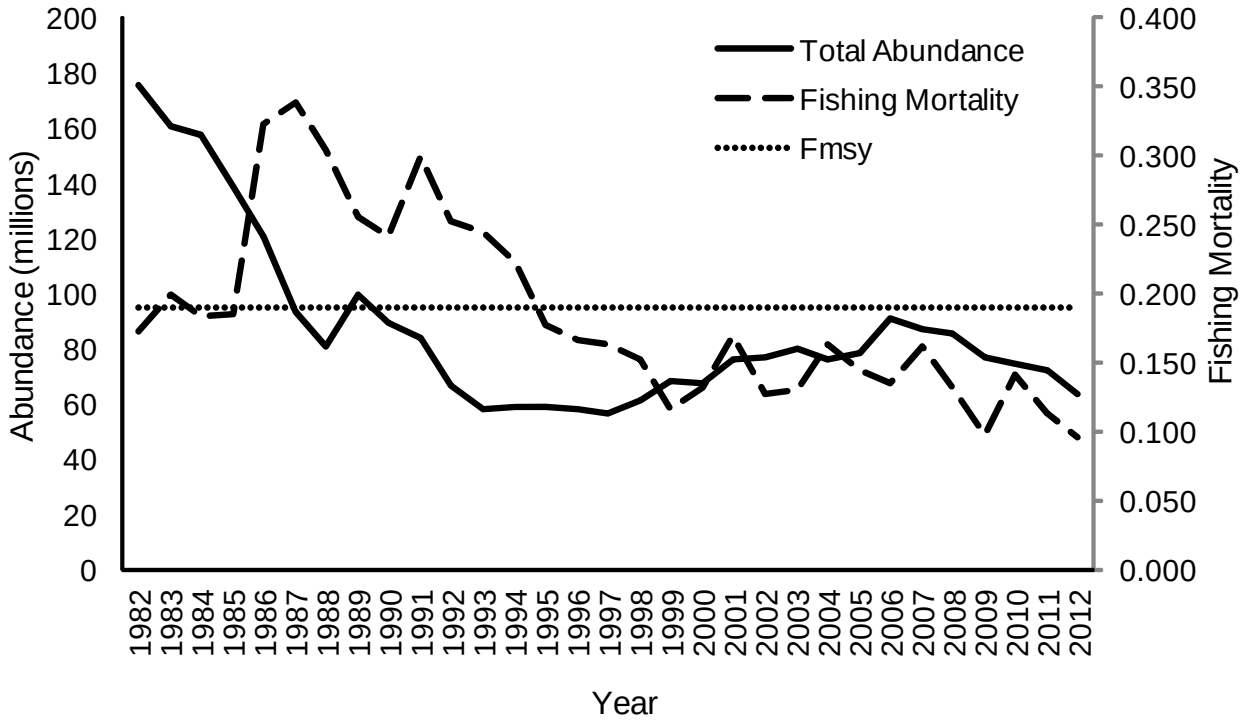

Figure 7. Total bluefish abundance and fishing mortality as estimated in ASAP model. F_{MSY} indicated by dotted horizontal line.

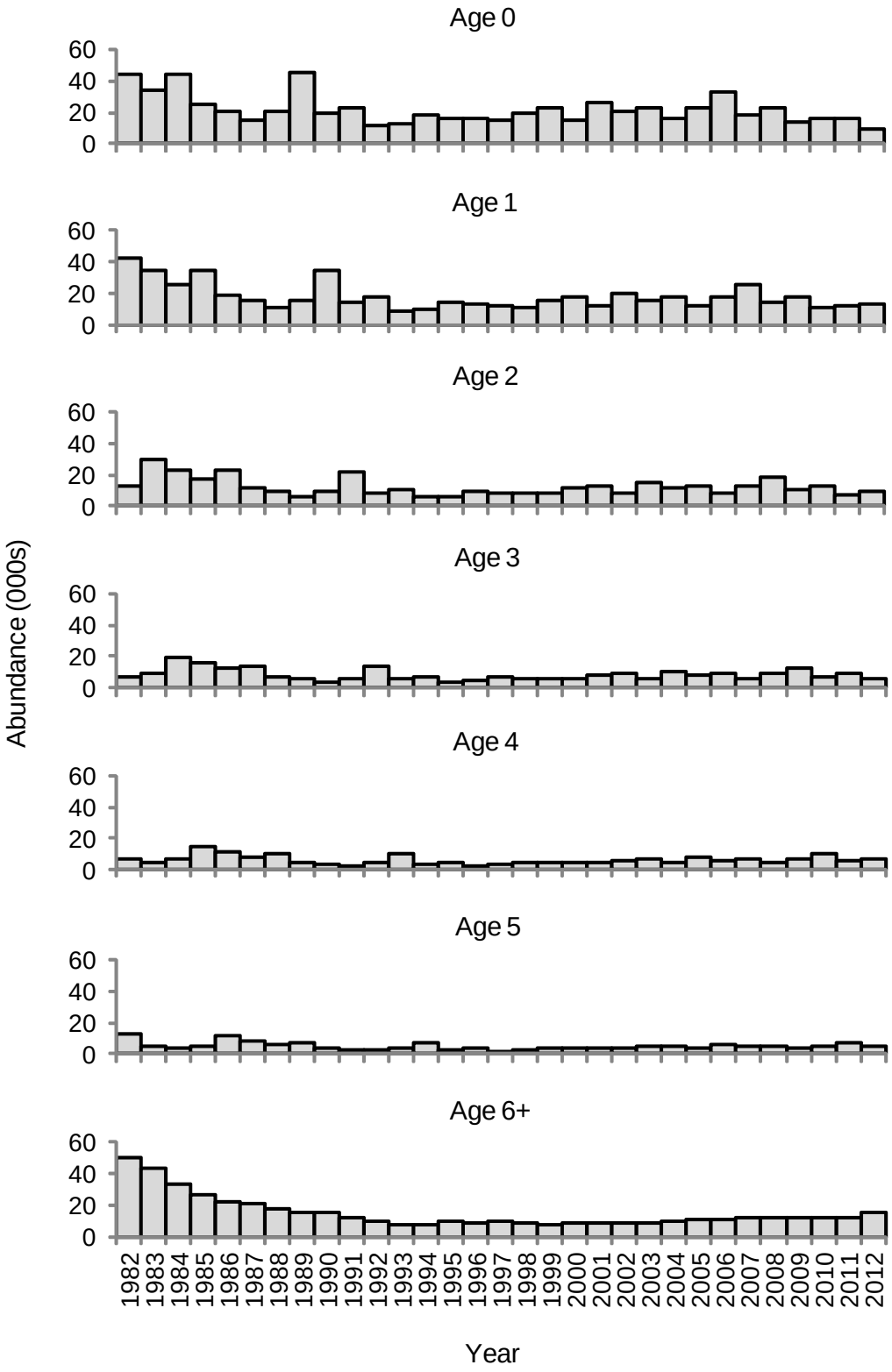

Figure 8. Total bluefish abundance (000s) at age from ASAP model results.

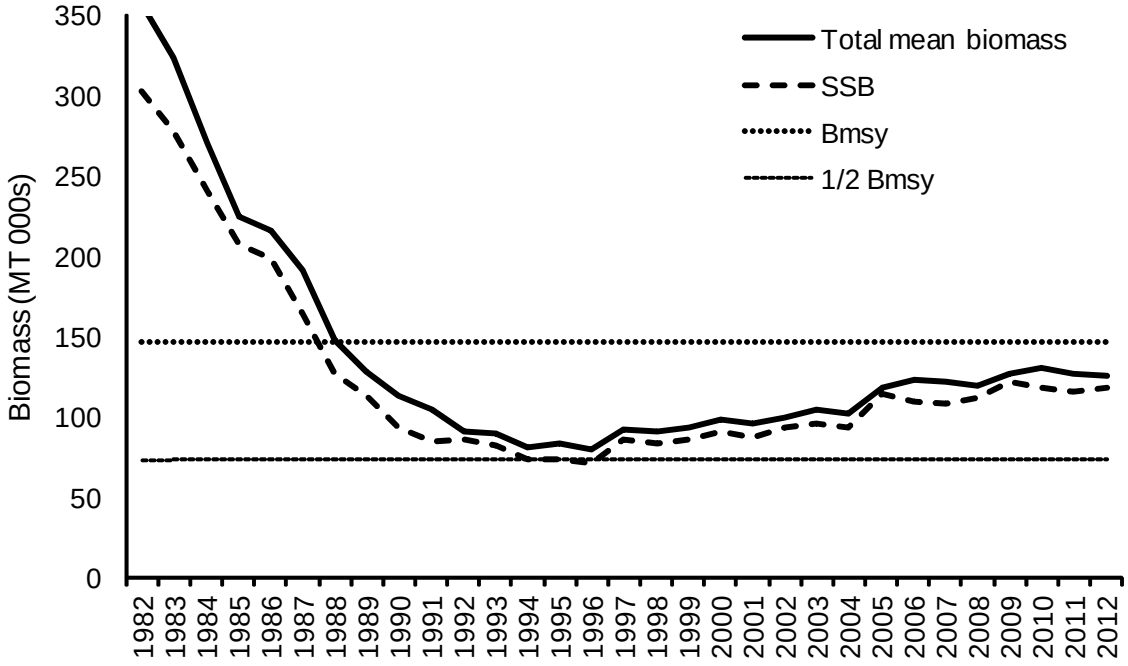

Figure 9. Time series of bluefish total mean biomass (000s mt) and spawning stock biomass (000s mt).

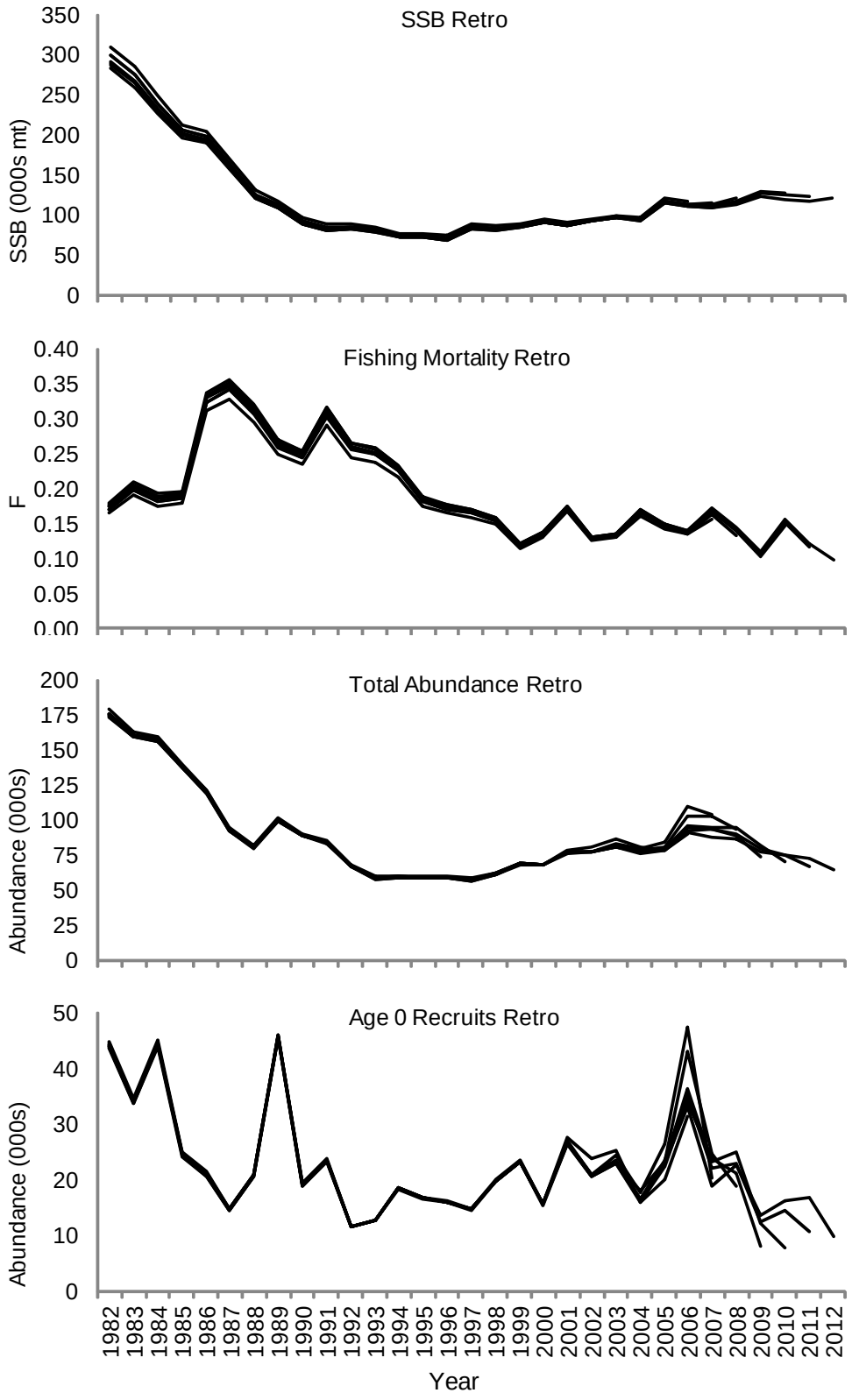

Figure 10. Retrospective bias in bluefish estimates from ASAP model.

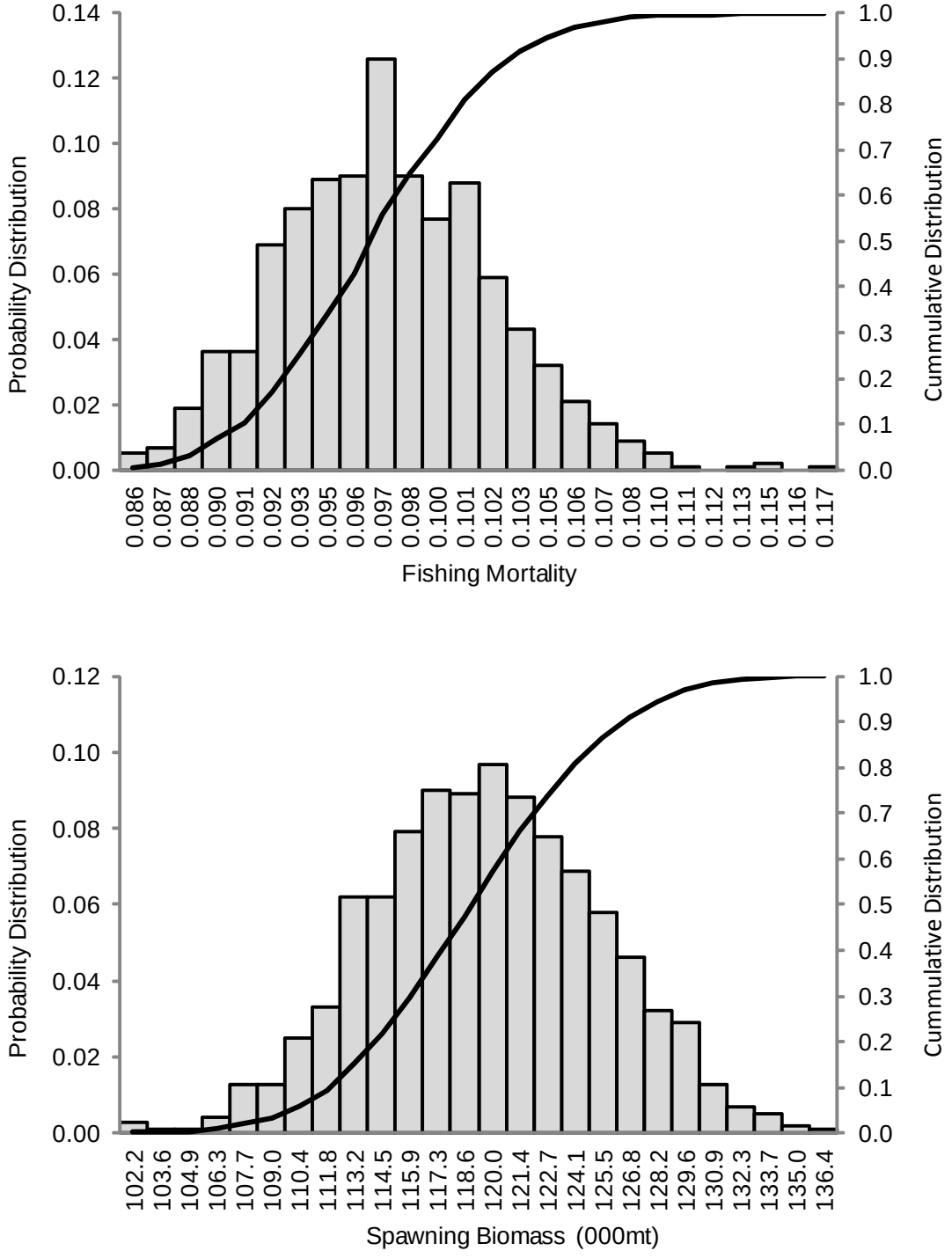

Figure 11. Distribution of bluefish fishing mortality and spawning stock biomass resulting from 1000 MCMC iterations in ASAP model.