Northeast Fisheries Science Center Reference Document 10-15

Bluefish 2010 Stock Assessment Update

by Gary R. Shepherd and Julie Nieland

July 2010

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Executive Summary

The updated stock assessment was completed by adding catch and indices through 2009 to the previous 2008 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 was 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 recruitment indices from the SEAMAP program in the South Atlantic in the forward projecting catch at age model ASAP. Fishery dependent and independent information was partitioned into ages using a 2009 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 2009 was 0.10, below the biological reference point (F_{MSY}) of 0.19. Fishing mortality steadily declined from 0.31 in 1987 to 0.12 in 2002 and has remained steady since 2000 with an average F=0.14. Recent mean biomass estimates peaked in 1982 at 425.0 thousand MT, then declined to 103.8 thousand MT by 1996 before increasing to the 2009 level of 156.0 thousand MT. Recruitment estimated in the ASAP model has remained relatively constant since 2000 at around 22.5 million age-0 bluefish, with the exception of a relatively large 2006 cohort estimated as 35.2 million fish. The 2009 recruitment estimate was well below average at 8.0 million fish. There was no significant retrospective bias in the results. A projection of the results through 2012, under five different fishing scenarios, suggest that biomass will decline at fishing above status quo F due to a very poor incoming year class. However, abundance increases with F less than 0.18. Changes in NMFS survey, limited age information and discard size data 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 2009 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 2009 a total of 4,525 measurements from 102 samples were collected across all market categories from total landings of 1,959 mt (62% 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 7,155 measurements from 73 samples were collected from landings of 1,096 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 2009 commercial landings were also available. A total of 654 lengths from 22 samples were used to expand commercial landings of 97 mt (Table 1). No landings were reported for South Carolina or Georgia. Total coast-wide commercial landings in 2009 were 3,151 mt, an increase from 2,585 mt in 2008.

Length frequencies from commercial fisheries are characterized by a multi-modal distribution (Figure 1). In 2009 the distribution was strongly bimodal with one peak at 39 cm and a second around 65 cm. There were few fish below 25 cm. In comparison, the 2006 and 2008 distribution included a third mode around 55 cm. The 2007 distribution was bimodal, similar to 2009 except the first mode peaked around 25 cm.

Recreational landings are sampled for length as part of the MRFSS program. The 2009 recreational landings were 6,161 mt, a decrease from 8,573 mt in 2008 (Table 2, Figure 2). The MRFSS 2009 length samples (N=6,066) were used to expand recreational landings per half year. Recreational discards in 2009 were estimated at 6,403 mt, however after adjusting for a 15% mortality rate, the resulting discard loss was 960 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 for bluefish discards was limited. MRFSS at-sea sampling of recreational party boats provided lengths of 765 discarded bluefish. Total combined (commercial and recreational) length frequencies are presented in Figure 3.

Age data (n=380) was provided by Virginia Marine Resources Commission and Old Dominion University ageing lab. Since the age key developed from the VA samples was the only 2009 age information available, it was applied to both fishery dependent and independent length data. Age data was provided by cm, fork length by half year. In the previous year the fish were measured to total length, inches while the length frequencies were measured in fork length to the nearest cm. Consequently, previous length frequencies were converted to TL, inches using the following equation:

$$TL(in) = 0.245(FL(cm)) + 0.440$$

The resulting catch at age through 2009 is presented in table 3. 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. Adjustments were made in the 2004-2006 catch at age data to reflect new MRFSS catch estimates.

Fisheries Independent Data

Survey indices as used in the previous bluefish assessment were updated for 2009. These indices include SEAMAP juvenile (age 0) 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, CT bottom trawl survey indices for ages 0 to 6+, DE bottom trawl survey indices for ages 0 to 2 and Marine Recreational Fisheries Statistics Survey (MRFSS) recreational catch per angler trip (CPA) for ages 0 to 6+ (adjusted using a general linear model with negative binomial transformation). The CT survey in 2008 was not conducted during the month of September, therefore the 2008 index was 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 to 7.0 in 2009 from 12.8 in 2008 (Table 4). The series arithmetic average index equaled 27.3 (geometric mean of 14.26). The 2009 Delaware survey index of ages 0 to 2 was 0.342 fish per tow, below the time series average (0.531 per tow; Table 5). New Jersey trawl survey indices of ages 0 to 2 for 2009 (3.2 fish/tow) was also below the time series average of 6.6 per tow (Table 5). Indices of bluefish abundance in Long Island Sound from the CT DEP survey for ages 0 to 6+ in 2009

(32.86 per tow) were about average for the series (33.42 per tow; Table 6). In contrast, recreational catch per angler trip showed the highest annual increase in the time series, increasing from 0.37 fish per angler trip in 2008 to 0.83 in 2009 (Table 7). The increase was most prevalent at age 1 but was above average at all ages except age 0.

Standardized recruitment indices (age 0) were developed using Z scores to compare the relative 2009 indices to time series averages. Indices from NEFSC, DE, NJ, and the Recreational CPA were all below average, CT was slightly above average whereas the SEAMAP index was well above average (Table 8, Figure 4).

ASAP Model

The ASAP model (version 2.0.19) was run with the previous 1982-2008 input file updated for 2009 total catch, catch 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. Weights at age remained constant since 2005. Natural mortality was fixed at 0.2 and maturity at age was held constant with full maturity at age 3.

The results of the ASAP model showed a decrease in total abundance since 2007, declining from 97.9 million to 77.7 million (Table 9, Figure 5). The decline is primarily the result of a poor 2009 year class. Recruitment has remained relatively constant since 2000 around 22.5 million age-0 bluefish, with the exception of a large 2006 cohort estimated as 35.2 million fish. The 2009 recruitment estimate was well below average at 8.0 million fish compared to the series average of 23.1 million (Figure 6). However among other age groups, the 6 plus category was the largest since 1991. Total biomass in 2009 was the highest since 1989 and equaled 155,991 mt. (Table 10) The corresponding spawning stock biomass (SSB) at 126,200 mt was also the highest since 1989 (Figure 7). The 2009 estimate of total biomass is above the biomass necessary to sustain maximum yield (B_{MSY}) of 147,052 mt (Figure 7).

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 2009 F_{MULT} value equals 0.10 (Figure 5). Fishing mortality steadily declined from 0.31 in 1987 to 0.12 in 2002 and has remained steady since 2000 with an average F=0.14. The 2009 estimate of fishing mortality (0.10) is above the biological reference point for F_{MSY} at 0.19.

Retrospective bias for the final model was examined for F, total abundance, recruitment (age 0) and total biomass. The analysis shows little evidence of significant bias in the estimates (Figure 8). The variation in the final model results for F and SSB was determined using a Monte Carlo Markov chain with 2500 iterations. The MCMC results of variation around F ranged from 0.096 to 0.115, with the 80% CI between 0.099 and 0.109. Estimates for SSB ranged from 111,800 to 133,500 mt, with an 80% CI between 117,200 mt and 128,100 mt. (Figure 9).

Projections

Bluefish abundance and biomass through 2012 was examined for a range of fishing scenarios with a stochastic projection in AGEPRO software. The weight at age in 2010-2012 was assumed equal to 2009. Recruitment was derived from a random draw of 28 empirical estimates of age 0 abundance since 1982 and population size was drawn from the output of the MCMC run. Fishing mortality for 2010 was assumed equal to 2009. Five projection scenarios were examined: F status quo (0.10), F equal to 75% of F_{MSY} (0.14), F_{target} (0.17) which equals 90% of F_{MSY} as defined in FMP, $F_{0.1}$ (0.18) 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 other than status quo F (F=0.10) (Table 11). However, abundance would continue to increase for F less than 0.18, and in all 5 cases the yield through 2012 would increase above the 2010 yield of 9,563 mt. Under status quo F, projected 2012 yield would increase to 10,821 mt, which includes commercial and recreational landings as well as recreational discards losses.

Conclusion

The conclusion of the updated assessment is that the Atlantic coast bluefish stock continues to remain above the biological reference points (F_{MSY} and B_{MSY}) and is not considered overfished or experience 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 continues to be limited to one age key 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.

	ME - VA	NC	SC-FL	Total
1982	4,137	1,946	914	6,997
1983	3,421	3,061	685	7,166
1984	3,046	1,615	720	5,380
1985	4,199	1,634	289	6,122
1986	4,559	1,562	531	6,651
1987	3,805	2,069	705	6,578
1988	4,277	2,286	599	7,161
1989	2,793	1,493	455	4,740
1990	3,684	2,076	489	6,250
1991	3,709	1,778	673	6,160
1992	3,423	1,288	495	5,205
1993	3,039	1,226	543	4,808
1994	3,071	809	424	4,304
1995	2,034	1,365	229	3,628
1996	2,654	1,496	62	4,212
1997	2,165	1,815	129	4,109
1998	2,257	1,327	155	3,739
1999	1,921	1,252	157	3,330
2000	2,057	1,525	64	3,647
2001	2,038	1,844	63	3,945
2002	2,025	1,054	37	3,116
2003	1,739	1,574	45	3,358
2004	1,885	1,707	56	3,647
2005	1,844	1,122	71	3,037
2006	1,851	1,146	45	3,042
2007	2,282	909	76	3,267
2008	1,766	762	57	2,585
2009	1,959	1,096	97	3,151

Table 2. Commercial landings, recreational landings, recreational discard loss and total catch for bluefish, ME-FL.

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 commercial discards)
1974	4,538	10,005					
1975	4,402	9,705		**assumes same**			
1976	4,546	10,022		**mean wt**			
1977	4,802	10,587		**as landings**			
1978	4,986	10,992					
1979	5,693	12,551					
1980	6,857	15,117					
1981	7,465	16,457	43,222	*2,001*	*45,223*		52,688
1982	6,997	15,426	37,651	*832*	*38,483*	44,648	45,480
1983	7,166	15,798	40,425	*1,280*	*41,705*	47,591	48,871
1984	5,380	11,861	30,597	*1,260*	*31,857*	35,977	37,237
1985	6,122	13,497	23,821	*599*	*24,420*	29,943	30,542
1986	6,651	14,663	42,133	*1,544*	*43,677*	48,784	50,328
1987	6,578	14,502	34,769	*1,615*	*36,384*	41,347	42,962
1988	7,161	15,787	21,873	*1,146*	*23,019*	29,034	30,180
1989	4,740	10,450	17,808	*989*	*18,797*	22,548	23,537
1990	6,250	13,778	13,860	*929*	*14,789*	20,110	21,039
1991	6,160	13,580	14,967	*1,194*	*16,161*	21,127	22,320
1992	5,205	11,475	11,011	*979*	*11,990*	16,216	17,195
1993	4,808	10,600	9,204	*1,013*	*10,217*	14,012	15,025
1994	4,304	9,488	7,049	*1,128*	*8,177*	11,353	12,481
1995	3,628	7,998	6,489	*1,003*	*7,492*	10,117	11,120
1996	4,113	9,066	5,328	*1,010*	*6,338*	9,441	10,451
1997	4,064	8,960	6,487	*1,287*	*7,774*	10,551	11,838
1998	3,739	8,242	5,595	*999*	*6,594*	9,334	10,333
1999	3,330	7,341	3,744	*1,191*	*4,935*	7,074	8,264
2000	3,647	8,040	4,811	*1,675*	*6,486*	8,458	10,132
2001	3,945	8,697	6,001	*1,857*	*7,858*	9,946	11,803
2002	3,116	6,869	5,158	*1,448*	*6,606*	8,274	9,721
2003	3,358	7,403	5,958	*1,331*	*7,289*	9,316	10,647
2004	3,647	8,041	7,179	*1,761*	*8,940*	10,826	12,587
2005	3,187	7,026	8,225	*1,915*	*10,140*	11,412	13,327
2006	2,926	6,450	7,663	*1,860*	*9,523*	10,589	12,449
2007	3,267	7,182	9,608	*2,653*	*12,261*	12,874	15,527
2008	2,585	5,655	8,573	*2,443*	*11,016*	11,158	13,601
2009	3,151	6,990	6,161	*960*	*7,121*	9,312	10,273

Table 3. Total bluefish catch at age (000s), 1982-2009, ME to FL.

	Age							
	0	**1**	**2**	**3**	**4**	**5**	**6+**	**total**
1982	11164.1	9747.9	2850.8	2439.3	795.3	1213.5	3736.3	31,947
1983	4778.4	7666.7	8686.1	3022.0	970.6	1325.3	4778.4	31,228
1984	7121.3	6807.3	6718.5	2039.9	895.1	744.7	3176.7	27,503
1985	4676.7	6468.8	5773.3	2925.5	1328.5	520.0	2377.1	24,070
1986	5169.3	8070.7	8728.0	2801.7	1056.4	1703.1	4465.0	31,994
1987	3127.1	5419.5	5177.8	5757.4	2009.3	1083.0	3948.2	26,522
1988	1709.8	2083.6	2524.0	1588.6	1984.1	1598.6	2740.4	14,229
1989	3473.6	5672.6	3221.1	992.1	395.9	1168.5	2409.8	17,334
1990	2726.7	7185.8	1840.7	687.2	381.8	431.6	2478.6	15,732
1991	3694.6	5292.6	7391.9	1590.7	310.9	224.7	2136.5	20,642
1992	2131.3	9633.3	1709.8	2352.9	583.4	479.2	967.2	17,857
1993	1194.1	2081.6	1566.9	593.0	1040.8	669.0	1178.9	8,324
1994	1970.8	3144.3	1313.3	368.1	296.7	849.5	1073.1	9,016
1995	1822.8	3371.4	735.7	137.7	214.1	695.7	1057.8	8,035
1996	1701.5	2145.1	631.5	202.2	207.2	545.0	1411.8	6,844
1997	1634.1	4299.3	1496.2	510.5	196.6	93.4	1212.3	9,443
1998	683.5	2754.1	2786.1	861.3	261.0	308.0	458.8	8,113
1999	1638.5	1946.1	2096.7	572.8	174.7	352.5	482.8	7,264
2000	667.4	4396.5	2693.3	717.7	96.9	536.0	155.9	9,264
2001	1414.3	4466.7	3466.2	1151.9	198.3	608.0	243.5	11,549
2002	587.1	5145.6	1661.6	542.6	340.3	236.8	415.9	8,930
2003	819.3	2646.0	3975.0	774.6	377.9	319.8	644.0	9,557
2004	434.4	5270.8	2289.6	1265.2	435.4	473.5	662.8	10,832
2005	3262.8	2560.5	4179.2	1389.9	411.9	585.4	494.7	12,884
2006	2718.6	3489.6	2975.5	1090.2	301.9	283.5	662.6	11,522
2007	695.0	3065.0	5390.0	1548.2	852.7	582.7	1375.2	13,509
2008	893.1	3725.3	4011.6	463.1	615.1	239.1	396.3	10,344
2009	144.5	3083.9	2857.8	482.1	354.2	236.5	599.9	7,759

Table 4. NEFSC bluefish indices by age using fall inshore strata and re-transformed loge stratified mean number per tow.

	0	1	2	3	4	5	6+	total
1982	18.768	10.788	0.064	0.053	0.011		0.023	29.707
1983	8.189	16.695	0.845	0.034	0.004	0.017	0.068	25.852
1984	81.356	40.869	1.257	0.201	0.120	0.052	0.147	124.002
1985	17.473	9.703	0.925	0.428	0.096	0.036	0.088	28.749
1986	21.055	0.923	0.042	0.060	0.024	0.028	0.033	22.165
1987	7.589	1.768	0.167	0.238	0.098	0.049	0.158	10.067
1988	9.493	0.067	0.009	0.010	0.028	0.006	0.023	9.636
1989	237.573	1.254	0.113	0.130		0.014	0.119	239.203
1990	6.186	3.637	0.006	0.016	0.016		0.084	9.945
1991	7.878	0.154	0.050	0.026	0.001		0.001	8.110
1992	6.625	0.637	0.016	0.022	0.002	0.002	0.008	7.312
1993	1.109	0.123	0.044	0.003	0.034	0.023		1.336
1994	6.580	0.760	0.010	0.019	0.030	0.021	0.006	7.426
1995	9.222	4.122	0.115	0.015	0.015	0.025	0.062	13.576
1996	9.643	1.638	0.211	0.144	0.027	0.021	0.019	11.703
1997	4.179	0.482	0.217	0.107	0.002	0.007	0.013	5.007
1998	4.793	0.387	0.074	0.045	0.017			5.316
1999	15.266	1.528	0.061	0.051	0.018	0.002	0.008	16.934
2000	2.485	1.517	0.157	0.017	0.015	0.006		4.197
2001	8.819	0.754	0.148	0.020	0.002	0.001	0.003	9.747
2002	7.815	1.210	0.042	0.037				9.104
2003	48.332	3.085	0.277	0.019	0.006	0.022	0.043	51.784
2004	7.048	5.307	0.372	0.079	0.008	0.012	0.031	12.857
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				38.047
2007	8.837	7.064	0.583	0.082	0.012	0.004	0.009	16.590
2008	7.444	4.543	0.797	0.012	0.010	0.009	0.026	12.840
2009*	*1.050*	*5.385*	*0.503*	*0.013*	*0.011*	*0.000*	*0.037*	6.999

*Bigelow adj 1.16 and reduced strata

Table 5. Bluefish survey indices by age (stratified geometric mean number per tow) from Delaware and New Jersey state trawl surveys.

	Delaware				New Jersey			
	0	**1**	**2**	**total**	**0**	**1**	**2**	**total**
1982								
1983								
1984								
1985								
1986								
1987								
1988					26.066	0.411	0.002	26.48
1989					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	7.07
2004	0.074	0.836	0.030	0.940	2.217	0.510	0.422	3.15
2005	0.060	0.127	0.009	0.195	6.075	0.286	0.180	6.54
2006	0.039	0.070	0.020	0.129	6.572	0.144	0.088	6.80
2007	0.093	0.321	0.021	0.436	9.161	3.750	0.326	13.24
2008	0.087	0.172	0.016	0.275	8.629	1.213	0.070	9.91
2009	0.031	0.282	0.029	0.342	2.907	0.286	0.016	3.21

Table 6. Bluefish survey indices by age (stratified geometric mean number per tow) from CT DEP trawl survey.

	Age							
	0	1	2	3	4	5	6+	total
1982								
1983								
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								
2009	30.217	1.702	0.733	0.107	0.067	0.006	0.029	32.860

Table 7. Recreational catch per angler trip for bluefish, ME-FL, by age predicted from General linear model with negative binomial transformation.

	Age							
	0	1	2	3	4	5	6+	total
1982	0.108	0.098	0.027	0.021	0.01	0.016	0.048	0.328
1983	0.041	0.061	0.067	0.026	0.009	0.011	0.045	0.26
1984	0.093	0.075	0.06	0.027	0.013	0.009	0.046	0.323
1985	0.071	0.086	0.087	0.045	0.016	0.008	0.036	0.349
1986	0.053	0.066	0.082	0.034	0.013	0.018	0.053	0.319
1987	0.035	0.064	0.063	0.065	0.023	0.014	0.052	0.316
1988	0.022	0.027	0.031	0.023	0.028	0.023	0.043	0.197
1989	0.056	0.085	0.044	0.016	0.005	0.014	0.038	0.258
1990	0.038	0.115	0.033	0.012	0.006	0.005	0.029	0.238
1991	0.047	0.059	0.061	0.028	0.005	0.003	0.028	0.231
1992	0.016	0.049	0.034	0.055	0.013	0.005	0.024	0.196
1993	0.022	0.049	0.023	0.013	0.024	0.016	0.016	0.163
1994	0.044	0.066	0.03	0.01	0.006	0.013	0.019	0.188
1995	0.016	0.075	0.042	0.008	0.005	0.012	0.021	0.179
1996	0.038	0.082	0.034	0.007	0.002	0.003	0.022	0.188
1997	0.038	0.079	0.057	0.013	0.006	0.007	0.034	0.234
1998	0.031	0.077	0.067	0.029	0.01	0.007	0.018	0.239
1999	0.116	0.098	0.071	0.029	0.008	0.009	0.017	0.348
2000	0.035	0.182	0.089	0.028	0.003	0.012	0.007	0.356
2001	0.062	0.162	0.098	0.036	0.006	0.012	0.009	0.385
2002	0.064	0.196	0.051	0.024	0.008	0.008	0.018	0.369
2003	0.035	0.096	0.135	0.025	0.008	0.01	0.02	0.329
2004	0.018	0.157	0.088	0.051	0.013	0.016	0.024	0.367
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	0.567
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	0.020	0.347	0.311	0.050	0.037	0.015	0.051	0.832

Table 8. Standardized Z scores of bluefish age 0 recruitment indices.

	age 0 NMFS	DE	NJ trawl	CT	Rec CPA	SEAMAP
1982	-0.08				1.99	
1983	-0.31				-0.23	
1984	1.30			1.81	1.49	
1985	-0.11			0.61	0.76	
1986	-0.03			-1.50	0.17	
1987	-0.32			-1.07	-0.43	
1988	-0.28		3.59	-1.17	-0.86	
1989	4.74		0.31	1.49	0.26	
1990	-0.36	-0.27	0.12	-0.03	-0.33	0.68
1991	-0.32	0.53	-0.28	0.62	-0.03	1.60
1992	-0.35	-0.45	-0.26	-0.29	-1.06	0.91
1993	-0.47	-0.57	-0.48	-0.20	-0.86	-0.82
1994	-0.35	0.06	1.02	0.13	-0.13	-0.76
1995	-0.29	-0.09	-0.03	-0.14	-1.06	1.71
1996	-0.28	-0.29	-0.48	1.07	-0.33	-0.28
1997	-0.40	0.76	-0.23	0.92	-0.33	-0.09
1998	-0.39	-0.31	-0.61	0.49	-0.56	-0.48
1999	-0.16	-0.03	-0.61	1.27	2.25	-0.51
2000	-0.44	0.23	-0.66	-0.44	-0.43	-0.61
2001	-0.30	3.06	-0.84	0.43	0.46	-0.97
2002	-0.32	0.96	0.46	-1.22	0.53	-0.78
2003	0.57	-0.97	0.27	-0.08	-0.43	-0.54
2004	-0.34	-0.40	-0.52	-0.63	-0.99	2.52
2005	0.04	-0.63	0.14	0.10	1.75	-0.57
2006	0.31	-0.96	0.23	-1.07	4.83	-0.28
2007	-0.30	-0.09	0.67	-0.21	-0.86	-0.01
2008	-0.33	-0.20	0.58		-0.40	-0.71
2009	-0.47	-1.09	-0.41	0.14	-0.93	0.98

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

	Jan 1 abundance 000s							
	0	1	2	3	4	5	6+	total
1982	39,961	31,540	15,136	9,642	8,332	7,299	61,230	173,140
1983	39,508	31,101	22,228	10,760	7,351	6,480	49,099	166,528
1984	48,439	30,446	21,286	15,373	8,090	5,660	38,811	168,103
1985	26,731	37,554	21,214	14,972	11,656	6,267	31,564	149,959
1986	20,099	20,727	26,177	14,926	11,354	9,031	26,897	129,210
1987	13,728	14,928	12,719	16,334	10,653	8,420	22,972	99,753
1988	19,547	10,130	8,984	7,793	11,551	7,848	19,765	85,618
1989	44,245	14,593	6,312	5,688	5,603	8,612	17,926	102,980
1990	18,400	33,601	9,565	4,191	4,189	4,250	18,018	92,214
1991	22,979	14,029	22,284	6,422	3,104	3,191	15,175	87,183
1992	11,319	17,247	8,882	14,320	4,652	2,327	12,007	70,754
1993	12,569	8,609	11,356	5,922	10,569	3,534	9,693	62,253
1994	18,775	9,573	5,691	7,601	4,380	8,041	9,022	63,083
1995	17,147	14,386	6,442	3,874	5,669	3,352	11,920	62,789
1996	16,445	13,307	10,055	4,544	2,941	4,396	10,905	62,593
1997	15,023	12,801	9,382	7,150	3,465	2,288	11,032	61,140
1998	20,492	11,598	8,807	6,520	5,389	2,672	9,365	64,843
1999	23,766	15,974	8,213	6,290	4,982	4,198	8,694	72,118
2000	15,662	18,707	11,640	6,025	4,872	3,919	9,568	70,393
2001	27,146	12,288	13,503	8,464	4,646	3,820	9,922	79,790
2002	21,201	21,155	8,694	9,634	6,464	3,618	9,935	80,700
2003	23,042	16,649	15,310	6,337	7,438	5,073	9,985	83,833
2004	16,954	17,990	11,845	10,982	4,853	5,803	10,959	79,385
2005	23,053	13,218	12,745	8,462	8,392	3,781	12,158	81,808
2006	35,163	17,922	9,285	9,033	6,441	6,519	11,437	95,800
2007	26,028	27,444	12,737	6,653	6,914	5,024	13,066	97,865
2008	22,163	20,165	19,083	8,941	5,040	5,352	12,886	93,630
2009	8,013	17,339	14,433	13,765	6,866	3,940	13,321	77,678

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

	biomass at age		mt					
	0	1	2	3	4	5	6+	total
1982	5,595	15,454	23,006	19,767	26,664	30,890	303,578	424,954
1983	3,951	13,062	22,006	23,135	23,229	28,623	273,825	387,830
1984	4,844	12,483	19,796	28,132	23,541	25,372	219,284	333,451
1985	2,673	15,022	20,578	28,895	32,870	25,011	159,494	284,543
1986	2,412	10,156	31,412	34,628	35,764	38,859	130,395	283,627
1987	1,647	4,478	15,008	32,994	31,532	33,066	114,490	233,217
1988	3,323	4,052	8,984	15,975	32,804	27,971	91,374	184,483
1989	5,752	4,378	6,691	12,059	20,395	35,360	84,611	169,245
1990	3,864	16,800	8,417	7,250	13,573	17,753	80,613	148,271
1991	3,217	4,630	15,599	11,109	8,722	12,645	75,343	131,265
1992	1,811	6,726	9,237	27,065	13,025	7,685	61,321	126,871
1993	2,262	5,079	10,788	14,569	28,854	11,441	47,302	120,296
1994	2,253	3,829	5,122	14,290	13,314	30,211	36,925	105,945
1995	2,915	6,330	6,313	6,701	16,156	13,604	55,975	107,994
1996	2,796	5,855	9,854	7,861	8,383	17,839	51,208	103,795
1997	1,953	6,528	9,757	15,874	10,602	9,403	50,745	104,861
1998	3,893	6,959	8,279	15,323	18,323	10,743	50,381	113,900
1999	3,327	8,466	7,556	13,146	17,089	17,212	44,946	111,743
2000	2,662	8,605	11,640	16,389	17,100	14,149	53,966	124,511
2001	4,343	5,407	12,288	21,329	17,980	14,822	53,879	130,048
2002	3,604	11,635	10,171	22,063	18,746	13,676	46,295	126,190
2003	2,765	9,323	15,310	13,751	19,636	18,567	41,040	120,392
2004	1,356	8,096	15,636	23,500	15,868	21,763	50,848	137,067
2005	1,844	5,948	16,823	18,109	27,443	14,177	56,413	140,757
2006	2,813	8,065	12,256	19,330	21,062	24,448	53,067	141,042
2007	2,082	12,350	16,813	14,238	22,607	18,839	60,625	147,553
2008	1,773	9,074	25,190	19,133	16,480	20,070	59,792	151,512
2009	641	7,803	19,051	29,457	22,453	14,775	61,811	155,991

Table 11. Projection results for bluefish through 2012 under 5 different fishing scenarios.

Scenario	Year	F	1-Jan Abundance (000s)	Mean Biomass (000s mt)	SSB (000s mt)	Yield mt
F status quo	**2010**	0.10	79,513	138.6	131.2	9,563
	2011	0.10	83,368	138.6	130.1	9,779
	2012	0.10	86,108	141.0	129.2	10,821
75% Fmsy	**2010**	0.10	79,513	138.6	131.2	9,563
	2011	0.14	83,368	136.7	128.3	13,489
	2012	0.14	84,493	135.2	123.8	14,490
Ftarget	**2010**	0.10	79,513	138.6	131.2	9,563
	2011	0.17	83,368	158.1	127.4	15,302
	2012	0.17	83,704	157.0	121.1	16,197
F0.1	**2010**	0.10	79,513	138.6	131.2	9,563
	2011	0.18	83,368	134.9	126.5	16,654
	2012	0.18	82,926	129.7	118.6	17,096
Fmsy	**2010**	0.10	79,513	162.8	131.2	9,563
	2011	0.19	83,368	162.5	126.1	17,972
	2012	0.19	82,542	157.2	117.3	18,608

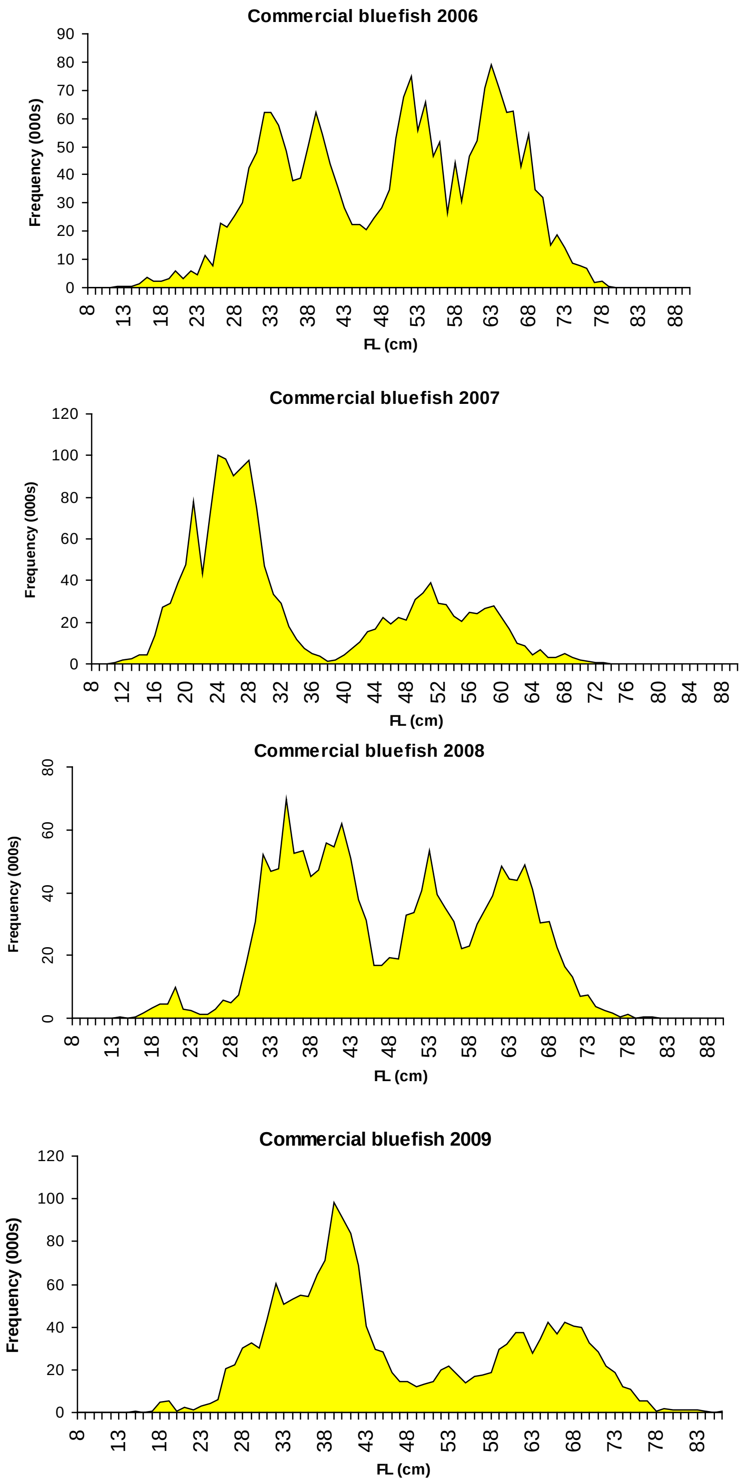


Figure 1. Length frequency distribution of commercial bluefish landings, ME-FL, 2006-2009.

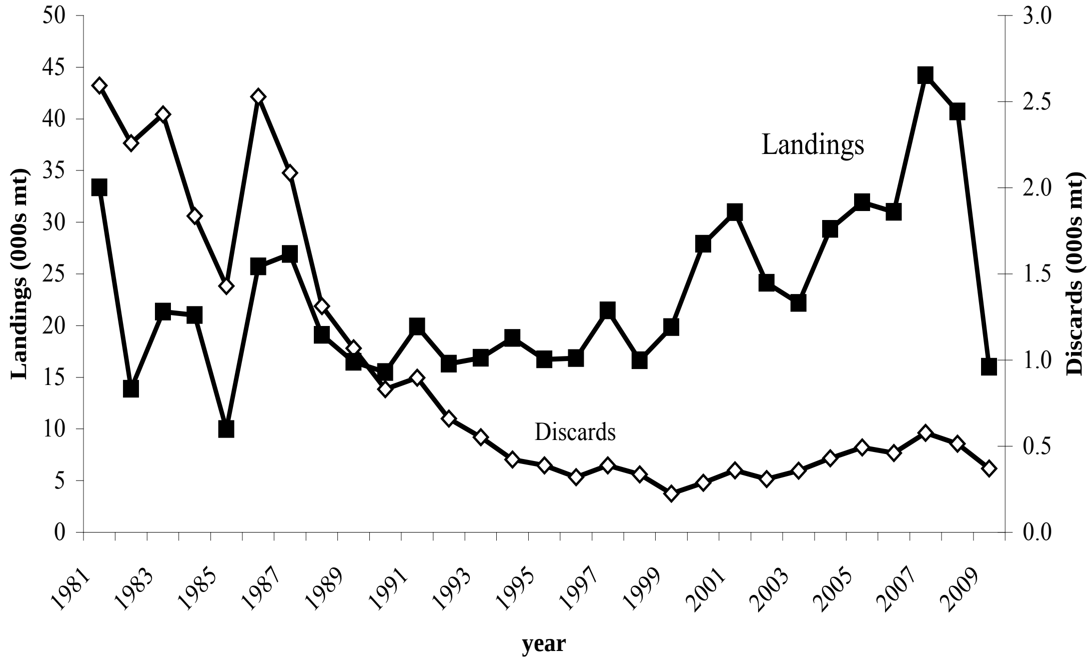


Figure 2. Recreational landings (mt) and recreational discard losses (MRFSS B2 estimates * 15%), ME-FL.

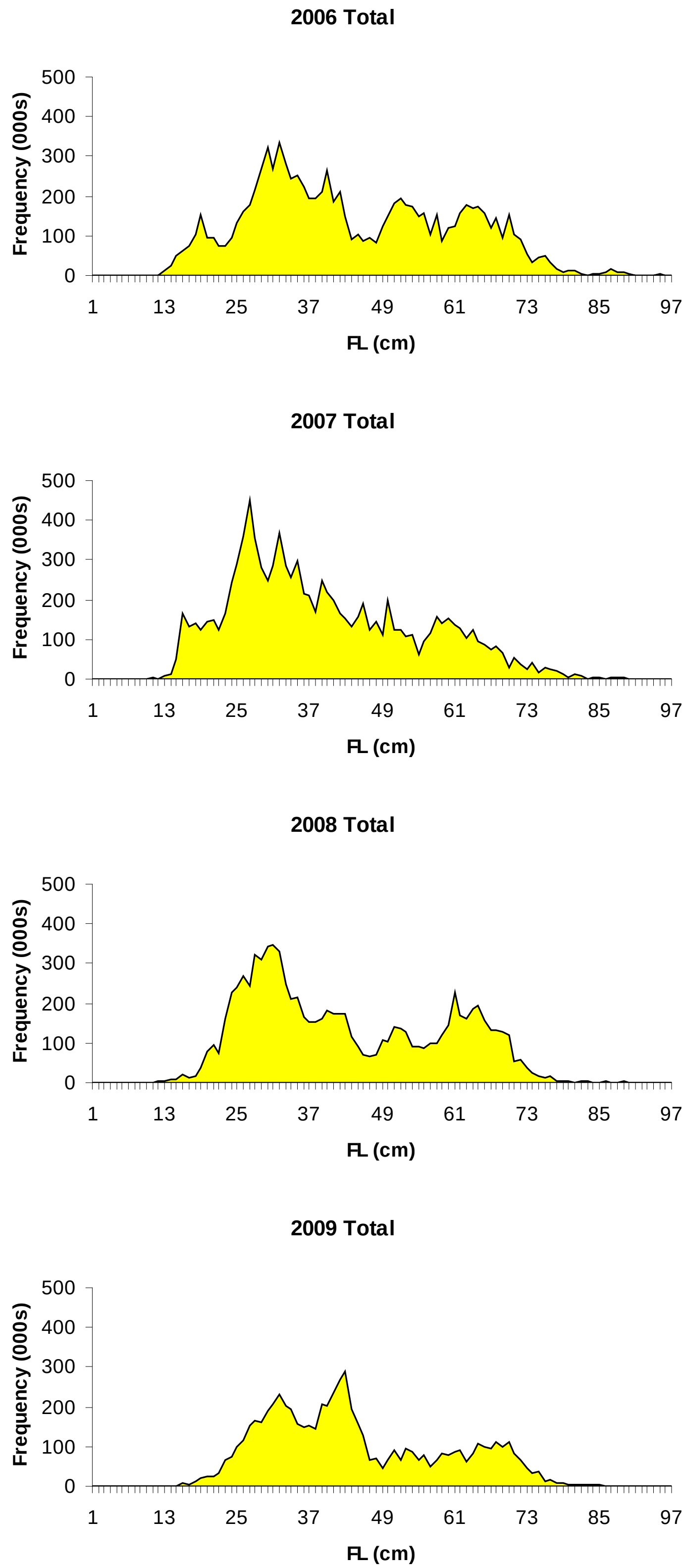


Figure 3. Total length frequencies of combined bluefish commercial and recreational fisheries, 2006-2009.

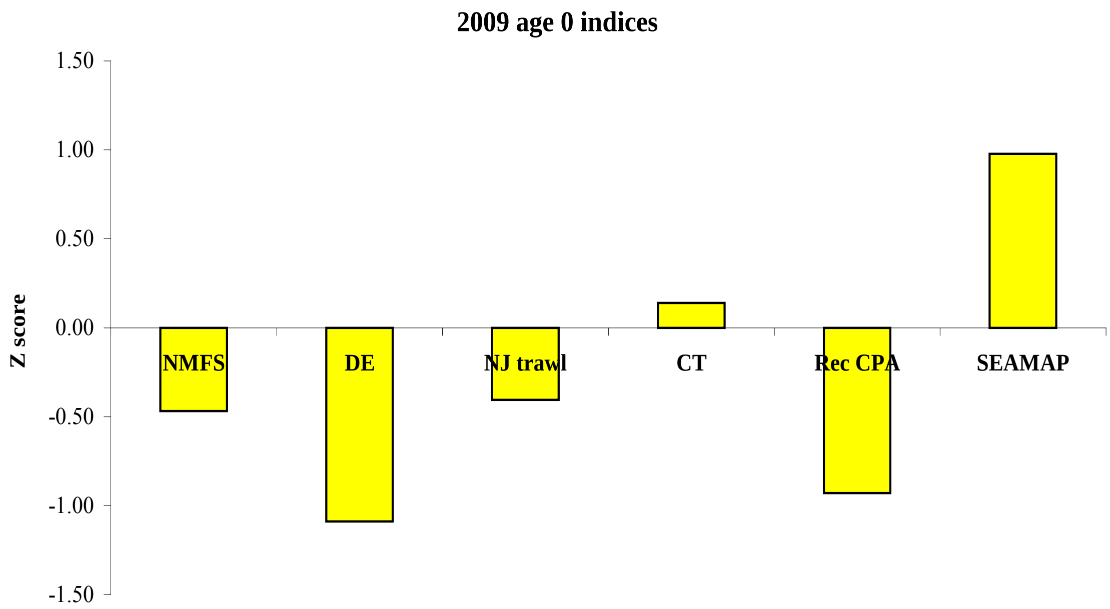


Figure 4. Standardized age 0 recruitment indices for 2009 by program.

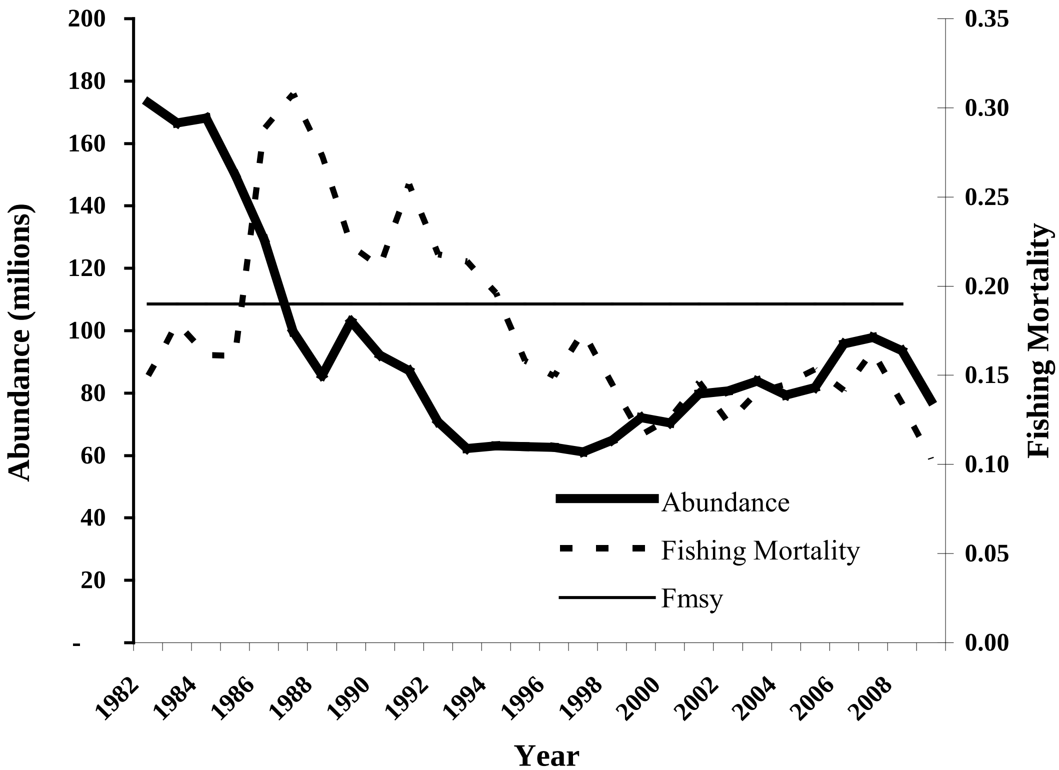


Figure 5. Total bluefish abundance and fishing mortality as estimated in ASAP model. FMSY indicated by solid horizontal line.

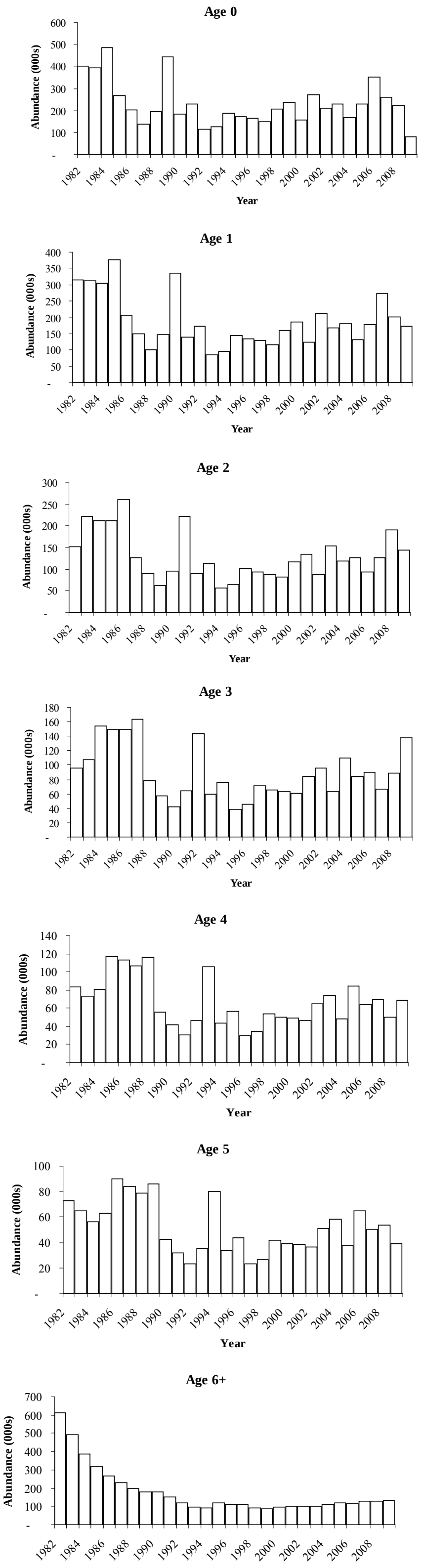


Figure 6. Total bluefish abundance at age from ASAP model results.

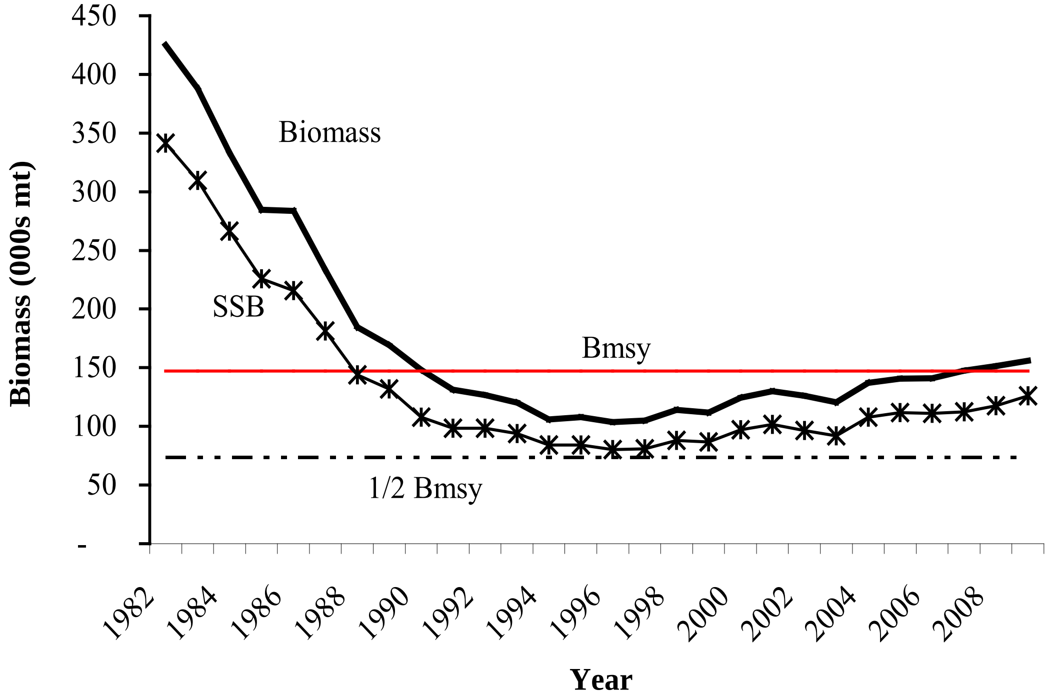


Figure 7. Total bluefish biomass, spawning stock biomass and reference points.

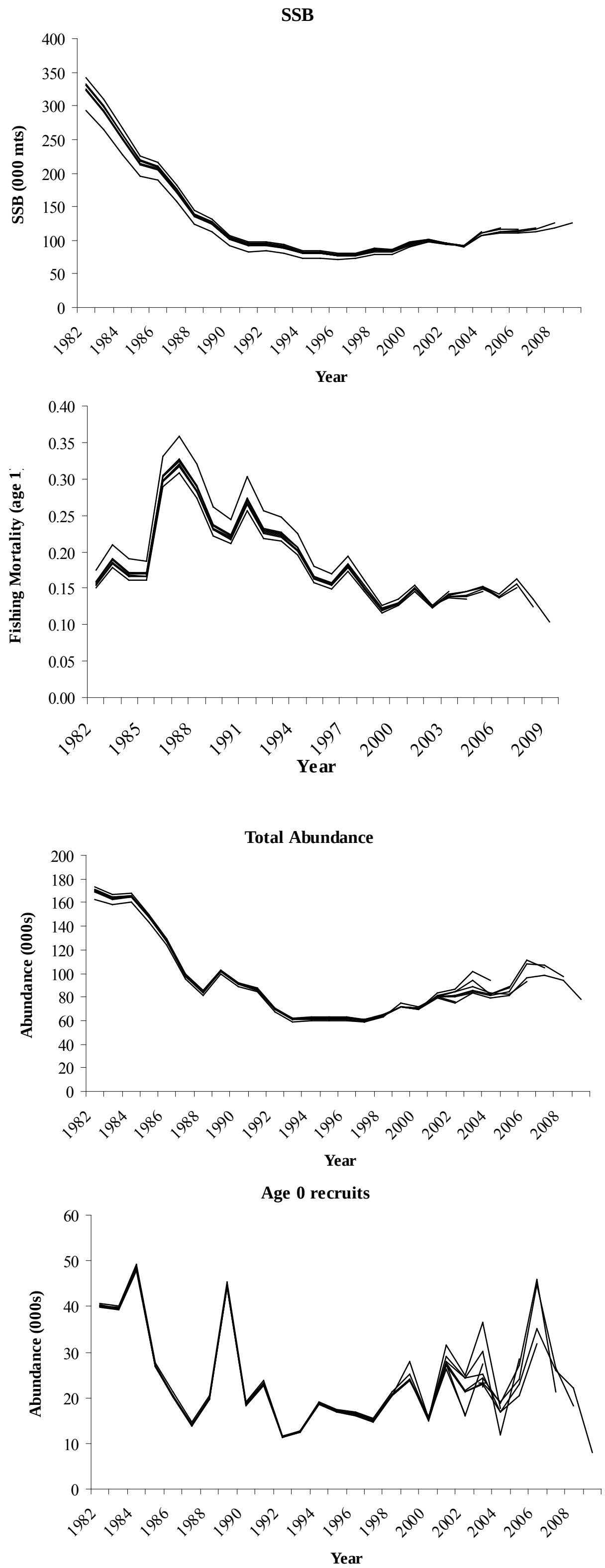
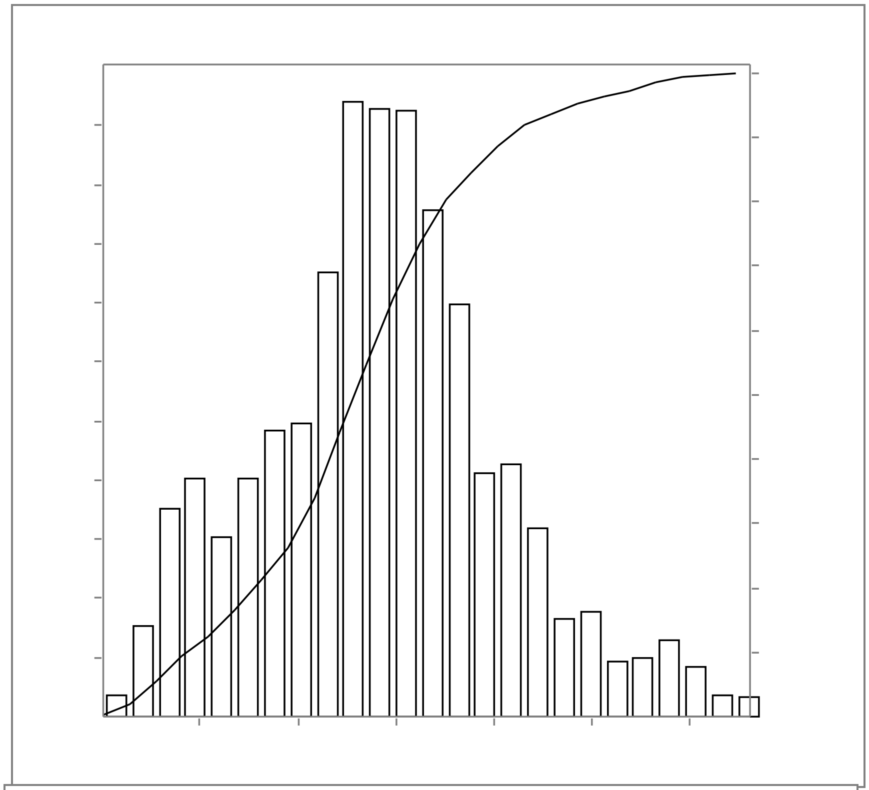


Figure 8. Retrospective bias in bluefish estimates from ASAP model.



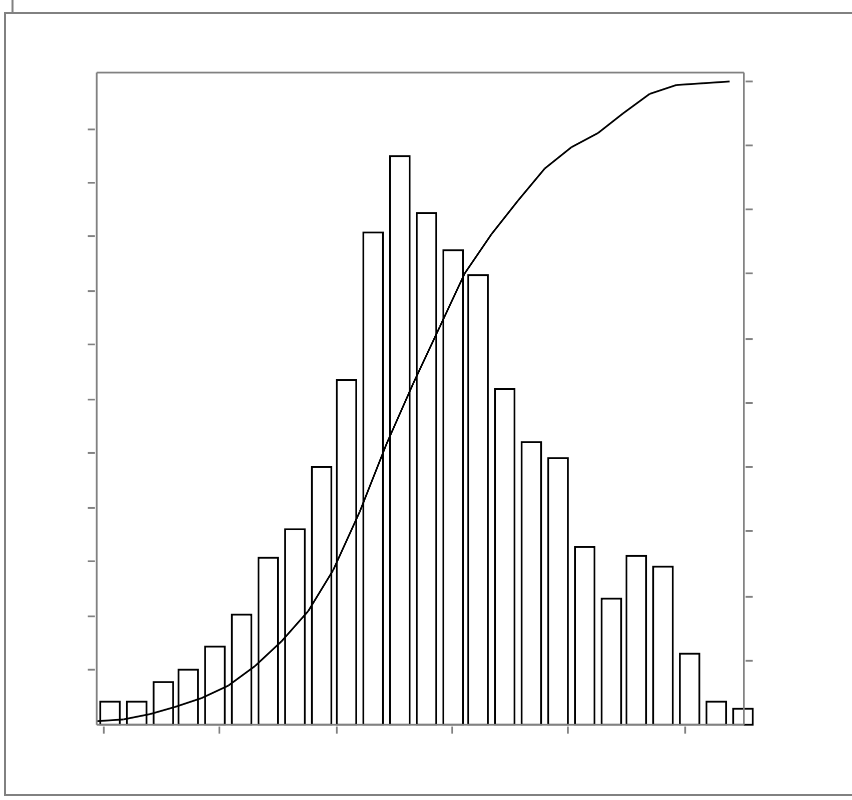


Figure 9. Distribution of bluefish fishing mortality and spawning stock biomass resulting from 2500 MCMC iterations in ASAP model.

Appendix I. ASAP model output.

obj_fun	=	343377
Component	Lambda	obj_fun
__Catch_Fleet_1	2000	339671
Catch_Fleet_Total	2000	339671
Discard_Fleet_Total	0	0
__Index_Fit_1	10	1309.8
__Index_Fit_2	5	707.571
__Index_Fit_3	5	491.779
__Index_Fit_4	5	47.4302
__Index_Fit_5	5	-100.68
__Index_Fit_6	5	-136.11
__Index_Fit_7	5	27.1739
__Index_Fit_8	5	-157.26
__Index_Fit_9	5	30.4989
__Index_Fit_10	5	-51.007
__Index_Fit_11	5	438.972
__Index_Fit_12	5	330.797
__Index_Fit_13	5	201.747
__Index_Fit_14	5	518.341
__Index_Fit_15	5	605.402
__Index_Fit_16	5	191.618
__Index_Fit_17	5	135.418
__Index_Fit_18	5	33.6683
__Index_Fit_19	5	189.468
__Index_Fit_20	5	-37.056
__Index_Fit_21	5	-342.09
__Index_Fit_22	5	-238.11
__Index_Fit_23	5	-247.99
__Index_Fit_24	5	-430.29
__Index_Fit_25	5	-568.34
__Index_Fit_26	5	-564.71
__Index_Fit_27	5	-453.55
__Index_Fit_28	5	386.671
Index_Fit_Total	145	2319.18
Catch_Age_Comps	see_below	292.509
Discard_Age_Comps	see_below	0
Survey_Age_Comps	see_below	0
Sel_Params_Total	0	0
Index_Sel_Params_Total	0	0
__q_year1_index_1	0.01	0.45336
__q_year1_index_2	0.01	0.25175
__q_year1_index_3	0.01	0.03261
__q_year1_index_4	0.01	-0.0273
__q_year1_index_5	0.01	-0.073
__q_year1_index_6	0.01	-0.0663
__q_year1_index_7	0.01	-0.0898
__q_year1_index_8	0.01	-0.0308

__q_year1_index_9	0.01	0.09016
__q_year1_index_10	0.01	-0.0808
__q_year1_index_11	0.01	0.34198
__q_year1_index_12	0.01	0.0795
__q_year1_index_13	0.01	-0.027
__q_year1_index_14	0.01	0.60538
__q_year1_index_15	0.01	0.256
__q_year1_index_16	0.01	0.22285
__q_year1_index_17	0.01	0.10887
__q_year1_index_18	0.01	0.05431
__q_year1_index_19	0.01	0.04029
__q_year1_index_20	0.01	-0.0534
__q_year1_index_21	0.01	-0.0786
__q_year1_index_22	0.01	-0.0199
__q_year1_index_23	0.01	-0.0225
__q_year1_index_24	0.01	-0.0599
__q_year1_index_25	0.01	-0.0901
__q_year1_index_26	0.01	-0.0777
__q_year1_index_27	0.01	-0.0872
__q_year1_index_28	0.01	0.26622
q_year1_Total	0.28	1.91894
q_devs_Total	2800	0
__Fmult_year1_fleet_1	0.5	-0.6594
Fmult_year1_fleet_Total	0.5	-0.6594
Fmult_devs_fleet_Total	0	0
N_year_1	1	479.868
Recruit_devs	0.1	29.2025
SRR_steepness	1	1.59008
SRR_unexpl_stock	1	582.08
Fmult_Max_penalty	1000	0
F_penalty	0	0
Component	#resids	RMSE
_Catch_Fleet_1	28	0.00056
Catch_Fleet_Total	28	0.00056
_Discard_Fleet_1	0	0
Discard_Fleet_Total	0	0
_Index_1	28	2.18616
_Index_2	28	3.02499
_Index_3	28	3.35732
_Index_4	28	2.69215
_Index_5	25	2.66098
_Index_6	21	2.51511
_Index_7	23	2.82738
_Index_8	20	1.3638
_Index_9	20	1.71315
_Index_10	20	2.63191
_Index_11	22	2.28096
_Index_12	22	2.9382
_Index_13	22	3.13309
_Index_14	25	1.34675

_Index_15	25	2.96059
_Index_16	25	1.85805
_Index_17	25	2.31423
_Index_18	24	2.3515
_Index_19	24	3.01591
_Index_20	23	2.40967
_Index_21	28	1.24461
_Index_22	28	1.24388
_Index_23	28	1.48879
_Index_24	28	1.22357
_Index_25	28	1.12697
_Index_26	28	1.16985
_Index_27	28	1.04913
_Index_28	20	2.50095
Index_Total	694	2.26067
Nyear1	6	11.355
Fmult_Year1	1	1.4304
_Fmult_devs_Fleet_1	0	0
Fmult_devs_Total	0	0
Recruit_devs	28	0.76885
Fleet_Sel_params	0	0
Index_Sel_params	0	0
q_year1	28	6.66269
q_devs	0	0
SRR_steepness	1	2.83696
SRR_unexpl_S	1	-33.8573

F0.1	0.18
Fmax	0.28
F40%	0.18
Fmsy	0.14
Fcurrent	0.10
SSmsy	111,901
MSY	12,856

steepness	0.607
alpha	32405.3
beta	62627.4
virgin	325073

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