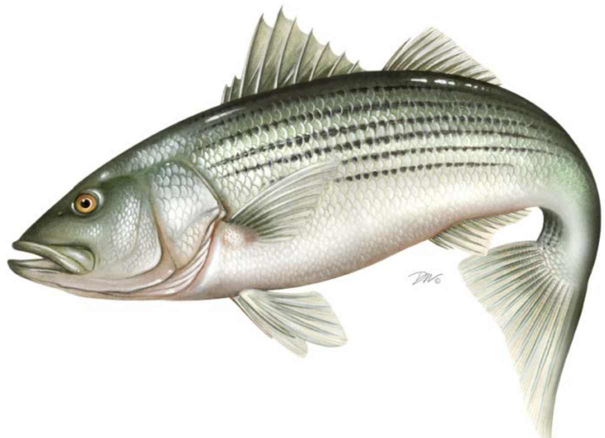
Atlantic States Marine Fisheries Commission
Striped Bass Stock Assessment Update
2011



Prepared by:

Striped Bass Stock Assessment Subcommittee
Striped Bass Tagging Subcommittee

Healthy, self-sustaining populations of all Atlantic coast fish species or successful restoration well in progress by the year 2015

Accepted for Management Use
November 8, 2011

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Striped Bass Assessment Summary **ASMFC Striped Bass SASC, August 2011**

State of Stock: Relative to the biological reference points accepted by the Striped Bass Management Board, the striped bass stock complex in 2010 is not overfished and overfishing is not occurring (SSB threshold = 36,881 mt; F_{MSY} = 0.34). This conclusion is based on a 2010 female spawning stock biomass estimate of 50,548 mt and average age 8-11 F=0.23 from the statistical catch at age (SCA) model. Using state and federal indices, the SCA model estimated low fishing mortality rate (*F)* and declining spawning and total biomass since 2006. Abundance estimates increased from a low of 8.3 million fish in 1982 to a peak of 67.5 million fish in 2004, and have since decreased to 42.3 million fish in 2010.

Forecast: Forecasts of age 8+ abundance from 2011 to 2017 and spawning stock biomass from 2011 to 2013 at status quo F (0.23) and selectivity show increases in abundance through 2011, but a subsequent decline in abundance through 2017. Spawning stock biomass will increase slightly in 2011, but decline through 2013. Projected landings of age 8+ fish at status quo F will increase in 2011 but will decline through 2017.

Catch and Status Table (weights in '000 mt): Striped Bass

Year	2004	2005	2006	2007	2008	2009	2010	Max	Min	Mean
USA Commercial landings[1]	3.3	3.2	3.1	3.2	3.3	3.3	3.2	5.9	0.1	2.4
USA Recreational landings[2]	12.6	11.6	13.8	11.1	12.3	11.6	10.4	13.8	0.1	5.7
Total Catch[3]	15.9	14.8	16.9	14.3	15.6	14.9	13.6	16.9	0.1	7.5

[1] Min, max and mean since 1947.
[2] Min, max and mean landings since 1982.
[3] Min, max, and mean total catch since 1982.

Stock Distribution and Identification: Striped bass along the U.S. Atlantic coast are a highly migratory species found in coastal waters between North Carolina and Maine. Striped bass are managed as a single stock although there are at least three distinct stocks contributing to the coastal migratory group: Hudson River, Delaware River, and Chesapeake Bay and tributaries.

Catches: Striped bass are one of the most sought after species by recreational anglers along the Atlantic Coast. In 2010, recreational anglers along the Atlantic Coast landed over 1.99 million striped bass weighing 10,400 metric tons (mt) (Figure 1 and 2; Table 1 and 2). Recreational landings have ranged from a low of 52 mt in 1986 to a high of 13,814 mt in 2006. Coast-wide recreational landings of 1.99 million fish in 2010 reflected a 28% decline from a high of 2.7 million fish in 2006 (Table 2). Changes in landings (numbers) have varied by state (Table 3), with MA, RI, CT, NY, NJ and NC showing an increase in numbers landed in 2010 compared to 2009, and the remaining states (ME, NH, DE, MD, and VA) showing a 45% decrease in numbers on average. Compared to 2009, total weight of recreational landings in 2010 declined by 5% to 223% in ME, NH, RI, DE, MD and VA, but increased by 16% to 71% in CT, NY, NJ and NC Recreational discard mortalities (assuming an 8% mortality of releases) in 2010 were 513,583 fish (Table 5), a 75% decrease from a high of 2.0 million fish in 2006. Since 2000, ME, MA, CT, NY, and MD has released the highest number of fish on average, accounting for almost 72% of total discard losses. Since 2009, discard numbers have declined by an average of 37% in most states. Landings from the commercial striped bass fishery have been consistently lower than the recreational catch (Figure 1). Commercial landings (Tables 1 and 6) increased from 63 mt in 1987 to 2,679 mt in 1997 and have remained stable due to quota restrictions. Commercial landings in 2010 were 3,203 mt (Figure 1; Table 1). Gill nets are the dominant commercial gear used to target striped bass. Other commercial fishing gears include hook and line, pound nets, seines, and trawls.

Data and Assessment: The ASMFC Striped Bass Stock Assessment Subcommittee (SB SAS) compiled the commercial and recreational catch at age data provided by state agencies (Figure 3, Table 7). Recreational landings, length data, and discard estimates were collected by the MRFSS survey and supplemented by state voluntary logbook programs as available. Commercial landings and length frequency data were collected by states with commercial fisheries (MA, RI, NY, DE, MD, VA, PRFC and NC). Commercial discards were estimated from tag returns as in previous assessments. State agencies conduct annual marine finfish surveys and the available indices were used in a forward projecting statistical catch at age (SCA) model. Indices included in the model were young of the year indices from NY, NJ, MD, and VA (Figure 4; Table 8); age 1 indices from MD and NY (Figure 4; Table 8); age specific indices from the NY ocean haul seine (through 2007), NJ trawl survey, MD spawning stock survey, and the DE spawning stock survey (Figure 4; Table 9); and age aggregated indices from MFRSS catch per angler, CT catch per angler, NEFSC trawl survey (through 2008), and the CT trawl survey (Figure 4; Table 9). The ASMFC Tagging Subcommittee analyzed tag release and recovery data through 2010 gathered by state and federal agencies as part of the USFWS Atlantic coast-wide cooperative striped bass tagging program. Estimates of fishing mortality from tag data were made using both catch equation and instantaneous rates models which relax the assumption of constant natural mortality.

Indices:

Hudson stock

The Hudson River juvenile indices in 2006 (3.82) and 2007(35.02) were years exhibiting low and high contrast for the entire time series since 1979 (Figure 4). From 2008 to 2010 the index was relatively stable at values near the long-term mean (13.7); values were 13.86 (2008), 9.73 (2009) and 12.90 (2010), respectively. The index of age-one abundance in the Western Long Island Sound seine survey showed a variable but declining trend since the peak in 2002 (Figure 4).

Delaware River stock

The young-of-the-year index of the Delaware River stock collected by NJ DEP shows an annually variable but relatively stable pattern since 1989 (Figure 4). The 2009 and 2010 indices were near average. The Delaware spawning stock index in 2009 (1.25) was below the time series average (2.48) while 2010 (2.69) was greater than the average index (Figure 4).

Chesapeake Bay stock

Maryland juvenile indices have a variable and declining trend since 2004 (Figure 4). The 2008 index was the lowest since the early 1990s and below the 25th percentile for the 1957-2009 period. The 2009 and 2010 indices were above the 25th percentile but below the average. An index of the Chesapeake Bay stock collected in VA also shows a high annual variability with declining trend since 2004 (Figure 4). However, none of the VA juvenile index values fell below the 25th percentile in recent years. The Maryland age-1 index shows a relatively stable pattern since the 1990s with the exception of several large year classes (1993, 2001, and 2003) (Figure 4). Although neither MD nor VA indices fell below the 25th percentile for three years in a row to qualify for the recruitment failure, consistently low recruitment since 2004 will result in the continuing decline of striped bass population in near future. The MD spawning stock survey shows significant variability in spawning stock biomass with no trend for males and females combined. The spawning stock index in the spring of 2010 was slightly below the average, while the index for age 8 and older fish (primarily females) was above average (Figure 4).

Coastal mixed stock

Among the age-based indices of relative abundance, the NJ trawl survey index continued to decline through 2010 (Figure 4). The age-aggregated index based on MRFSS total catch per angler trip showed an increase between 2003 and 2006, then a sharp decrease in 2007. The 2009 and 2010 index values increased slightly but were still below the rates observed in the mid-1990s (Figure 4). The CT DEP trawl index was variable but relatively stable from the mid-1990s through 2007, and has since declined through 2010 (Figure 4). The CT CPUE recreational fisheries index from volunteer anglers increased dramatically between 2003 and 2008, but has since declined to a level slightly above the time series average (Figure 4).

Fishing Mortality – Catch at age model: Fishing mortality estimates for management of striped bass are reported as the average F for ages 8 to 11. In addition, average F for ages 3 to 8 and 7 to 11 (weighted by N) are reported for comparison to tag-based F estimates. Estimates for both categories have remained relatively stable since 2008 (Figure 5; Table 10). Fishing mortality for ages 8 to 11 was estimated at 0.23 for 2008-2010 while F on ages 3 to 8 remained at 0.16. Fishing mortality for ages 7-11 weighted by N (Figure 5) follows the same pattern as ages 8 to 11. Little retrospective bias was observed for the last three years of data and the 2008 average 8-11 F estimates from the 2009 assessment changed only slightly (0.21 to 0.23).

Fishing Mortality – Tag models:

Coastal programs -The estimates of fishing mortality in 2010 for striped bass greater than 28 inches ranged from 0.08 to 0.16 using the catch equation method and from 0.08 to 0.12 using the instantaneous rates tag return model (IRCR)(Figure 6; Table 10). The average fishing mortality in 2010 across the two models and programs equaled 0.12. Fishing mortality from the Massachusetts and North Carolina Cooperative tagging programs has remained relatively stable since 2002 and 2000, respectively (Figure 6). Fishing mortality from the NY Ocean Haul/Trawl tag program declined after 2006. Estimates from the New Jersey/Delaware program have steadily increased since 1999 (Figure 6; Table 10).

Hudson River - Striped bass fishing mortality in 2010 for fish 28 inches and greater equaled 0.23 averaged across the two models (Figure 6; Table 10). Average F over the time series has ranged from 0.29 in 1997 to 0.08 in 1989. F increased to 0.23 in 2004, declined 0.20 in 2008 and has increased slightly through 2010. F in 2010 on fish 18 inches and greater averaged 0.14.

Delaware River - Average striped bass fishing mortality in 2010 for fish 28 inches and greater equaled 0.28 which was an increase from 0.19 in 2008. Fishing mortality for fish 18 inches and greater in 2010 was 0.15, and is a slight increase from an F=0.14 in 2008 (Figure 6; Table 10).

Chesapeake Bay - The estimates of fishing mortality in 2010 for striped bass greater than 18 inches averaged 0.16. F steadily decreased from 0.28 in 1998 to 0.12 in 2007, but has increased slightly since 2008 . Fishing mortality on fish 28” and greater from the Chesapeake stock averaged 0.13 in 2010 and has remained stable since 2000 (Figure 6; Table 10).

Abundance and Biomass: Striped bass total abundance and biomass were estimated using the SCA model (Figures 7 and 8; Tables 11 and 12). Abundance increased steadily from 8.3 million fish in 1982 to a peak of 67.5 million in 2004 then declined to 42.3 million fish in 2010. Abundance of striped bass age 8 and greater, representing approximately fish 28” and greater, was lowest in 1985 but then increased to a series high in 2004. Abundance of age 8+ fish decreased from 9.7 million fish in 2004 to 5.9 million fish in 2010. Total biomass followed a similar pattern increasing from a low in 1984 to a peak of 111,877 mt in 2002. Biomass since 2002 has declined to 87,771 mt in 2010 (Figure 8; Table 12).

Spawning Stock Biomass: SSB for striped bass is presented as female spawning biomass (Figure 8; Table 13). The 2010 estimate of SSB equaled 50,548 mt, a 4% decline since 2008 (52,570 mt). Female SSB has been declining since the peak of 63,714 mt in 2003. The threshold SSB is equivalent to the 1995 estimate; the 2010 estimate was 37% higher than the threshold (36,881 mt) and 9% higher than the target (46,101 mt).

Recruitment: Recruitment estimated in the SCA model as age-1 abundance averaged 13.5 million fish from 1994 (1993 year-class) through 2004 (2003 year-class) (Figure 9). The 2009 and 2010 estimates were slightly below and above, respectively, the average recruitment observed during 2005-2010 (8.1 million fish). The 2003 cohort (age 1 in 2004) remains the second largest year-class since 1982 at 20.8 million fish.

Biological Reference Points: The current biological reference points for Atlantic coast striped bass were approved at SARC 46 and updated in August 2008. The current F target equals 0.30 and the current F threshold (F_{MSY}) equals 0.34. The female SSB threshold equals 36,000 mt with a target SSB of 46,101 mt. The female SSB estimate for 2010 (50,548 mt) exceeds both the threshold and target and is not considered overfished (Figure 10). The current F of 0.23 is below the approved F target of 0.30 and F threshold of 0.34 and therefore, it is concluded that striped bass is not experiencing overfishing (Figure 10).

Projections: Projections of ages 3-8 abundance, ages 3-8 exploitable biomass, ages 8+ abundance, ages 8+ exploitable biomass, female spawning stock biomass, and landings from 2011 to 2017 were made for various levels of reduced fishing mortality under low (average 2005-2010 age-1 abundance) and average recruitment (average 1989-2008 age-1 abundance) and 2010 selectivity-at-age. Plots of population responses to changes in fishing mortality starting in 2012 are shown in Figure 11. For F = 0.23 (current fishing mortality), ages 3-8 abundance and exploitable biomass are expected to increase slowly or rapidly through 2017 depending on the recruitment scenario (Figure 11). Abundance and exploitable biomass of ages 8+ are expected to decline regardless of the recruitment scenario. Female SSB will fall slightly below the threshold by 2017 under both recruitment scenarios (Figure 11). Landings will continue to decline through 2017 under the low recruitment scenario, but they will increase slightly under the average recruitment scenario (Figure 11). With lower fishing mortality rates, ages 3-8 abundance and exploitable biomass are expected to rise more rapidly, while ages 8+ abundance and exploitable biomass are expected to decline more slowly or rise regardless of the recruitment scenario (Figure 11). Similarly, female SSB is expected to decline more slowly or rise regardless of the recruitment scenario. Lower F rates translate to lower, yet slightly or rapidly increasing landings over the time series under either recruitment scenario (Figure 11).

Special Comments: The updated striped bass assessment produces an estimate of status for the combination of the three primary stocks. Overall the conclusion is that stock abundance has declined since 2004. The decrease in abundance is reflected in a decline in coastwide landings in 2009 and 2010. The decline is more prevalent in areas largely dependent on contributions from the Chesapeake stocks (such as Maine) than areas such as New York that are dominated by the Hudson stock (Waldman et al 1990). Despite the decline in abundance, the spawning stock in 2010 remained relatively high due to the growth and maturation of the 2003 year class and the accumulation of spawning biomass from year classes prior to 1996. The latest results of the SCA model do not show much retrospective bias so it is unlikely that F is overestimated and abundance and biomass are underestimated (Figure 12).

Analysis of tag data also suggests an increasing natural mortality in Chesapeake Bay which could likely be the result of the mycobacteriosis. However, a recent tagging study by VIMS that examined the survival of infected versus uninfected striped bass suggests that the impact of the disease on the striped bass population may not be as significant as once thought due to the lagged nature of disease development. Table 14 summarizes the likely direction of other biases associated with various sources of uncertainty in the striped bass assessment results. Accounting for higher M (exact values unknown at this time) in the SCA model at the ages and in the years vulnerable to the disease in Chesapeake Bay will produce higher fishing mortality and lower female spawning biomass estimates.

Sources of Information:

Northeast Fisheries Science Center. 2008. Report of the 46st Northeast Regional Stock Assessment Workshop (46st SAW): 46st SAW Assessment Report. NEFSC CRD 08-03. February, 2008. 614 pp.

Waldman, J.R., D.J. Dunning, Q.E. Ross, and M.T. Mattson. 1990. Range dynamics of Hudson River Striped Bass along the Atlantic coast. Trans. Am. Fish. Soc. 119:910-919.

Figure 1. Commercial and recreational landings (mt) of striped bass from Maine to North Carolina, 1947-2010.

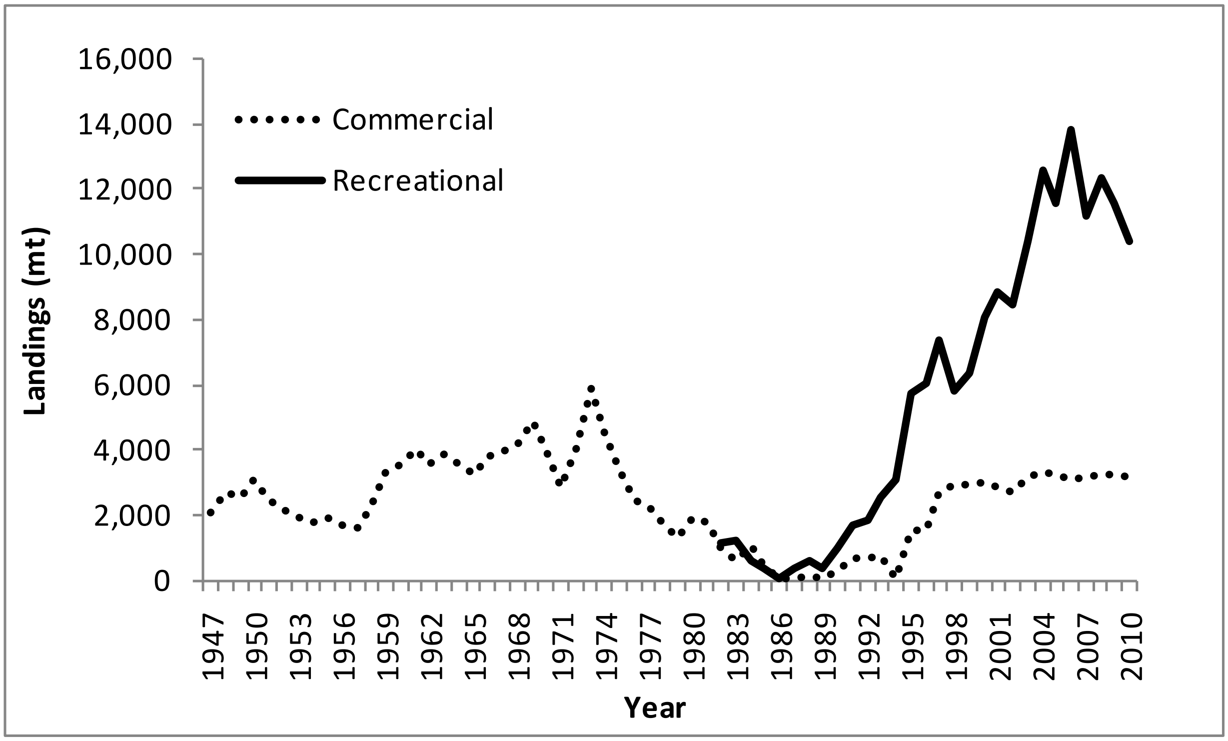

Figure 2. Total catch (landings plus recreational discards) in number (000s) for recreational and commercial fisheries of striped bass, Maine to North Carolina, 1982-2010.

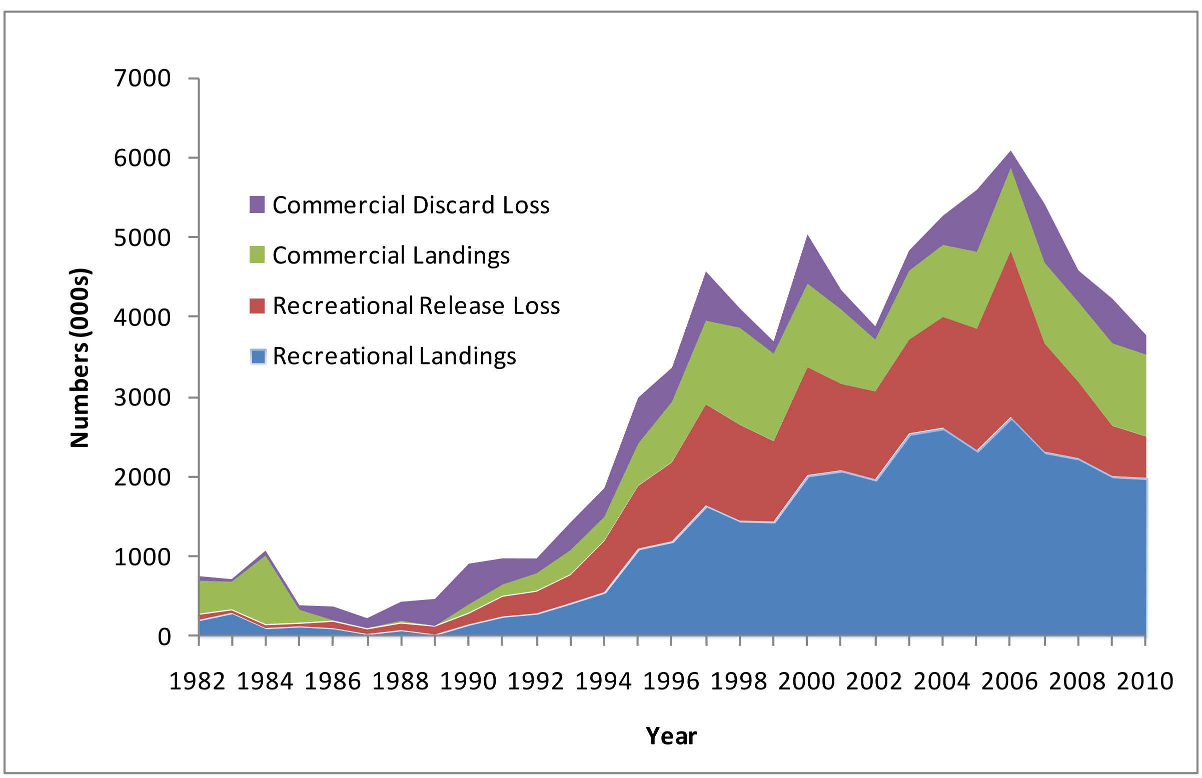

Figure 3. Total catch at age of striped bass along the Atlantic coast 1999-2010. Dominant year classes evident in juvenile indices in solid colors.

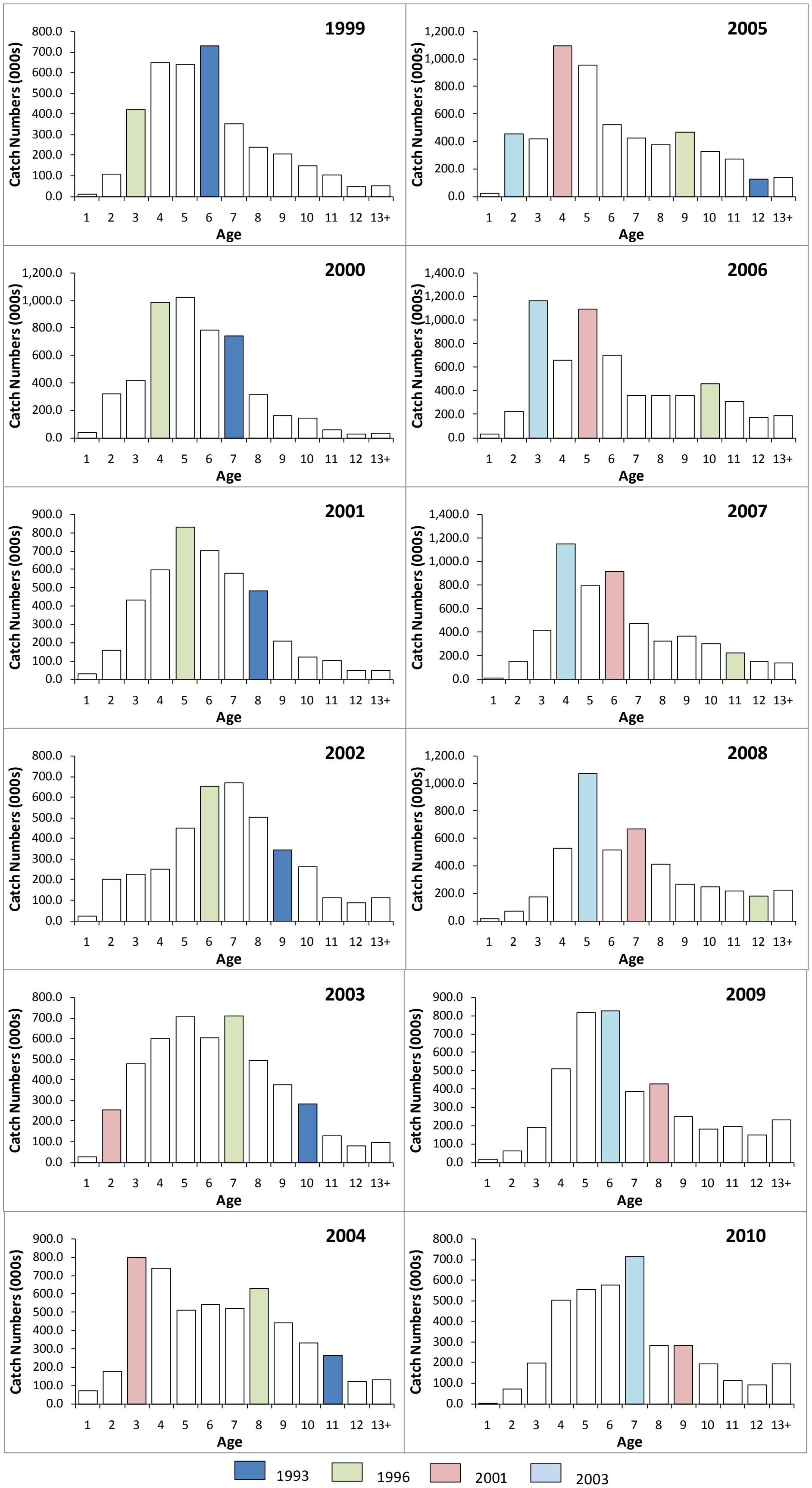

Figure 4. Indices of relative abundance for striped bass used in the SCA model.

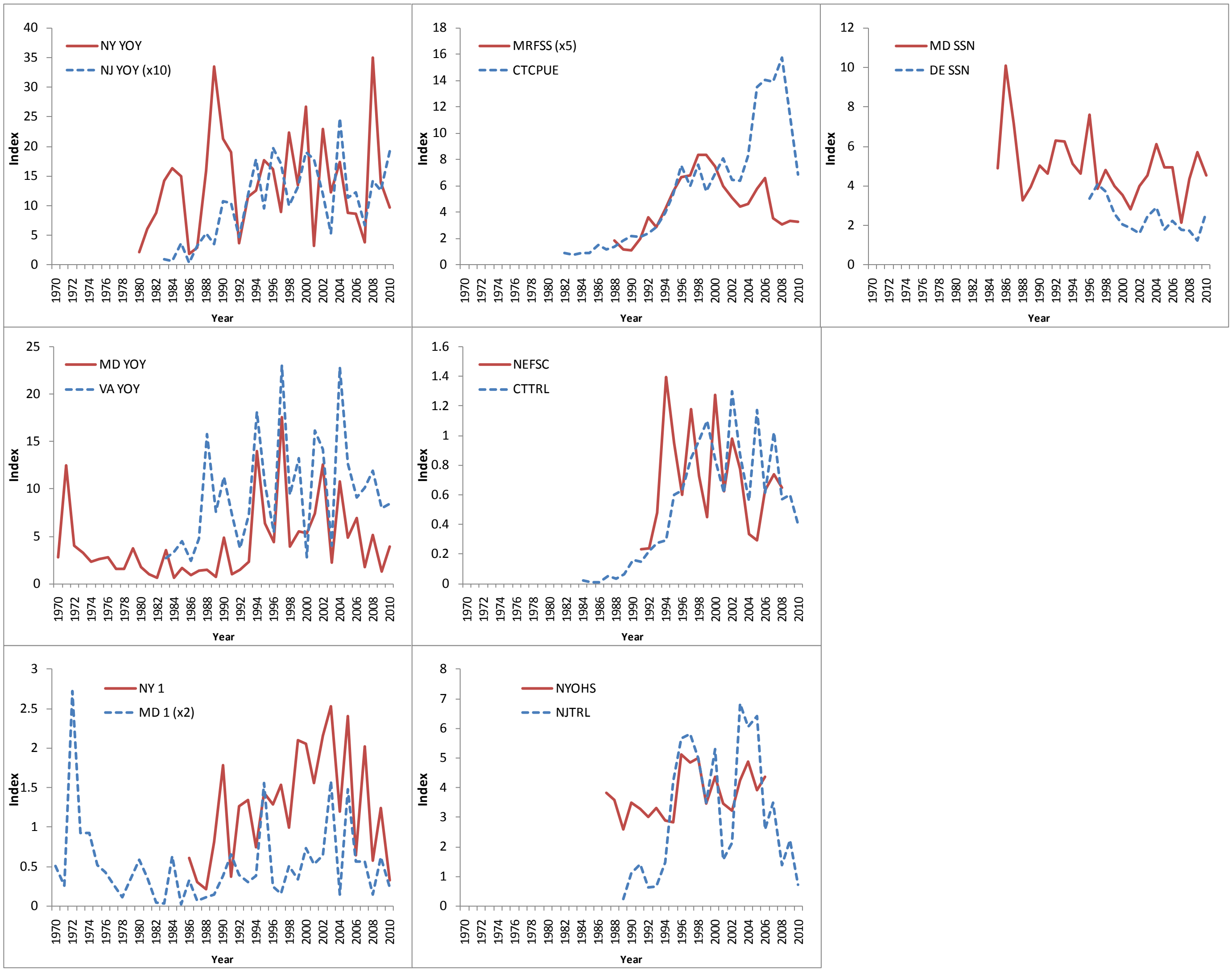

Figure 5. Fishing mortality estimates for striped bass from the SCA model, 1982-2010.

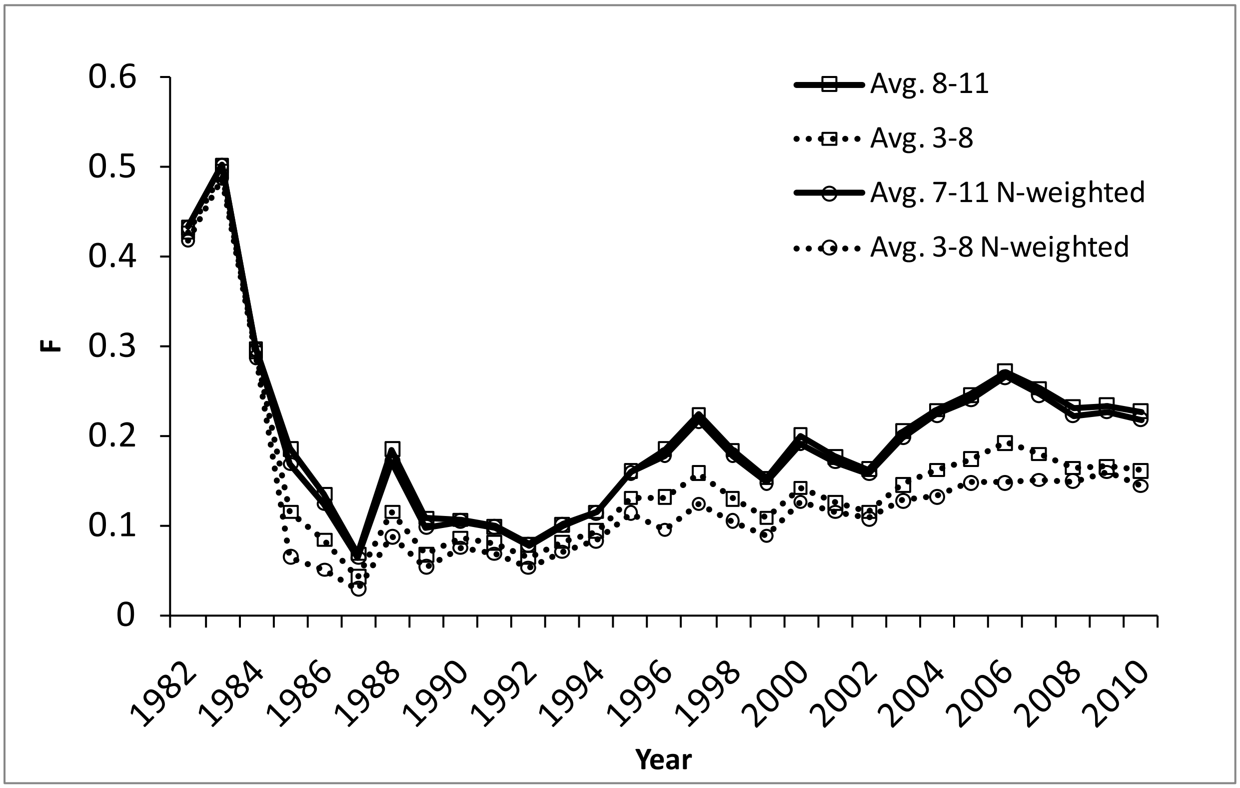

Figure 6. Tag based model averages of fishing mortality by coastal and producer area; dots indicate point estimates from CE and IRCR models.

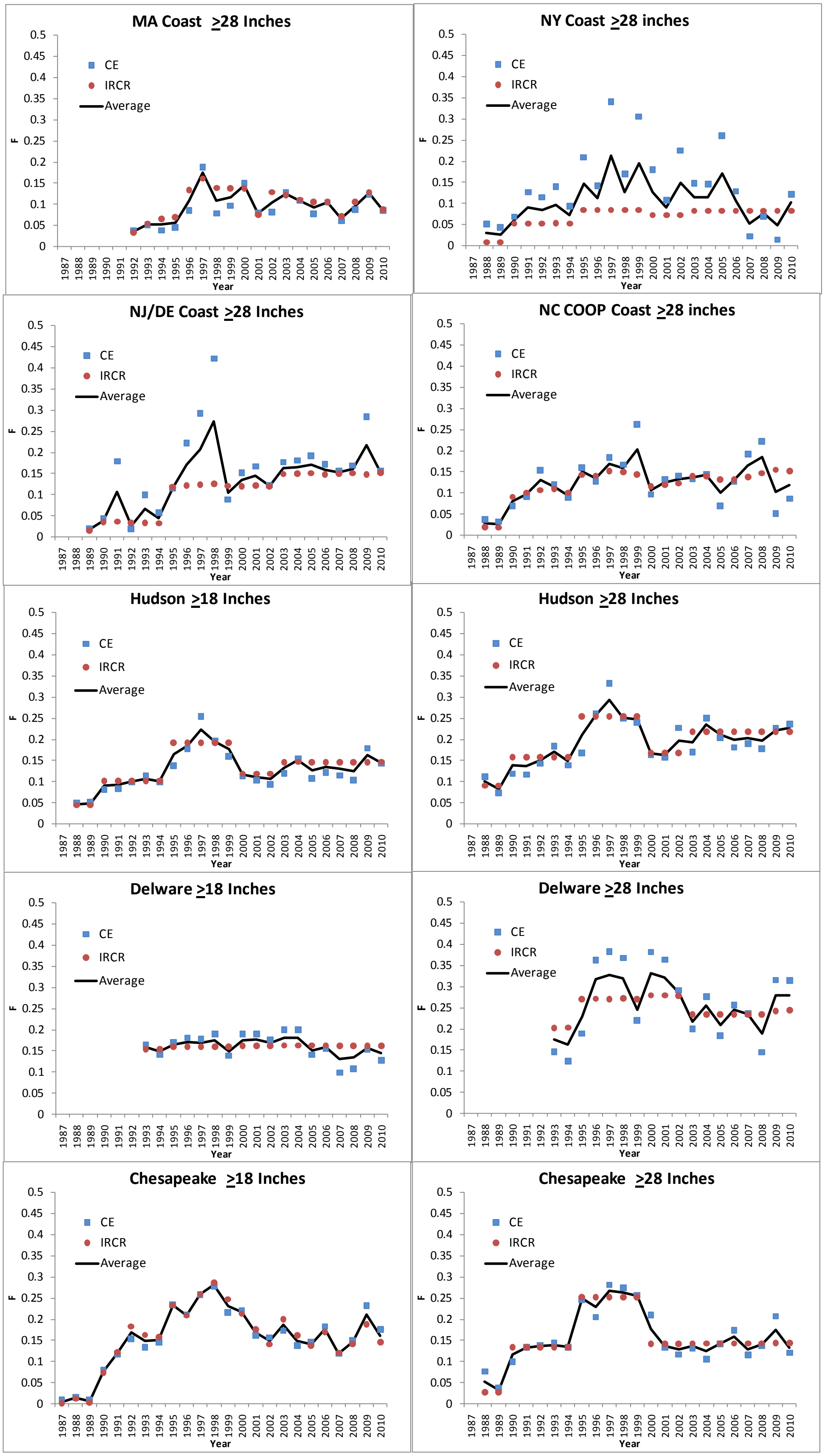

Figure 7. Total and age 8+ abundance (000s) of striped bass estimated in SCA model, 1982-2010.

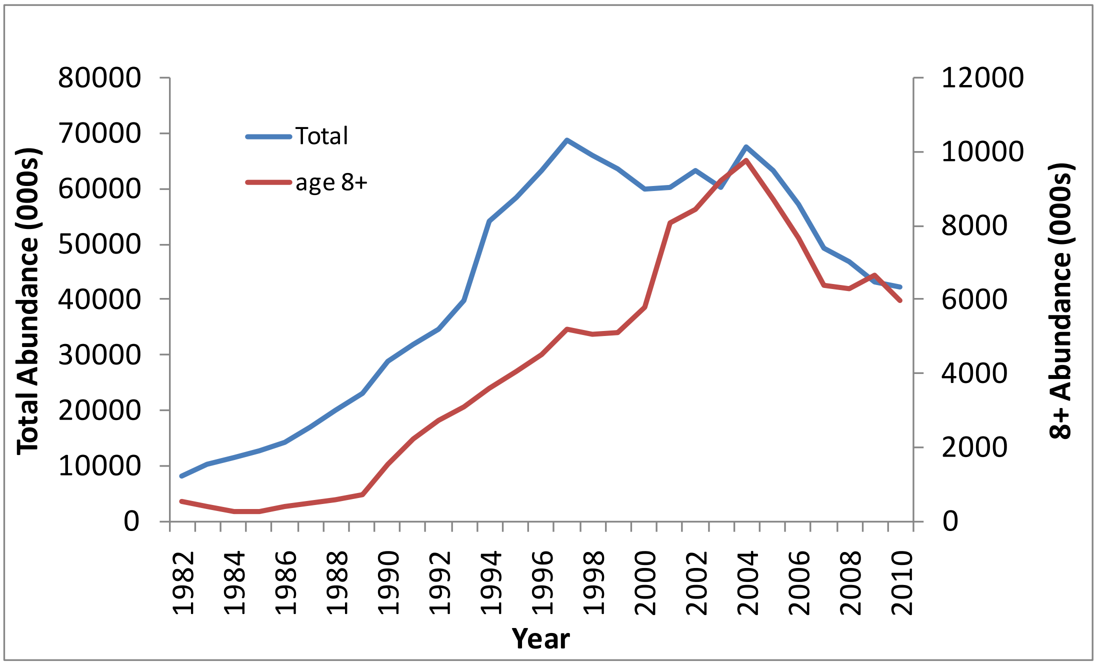

Figure 8. Total, spawning stock, and age 8+ biomass (metric tons) of striped bass estimated in SCA model, 1982-2010.

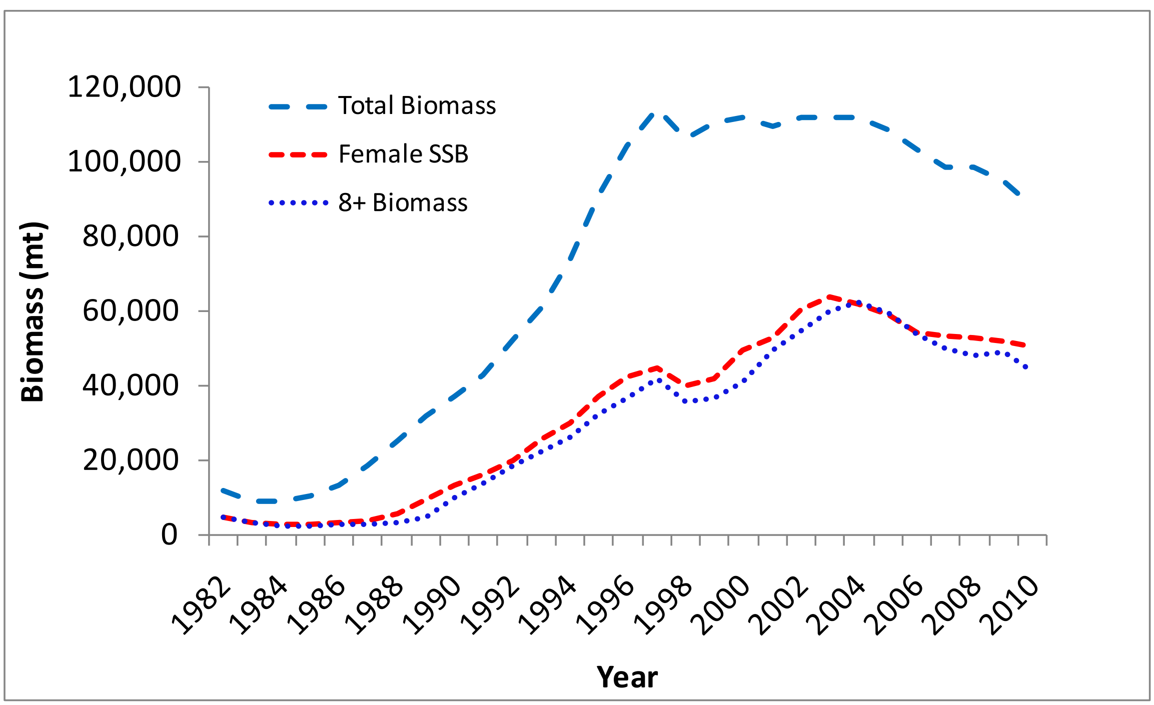

Figure 9. Recruitment (age 1) estimates for striped bass from SCA model; 1994-2004 average and 2005-2010 average are shown as dotted lines.

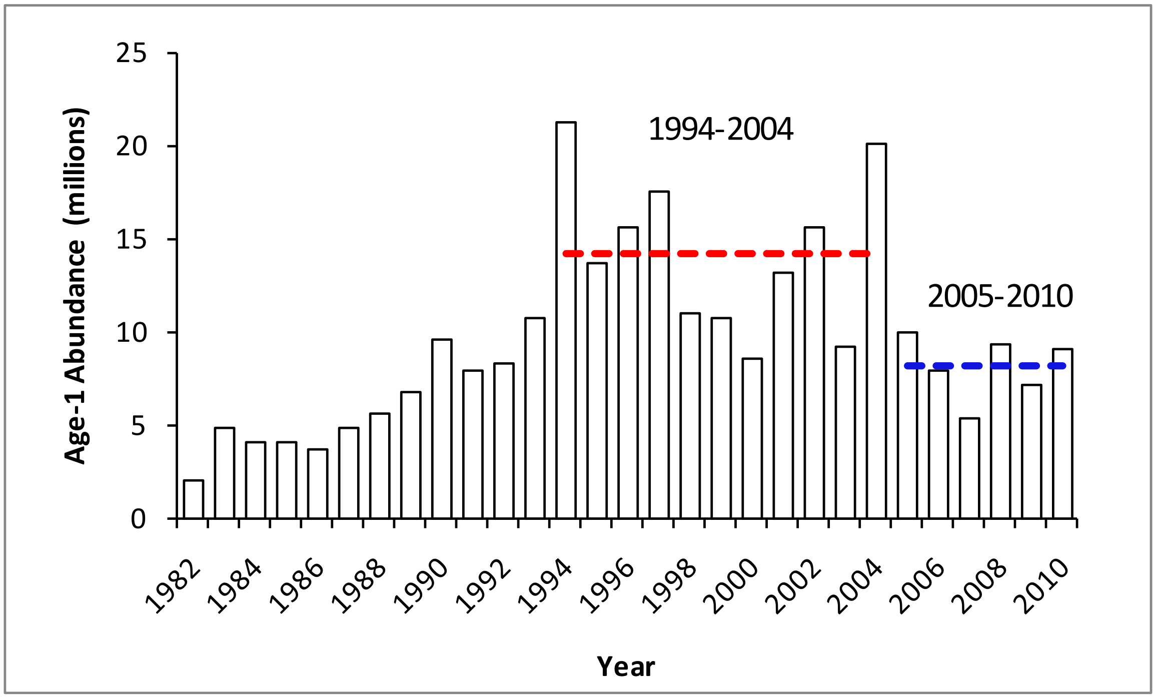

Figure 10. Ratios of year-specific estimates of fishing mortality and female spawning stock biomass to their respective reference points. The 2010 value is shown in red. Whiskers are the 95% confidence intervals.

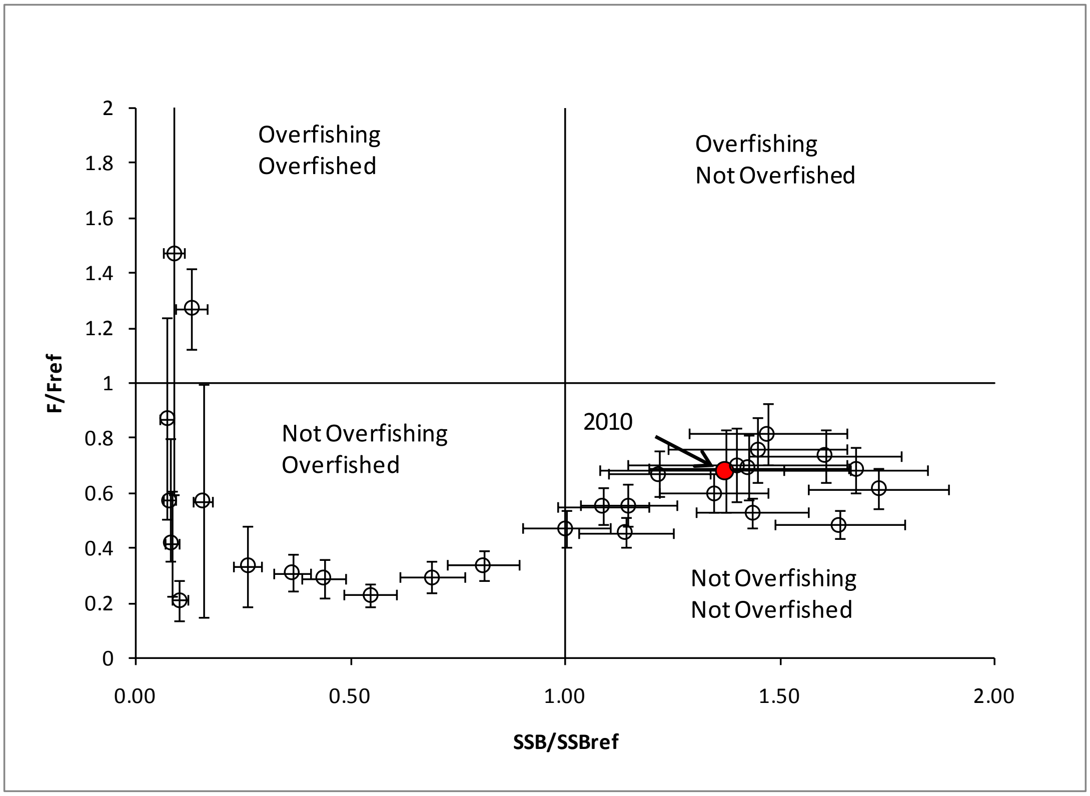

Figure 11. Projections of ages 3-8 abundance, ages 3-8 exploitable biomass, ages 8+ abundance, ages 8+ exploitable biomass, female spawning stock biomass, and landings for various levels of fishing mortality under low and average recruitment scenarios from 2012 to 2017. The SSB threshold is shown as a dotted line.

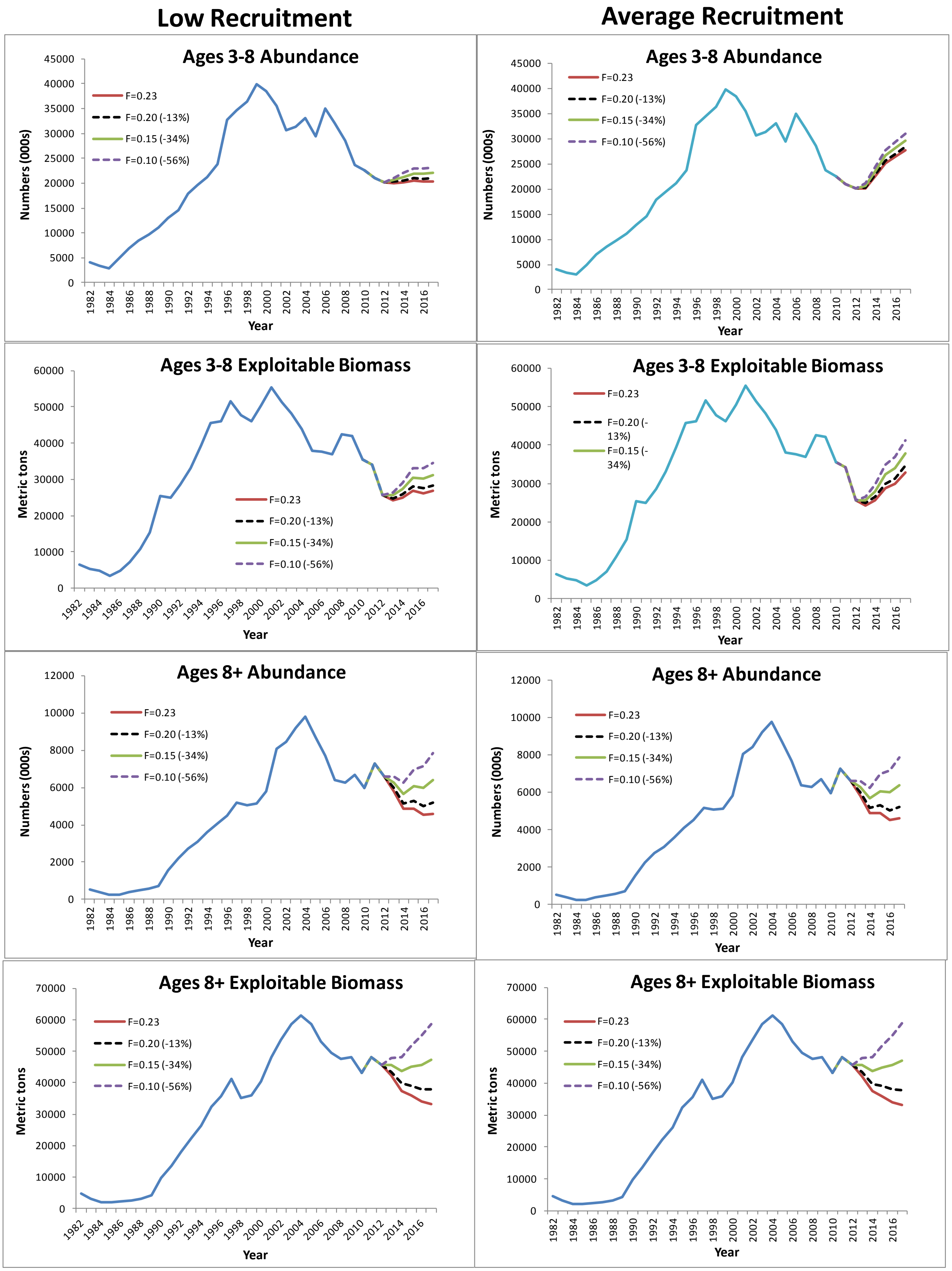

Figure 11 cont.

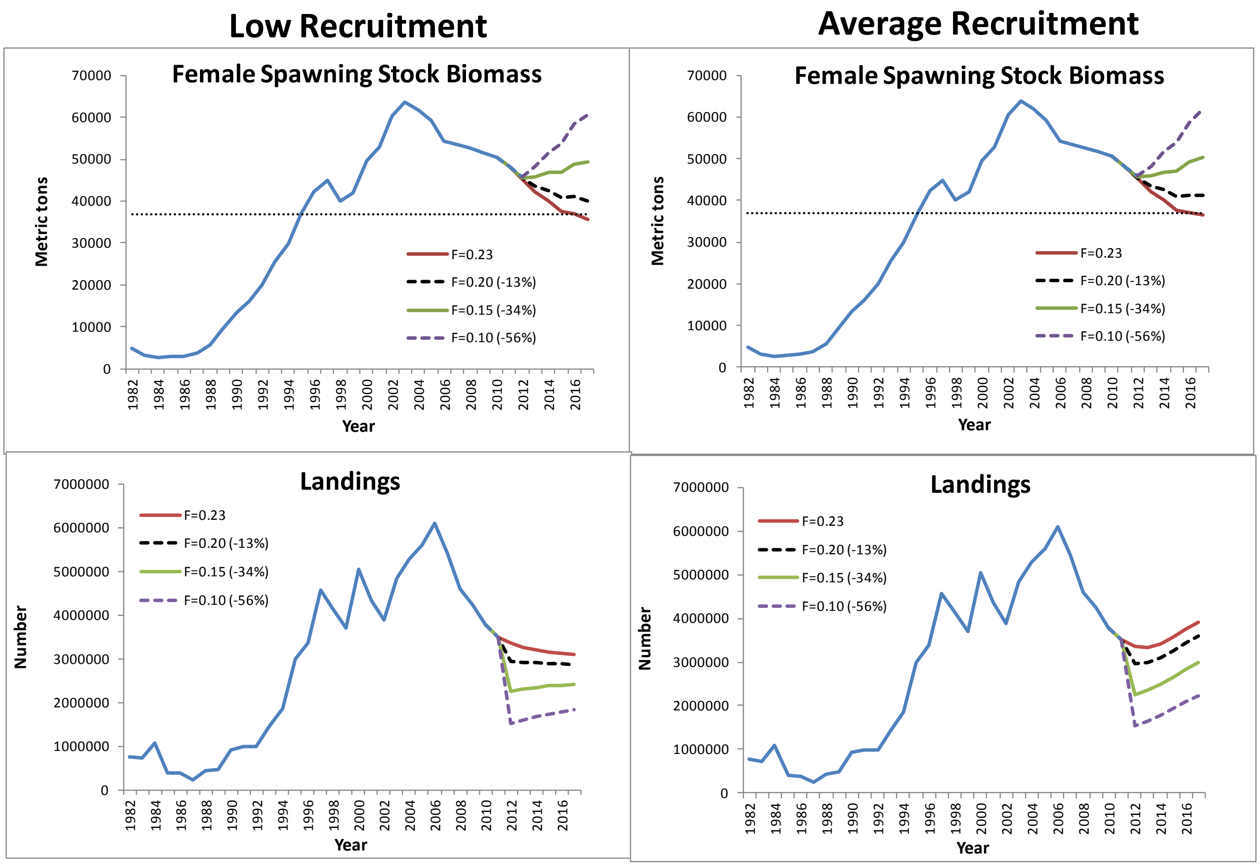

Figure 12. Retrospective pattern of fully-recruited fishing mortality, 8+ abundance and spawning stock biomass for striped bass in SCA model.

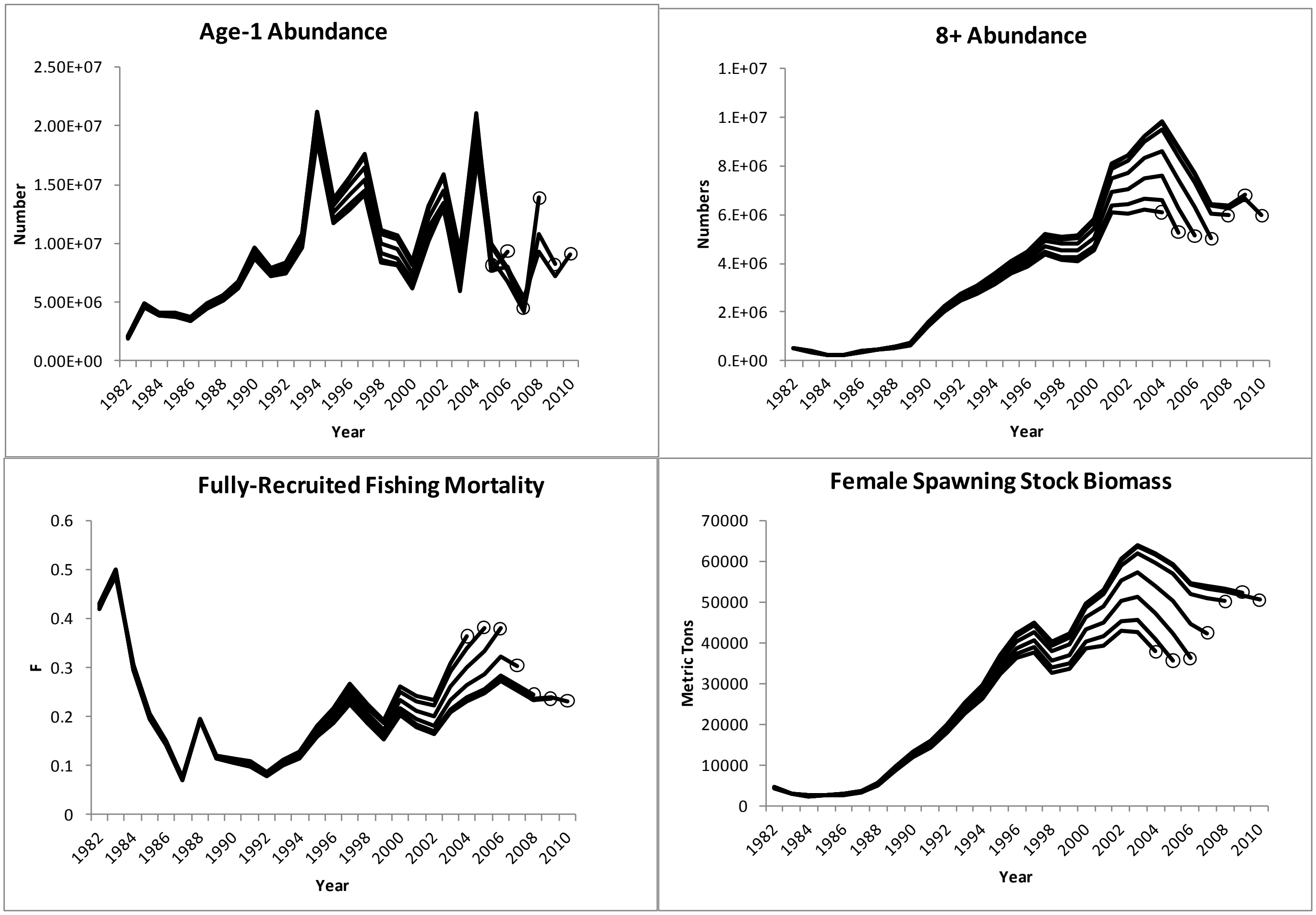

Table 1. Striped bass commercial and recreational landings in metric tons (mt) by year.

Year	Commercial	Recreational	Total	Year	Commercial	Recreational	Total
1947	2,085	-	2,085	1982	992	1,144	2,136
1948	2,726	-	2,726	1983	639	1,224	1,863
1949	2,543	-	2,543	1984	1,104	582	1,686
1950	3,128	-	3,128	1985	431	376	807
1951	2,444	-	2,444	1986	63	52	115
1952	2,148	-	2,148	1987	63	388	451
1953	1,960	-	1,960	1988	117	578	695
1954	1,759	-	1,759	1989	91	336	427
1955	1,906	-	1,906	1990	313	1,010	1,323
1956	1,686	-	1,686	1991	668	1,653	2,321
1957	1,619	-	1,619	1992	650	1,830	2,480
1958	2,266	-	2,266	1993	794	2,563	3,357
1959	3,317	-	3,317	1994	86	3,083	3,169
1960	3,524	-	3,524	1995	1,555	5,709	7,264
1961	4,042	-	4,042	1996	1,541	6,040	7,581
1962	3,567	-	3,567	1997	2,679	7,336	10,015
1963	3,879	-	3,879	1998	2,936	5,850	8,786
1964	3,558	-	3,558	1999	2,963	6,335	9,298
1965	3,278	-	3,278	2000	3,038	8,060	11,098
1966	3,820	-	3,820	2001	2,843	8,880	11,723
1967	3,924	-	3,924	2002	2,740	8,449	11,189
1968	4,169	-	4,169	2003	3,199	10,405	13,604
1969	4,912	-	4,912	2004	3,332	12,596	15,928
1970	3,999	-	3,999	2005	3,240	11,567	14,807
1971	2,890	-	2,890	2006	3,073	13,814	16,887
1972	4,012	-	4,012	2007	3,192	11,156	14,348
1973	5,888	-	5,888	2008	3,281	12,310	15,591
1974	4,536	-	4,536	2009	3,281	11,591	14,872
1975	3,416	-	3,416	2010	3,203	10,400	13,603
1976	2,494	-	2,494				
1977	2,245	-	2,245				
1978	1,764	-	1,764				
1979	1,290	-	1,290				
1980	1,895	-	1,895				
1981	1,744	-	1,744				

Table 2. Atlantic striped bass landings and discards in number of fish (000s), 1982-2010.

	Recreational			Commercial		
Year	Landings (A+B1)	Releases (B2)	Release Mortality	Landings	Dead Discards	Total Removals
1982	217.3	783.2	62.7	428.6	57.7	766.3
1983	307.1	384.2	30.7	357.5	32.3	727.6
1984	118.0	426.4	34.1	870.9	61.9	1,084.9
1985	139.5	374.6	30.0	174.6	56.7	400.8
1986	115.6	992.7	79.4	17.7	172.2	384.9
1987	43.8	708.2	56.7	13.6	125.1	239.2
1988	92.5	1,001.9	80.1	33.3	238.9	444.8
1989	38.1	1,200.8	96.1	7.4	338.4	480.0
1990	163.2	1,653.6	132.3	115.6	510.1	921.2
1991	262.5	3,061.3	244.9	153.8	327.2	988.4
1992	300.5	3,368.1	269.4	230.7	186.3	986.9
1993	428.7	4,345.2	347.6	312.9	347.9	1,437.1
1994	565.7	7,935.0	634.5	307.4	359.0	1,866.6
1995	1,108.6	9,758.9	779.5	534.9	576.7	2,999.7
1996	1,200.0	12,434.6	983.1	766.5	426.6	3,376.2
1997	1,648.1	15,884.8	1,257.5	1,058.2	616.3	4,580.1
1998	1,457.1	15,175.9	1,194.3	1,223.8	243.1	4,118.3
1999	1,446.4	12,772.7	1,001.2	1,103.8	153.0	3,704.4
2000	2,025.1	16,931.5	1,344.7	1,057.7	616.9	5,044.4
2001	2,085.1	13,513.2	1,075.6	941.7	241.6	4,344.0
2002	1,973.2	13,784.5	1,095.4	658.1	166.8	3,893.5
2003	2,545.1	14,847.1	1,168.9	874.8	253.3	4,842.1
2004	2,615.6	17,290.0	1,383.2	913.4	366.3	5,278.5
2005	2,335.4	18,949.4	1,516.0	973.9	776.8	5,602.1
2006	2,750.9	25,904.2	2,072.3	1,054.7	216.8	6,094.7
2007	2,316.2	16,869.0	1,349.5	1,023.0	736.1	5,424.8
2008	2,235.7	11,854.6	948.4	1,011.0	395.4	4,590.5
2009	2,012.5	7,814.2	625.1	1,042.6	558.3	4,238.5
2010	1,991.0	6,419.8	513.6	1,033.6	243.0	3,781.1

Table 3. Striped bass recreational landings (no. fish) including wave 1 estimates by state, 1982-2010.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	Total
1982	929		83,933	1,757	50,081	21,278	58,294		984			217,256
1983	7,212	4,576	39,316	1,990	42,826	43,731	127,912	135	31,746			299,444
1984			3,481	1,230	5,678	57,089	13,625	16,571	16,789			114,463
1985	11,862		66,019	670	15,350	23,107	13,145		2,965	404		133,522
1986			29,434	3,291	1,760	27,477	36,999		14,077	1,585		114,623
1987		90	10,807	2,399	522	14,191	9,279		4,025	2,442		43,755
1988		647	21,050	5,226	2,672	20,230	12,141		133	24,259	5,141	91,499
1989	738		13,044	4,303	5,777	12,388	1,312				512	38,074
1990	2,912	617	20,515	4,677	6,082	24,799	44,878	2,009	736	56,017		163,242
1991	3,265	274	20,799	17,193	4,907	54,502	38,300	2,741	77,873	42,224	391	262,469
1992	6,357	2,213	57,084	14,945	9,154	45,162	41,426	2,400	99,354	21,118	1,317	300,530
1993	612	1,540	58,511	17,826	19,253	78,560	64,935	4,055	104,682	78,481	264	428,719
1994	3,771	3,023	74,538	5,915	16,929	87,225	34,877	4,140	199,378	127,945	7,930	565,671
1995	2,189	3,902	73,806	29,997	38,261	155,821	254,055	15,361	355,237	149,103	30,821	1,108,553
1996	1,893	6,461	68,300	60,074	62,840	225,428	127,952	22,867	337,415	250,731	35,996	1,199,957
1997	35,259	13,546	199,373	62,162	64,639	236,902	67,800	19,706	334,068	518,483	96,189	1,648,127
1998	38,094	5,929	207,952	44,890	64,215	166,868	88,973	18,758	391,824	383,786	45,768	1,457,057
1999	21,102	4,641	126,755	56,320	55,805	195,261	237,010	8,772	263,191	411,873	65,658	1,446,388
2000	62,186	4,262	181,295	95,496	53,191	270,798	402,302	39,543	506,462	389,126	20,452	2,025,113
2001	59,947	15,291	288,032	80,125	54,165	189,714	560,208	41,195	382,557	355,020	58,876	2,085,130
2002	71,907	12,857	308,749	78,190	51,060	202,075	416,455	29,149	282,429	411,248	109,052	1,973,171
2003	57,765	24,878	407,100	115,471	95,983	313,761	391,842	29,522	525,191	455,812	127,727	2,545,052
2004	36,886	10,359	400,252	84,814	75,244	242,623	448,524	25,178	380,461	633,018	278,270	2,615,629
2005	68,638	26,026	368,422	112,918	114,965	298,387	327,016	19,955	490,275	403,792	104,997	2,335,391
2006	72,827	14,748	339,994	73,650	83,390	313,464	489,319	19,076	648,644	539,543	90,753	2,685,408
2007	71,443	7,070	347,102	102,112	109,856	370,722	206,275	10,096	679,024	366,964	45,502	2,316,166
2008	49,172	6,642	343,347	56,056	112,972	448,271	318,115	16,994	442,280	396,950	44,890	2,235,689
2009	52,997	10,761	336,470	75,051	72,901	329,402	269,162	21,761	530,394	306,272	7,375	2,012,546
2010	18,749	5,089	354,157	79,450	87,557	501,728	314,698	14,838	469,161	105,567	39,971	1,990,965

Table 4. Striped bass recreational landings (total weight) by state, 1982-2010. Total weights for VA wave 1 could not be estimated.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	Total
1982	2,663		2,003,948	16,012	110,964	61,438	327,024					2,522,049
1983	13,031	7,061	248,917	16,340	310,798	275,033	1,662,403	29	149,351			2,682,963
1984			33,697	12,879	91,705	896,770	58,616	139,626	44,262			1,277,555
1985	140,951		224,788		41,144	210,815	190,555		8,825	3,585		820,663
1986			298,816	97,961	21,537	33,115	644,394		3,104	5,362		1,104,289
1987		2,987	269,459	69,796	13,307	278,578	159,556		40,818	19,976		854,477
1988		13,549	421,317	108,182	47,536	348,920	136,374		1,058	178,626	2,555	1,258,117
1989	15,221		295,227	59,347	100,688	236,730	25,520					732,733
1990	60,483	11,363	319,092	73,349	193,011	505,440	588,974	18,115	12,967	443,751		2,226,545
1991	58,177	6,731	440,605	496,723	125,309	1,053,589	643,571	25,501	456,954	333,743	3,091	3,643,994
1992	107,693	44,612	972,116	203,109	196,278	921,201	746,343	25,677	613,174	187,852	8,602	4,026,657
1993	11,953	28,115	1,113,446	292,428	400,067	1,575,938	874,296	52,540	794,853	505,742	1,701	5,651,079
1994	66,451	66,017	1,686,049	109,817	355,829	1,974,759	438,080	63,832	1,096,409	870,140	50,503	6,777,886
1995	45,933	67,992	1,504,390	436,058	671,647	3,296,025	3,141,222	175,347	2,057,450	955,822	73,663	12,425,549
1996	44,802	102,271	1,291,706	950,973	915,418	4,809,381	1,736,508	281,481	1,560,389	1,340,414	89,989	13,123,332
1997	185,178	206,904	2,891,970	927,919	920,465	4,449,564	821,784	232,186	1,962,947	2,813,471	301,683	15,714,071
1998	178,584	114,342	2,973,456	671,841	989,923	2,318,291	1,333,329	236,926	1,908,344	1,581,560	150,626	12,457,222
1999	98,623	84,255	1,822,818	886,666	824,031	3,171,344	3,342,372	100,541	1,137,940	1,741,857	268,026	13,478,473
2000	269,325	71,370	2,618,216	1,160,304	515,962	4,050,569	4,286,040	346,905	2,100,854	2,005,721	72,946	17,498,212
2001	290,233	223,072	3,644,561	1,138,974	628,044	2,996,805	5,341,867	382,498	2,072,943	2,140,713	284,449	19,144,159
2002	383,270	152,342	4,304,883	1,192,295	600,482	2,813,596	4,133,678	299,561	1,423,515	2,648,115	267,406	18,219,143
2003	253,910	281,549	5,120,554	1,502,455	1,537,899	4,687,685	4,545,515	303,909	2,975,437	2,789,745	772,981	24,771,639
2004	168,099	121,566	5,539,086	1,169,589	927,116	2,324,334	4,714,602	288,650	1,678,532	3,101,870	6,298,384	26,331,828
2005	301,334	291,662	5,093,748	1,590,072	1,510,237	2,948,282	3,793,471	254,466	3,559,424	2,655,119	2,188,142	24,185,957
2006	393,431	212,012	4,907,270	916,104	1,393,495	4,768,272	6,623,538	190,943	3,606,719	4,133,292	2,154,565	29,299,641
2007	316,331	73,283	4,784,948	1,407,549	1,718,716	5,767,505	2,441,469	112,071	3,178,237	1,891,833	1,026,767	22,718,709
2008	238,452	92,179	5,516,183	732,564	1,799,097	7,009,424	4,743,038	209,995	2,637,998	1,767,646	938,718	25,685,294
2009	288,741	146,004	4,525,166	1,093,321	877,614	4,380,891	3,807,088	313,296	4,558,773	1,259,314	209,856	21,460,064
2010	109,531	53,962	4,062,205	1,037,147	1,050,820	6,480,208	4,693,882	193,723	2,552,257	389,775	714,145	21,337,655

Table 5. Striped bass recreational discard losses (discards x 0.08), by state 1982-2010.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	Total
1982	55	-	515	204	51,455	984	7,012	-	2,430	-	-	62,655
1983	-	-	2,721	436	-	118	9,425	-	17,079	960	-	30,739
1984	151	-	7,872	6,811	2,494	3,238	4,234	-	8,328	702	282	34,112
1985	6,492	7	989	3,245	2,156	4,603	442	56	11,768	208	-	29,966
1986	350	-	35,384	161	840	9,907	-	-	31,205	602	963	79,412
1987	1,448	35	7,493	5,108	6,275	20,319	4,536	1,359	9,472	609	-	56,654
1988	362	536	16,771	1,868	2,043	7,409	38,904	196	10,580	450	1,030	80,149
1989	1,282	386	15,445	3,041	10,030	29,257	21,277	385	9,142	5,821	-	96,066
1990	1,003	1,241	27,161	5,401	7,159	21,208	20,351	1,153	33,607	14,004	-	132,288
1991	5,399	525	35,899	2,478	24,118	60,533	13,296	3,067	82,881	16,668	20	244,884
1992	2,494	2,209	62,385	9,633	23,381	63,932	33,080	2,955	59,997	9,272	54	269,392
1993	29,845	1,198	66,685	8,079	21,705	55,529	24,660	7,163	124,548	8,030	122	347,564
1994	29,096	3,480	168,201	11,119	39,197	90,617	45,444	8,319	222,831	15,762	400	634,466
1995	40,461	22,839	262,471	28,506	40,570	96,767	55,591	9,229	192,102	29,676	1,298	779,510
1996	130,136	23,426	261,580	25,147	84,129	114,887	62,093	7,950	203,619	60,793	9,333	983,093
1997	113,438	22,344	433,420	48,540	57,817	81,511	58,939	10,406	321,599	98,586	10,868	1,257,468
1998	55,310	19,464	574,749	49,074	82,095	70,770	39,066	14,801	211,334	63,710	13,896	1,194,269
1999	51,985	11,658	366,097	28,810	56,322	98,290	92,215	8,456	191,009	75,260	21,076	1,001,178
2000	75,407	16,768	590,562	43,321	74,109	109,846	70,823	12,147	259,578	81,763	10,378	1,344,702
2001	69,642	13,147	432,872	30,198	88,617	65,942	77,252	13,014	231,204	49,676	3,996	1,075,560
2002	111,376	19,040	457,519	42,432	55,758	47,052	57,208	9,172	234,287	56,538	5,062	1,095,444
2003	67,737	20,813	348,937	35,897	67,443	86,705	74,071	13,521	372,224	77,644	3,916	1,168,908
2004	59,871	15,744	471,333	53,598	86,344	119,416	105,883	12,094	299,082	141,408	18,428	1,383,201
2005	241,943	41,022	387,180	59,282	137,083	107,870	95,795	17,987	300,266	118,763	8,763	1,515,954
2006	325,624	45,434	693,022	108,567	134,659	126,246	168,045	19,624	312,417	135,677	3,019	2,072,334
2007	88,428	23,119	461,768	59,275	146,552	116,484	119,566	20,086	239,847	73,108	1,296	1,349,529
2008	37,619	6,683	291,301	34,850	189,776	102,168	116,180	20,859	112,449	35,364	1,120	948,369
2009	19,772	5,247	199,231	28,679	102,515	73,782	57,534	12,204	97,467	28,411	293	625,136
2010	15,315	3,554	153,765	16,955	62,195	87,786	40,540	6,301	115,644	9,841	1,688	513,583

Table 6. Striped bass commercial landings (number of fish) by state, 1982-2010.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	PRFC	VA	NC	Total
1982			26,183	52,896	207	74,935		12,794	189,089	54,421	14,905	3,200	428,630
1983			9,528	48,173	83	66,334		5,806	147,079	63,171	15,962	1,405	357,541
1984			5,838	8,878	192	70,472		12,832	392,696	372,924	6,507	532	870,871
1985	90		7,601	7,173	350	52,048		1,359		82,550	23,450		174,621
1986			3,797	2,668						10,965	251		17,681
1987			3,284	23						9,884	361		13,552
1988			3,388							19,334	10,588		33,310
1989			7,402										7,402
1990			5,927	784		11,784		698	534	38,884	56,222	803	115,636
1991			9,901	3,596		15,426		3,091	31,880	44,521	44,970	413	153,798
1992			11,532	9,095		20,150		2,703	119,286	23,291	42,912	1,745	230,714
1993			13,099	6,294		11,181		4,273	211,089	24,451	39,059	3,414	312,860
1994			11,066	4,512		15,212		4,886	208,914	25,196	32,382	5,275	307,443
1995			44,965	19,722		43,704		5,565	280,051	29,308	88,274	23,325	534,914
1996			38,354	18,570		39,707		20,660	415,272	46,309	184,495	3,151	766,518
1997			44,841	7,061		37,852		33,223	656,416	87,643	165,583	25,562	1,058,181
1998			43,315	8,835		45,149		31,386	780,893	93,299	204,911	16,040	1,223,828
1999			40,838	11,559		49,795		34,841	650,022	90,575	205,143	21,010	1,103,783
2000			40,256	9,418		54,894		25,188	627,777	91,471	202,227	6,480	1,057,711
2001			40,248	10,917		58,296		34,373	538,808	87,809	148,346	22,936	941,733
2002			48,926	11,653		47,142		30,440	296,635	80,300	127,211	15,784	658,091
2003			61,262	15,497		68,354		31,530	439,482	83,090	161,778	13,823	874,816
2004			66,555	16,040		70,367		28,406	461,064	91,980	147,998	31,014	913,424
2005			65,703	14,949		70,560		26,336	569,964	80,615	119,244	26,572	973,943
2006			75,063	15,429		73,528		30,212	655,951	92,288	109,395	2,798	1,054,664
2007			57,634	13,934		78,287		30,717	598,495	86,695	140,602	16,621	1,022,985
2008			61,075	16,616		73,263		31,866	594,655	81,720	134,603	12,903	1,006,701
2009			63,876	20,725		82,574		20,696	618,076	89,693	138,303	8,675	1,042,619
2010			67,802	17,256		81,896		18,562	584,554	90,258	160,595	12,670	1,033,592

Table 7. Striped bass catch at age (000s of fish).

	Age													
Year	1	2	3	4	5	6	7	8	9	10	11	12	13+	Total
1982	1.8	105.6	256.7	220.8	58.4	19.2	24.2	16.8	11.7	10.6	11.0	13.7	15.7	766.2
1983	3.6	110.3	178.2	193.1	150.0	39.3	18.7	4.1	2.9	3.7	4.6	5.6	13.6	727.7
1984	5.6	542.8	302.7	82.4	60.4	51.7	18.3	4.7	2.1	2.1	0.7	0.3	11.1	1,084.9
1985	1.3	72.5	102.0	40.5	58.7	43.1	43.5	17.3	6.4	3.4	1.0	0.8	10.3	400.8
1986	11.3	21.0	63.8	132.9	49.9	32.0	20.4	24.0	9.2	5.3	3.4	1.6	10.1	384.9
1987	1.4	10.9	37.6	51.4	67.3	25.0	13.2	6.5	6.4	3.0	1.5	2.0	12.9	239.1
1988	2.6	30.9	41.8	63.2	107.1	97.9	40.6	24.4	14.0	5.8	3.7	3.3	9.6	444.9
1989	0.7	36.0	79.7	68.2	104.9	95.4	45.7	21.0	10.4	3.8	3.2	2.0	8.9	479.9
1990	2.1	46.2	124.5	187.8	173.2	165.2	104.1	67.9	20.7	7.3	5.1	3.5	13.7	921.3
1991	1.8	72.8	145.3	208.7	162.0	101.4	91.3	82.9	58.8	24.1	14.2	2.8	22.3	988.4
1992	2.9	45.8	199.7	189.2	177.1	109.5	62.4	67.8	58.4	44.8	9.3	4.1	15.9	986.9
1993	0.3	69.6	185.3	327.3	288.5	185.4	86.6	67.3	82.6	76.2	41.1	9.3	17.5	1,437.0
1994	5.7	145.4	348.8	290.6	367.8	232.4	135.4	86.7	99.9	81.0	36.0	22.3	14.6	1,866.6
1995	4.1	433.5	470.8	456.1	405.3	489.9	214.5	196.0	153.8	90.6	53.4	17.5	14.2	2,999.7
1996	1.0	98.8	649.4	650.1	542.9	468.7	442.2	209.6	136.8	68.9	42.5	46.3	19.0	3,376.2
1997	3.3	291.5	602.0	971.2	685.3	655.7	458.6	415.7	223.5	140.6	70.0	34.0	28.7	4,580.1
1998	26.4	183.4	485.4	706.7	1,125.0	510.9	280.4	265.0	215.5	113.8	95.1	45.2	65.5	4,118.3
1999	8.4	108.3	419.6	648.8	642.2	730.2	351.8	238.9	205.4	148.4	104.5	48.6	49.2	3,704.3
2000	37.9	321.5	417.7	984.5	1,020.0	781.6	744.0	313.7	161.3	142.0	59.8	29.4	30.9	5,044.4
2001	31.5	156.4	432.2	598.4	832.9	700.7	579.7	484.1	206.5	120.1	103.4	49.8	48.2	4,344.0
2002	24.5	201.5	224.5	252.4	450.2	654.9	671.7	501.0	343.5	260.8	110.2	86.7	111.5	3,893.5
2003	28.3	252.5	479.7	599.6	708.2	604.5	709.2	496.1	375.7	285.0	128.2	81.2	93.8	4,842.0
2004	70.3	176.9	797.1	740.9	511.2	542.1	518.4	630.4	441.1	331.4	264.9	123.5	130.4	5,278.6
2005	18.9	456.7	419.4	1,097.7	957.5	520.9	426.2	376.4	468.5	323.9	271.5	125.3	139.2	5,602.0
2006	33.7	225.8	1,165.8	657.4	1,092.7	700.8	359.9	359.4	362.9	461.3	307.5	177.1	190.1	6,094.6
2007	9.2	154.4	418.1	1,153.4	792.0	912.3	477.3	326.0	365.6	302.4	223.3	155.0	135.7	5,424.8
2008	15.9	69.4	172.7	530.9	1,070.0	513.9	669.0	413.6	263.2	249.9	217.8	179.4	224.9	4,590.6
2009	16.4	61.0	192.4	509.2	816.7	826.1	386.3	427.8	249.3	180.3	195.2	147.6	230.3	4,238.5
2010	1.9	72.6	197.8	503.5	554.7	576.2	716.2	283.8	283.8	194.5	110.4	93.0	192.5	3,781.1

Table 8. Young of year and juvenile indices of striped bass abundance from state surveys.

	YOY				Age 1	
Year	NY	NJ	MD	VA	NY	MD
1969			2.81			0.25
1970			12.52			0.13
1971			4.02			1.36
1972			3.26			0.46
1973			2.32			0.46
1974			2.63			0.26
1975			2.81			0.22
1976			1.58			0.13
1977			1.60			0.06
1978			3.75			0.18
1979	2.15		1.78			0.29
1980	6.08		1.02			0.18
1981	8.86		0.59			0.02
1982	14.17	0.10	3.57	2.71		0.02
1983	16.25	0.07	0.61	3.40		0.32
1984	15.00	0.37	1.64	4.47		0.01
1985	1.92	0.03	0.91	2.41	0.61	0.16
1986	2.92	0.32	1.34	4.74	0.30	0.03
1987	15.90	0.53	1.46	15.74	0.21	0.06
1988	33.46	0.35	0.73	7.64	0.81	0.07
1989	21.35	1.07	4.87	11.23	1.78	0.19
1990	19.08	1.05	1.03	7.34	0.37	0.33
1991	3.60	0.47	1.52	3.76	1.26	0.20
1992	11.43	1.18	2.34	7.35	1.34	0.15
1993	12.59	1.78	13.97	18.11	0.75	0.19
1994	17.64	0.96	6.40	10.48	1.43	0.78
1995	16.23	1.98	4.41	5.45	1.29	0.12
1996	8.93	1.70	17.61	23.00	1.54	0.08
1997	22.30	1.01	3.91	9.35	1.00	0.26
1998	13.39	1.31	5.50	13.25	2.10	0.17
1999	26.64	1.90	5.34	2.80	2.05	0.37
2000	3.16	1.78	7.42	16.18	1.56	0.26
2001	22.98	1.20	12.57	14.17	2.16	0.32
2002	12.32	0.53	2.20	3.98	2.53	0.79
2003	17.36	2.47	10.83	22.89	1.19	0.07
2004	8.81	1.13	4.85	12.70	2.41	0.74
2005	8.61	1.22	6.91	9.09	0.64	0.28
2006	3.82	0.67	1.78	10.10	2.02	0.28
2007	35.02	1.41	5.12	11.96	0.58	0.07
2008	13.86	1.26	1.26	7.97	1.24	0.31
2009	9.73	1.92	3.92	8.42	0.33	0.12
2010	12.90	1.30	2.54	9.07		0.17

Table 9. Age specific and multi-age indices of abundance used in SCA model.

	Multi-age				Age-specific			
Year	MRFSS	CTCPUE	NEFSC	CTTRL	NYOHS	NJTRL	MD SSN	DE SSN
1982		0.91						
1983		0.75						
1984		0.92		0.02				
1985		0.89		0.01			4.88	
1986		1.51		0.01			10.07	
1987		1.15		0.05	3.83		7.15	
1988	0.37	1.36		0.04	3.60		3.27	
1989	0.24	1.83		0.06	2.58	0.23	3.96	
1990	0.22	2.19		0.16	3.50	1.13	5.04	
1991	0.40	2.15	0.23	0.15	3.28	1.41	4.61	
1992	0.73	2.38	0.24	0.22	3.00	0.65	6.29	
1993	0.58	2.84	0.48	0.27	3.32	0.67	6.25	
1994	0.84	3.94	1.39	0.30	2.90	1.47	5.13	
1995	1.11	5.40	0.95	0.60	2.84	4.21	4.62	
1996	1.33	7.58	0.60	0.63	5.11	5.66	7.59	3.38
1997	1.36	5.98	1.18	0.85	4.84	5.82	3.87	4.10
1998	1.67	7.59	0.73	0.97	5.01	5.01	4.79	3.73
1999	1.67	5.55	0.45	1.10	3.46	3.51	3.97	2.59
2000	1.49	6.93	1.27	0.84	4.36	5.31	3.52	2.05
2001	1.20	8.12	0.62	0.61	3.47	1.58	2.83	1.88
2002	1.02	6.43	0.98	1.30	3.23	2.13	4.00	1.60
2003	0.89	6.41	0.77	0.87	4.24	6.83	4.55	2.47
2004	0.93	8.31	0.33	0.56	4.88	6.05	6.11	2.89
2005	1.15	13.48	0.29	1.17	3.91	6.41	4.96	1.77
2006	1.33	14.05	0.63	0.61	4.37	2.61	4.92	2.22
2007	0.71	13.95	0.74	1.02		3.50	2.14	1.78
2008	0.61	15.73	0.65	0.57		1.38	4.37	1.72
2009	0.67	11.34		0.60		2.24	5.70	1.25
2010	0.66	6.89		0.40		0.73	4.53	2.69

Table 10. Striped bass average F (ages 3-8, and ages 8-11) and N weighted F estimates (ages 7-11) from the SCA model, and tag-based F averaged among models (CE and IRCR) for striped bass 18” or greater and fish 28” or greater.

	Average F		N weighted F		MA DMF	NY TRAWL	NJ/DE	NCCOOP	Hudson River		Delware Bay		Chesapeake Bay	
Year	3-8	8-11	3-8	7-11	Tag F ≥28	Tag F ≥28	Tag F ≥28	Tag F ≥28	Tag F ≥18	Tag F ≥28	Tag F ≥18	Tag F ≥28	Tag F ≥18	Tag F ≥28
1982	0.43	0.43	0.42	0.43										
1983	0.49	0.50	0.49	0.50										
1984	0.29	0.30	0.29	0.30										
1985	0.12	0.19	0.06	0.17										
1986	0.08	0.13	0.05	0.12										
1987	0.04	0.07	0.03	0.06									0.01	
1988	0.11	0.18	0.09	0.17		0.03		0.03	0.05	0.10			0.01	0.05
1989	0.07	0.11	0.05	0.10		0.03	0.02	0.03	0.05	0.08			0.01	0.03
1990	0.09	0.11	0.07	0.10		0.06	0.04	0.08	0.09	0.14			0.08	0.12
1991	0.08	0.10	0.07	0.10		0.09	0.11	0.10	0.09	0.14			0.12	0.13
1992	0.06	0.08	0.05	0.08	0.04	0.08	0.03	0.13	0.10	0.15			0.17	0.14
1993	0.08	0.10	0.07	0.10	0.05	0.10	0.07	0.11	0.11	0.17	0.16	0.17	0.15	0.14
1994	0.09	0.11	0.08	0.11	0.05	0.07	0.05	0.10	0.10	0.15	0.15	0.16	0.15	0.13
1995	0.13	0.16	0.11	0.16	0.06	0.15	0.12	0.15	0.17	0.21	0.17	0.23	0.23	0.25
1996	0.13	0.18	0.09	0.18	0.11	0.11	0.17	0.13	0.18	0.26	0.17	0.32	0.21	0.23
1997	0.16	0.22	0.12	0.22	0.17	0.21	0.21	0.17	0.22	0.29	0.17	0.33	0.26	0.27
1998	0.13	0.18	0.10	0.18	0.11	0.13	0.27	0.16	0.19	0.25	0.18	0.32	0.28	0.26
1999	0.11	0.15	0.09	0.15	0.12	0.20	0.10	0.20	0.18	0.25	0.15	0.25	0.23	0.25
2000	0.14	0.20	0.13	0.19	0.14	0.13	0.14	0.11	0.12	0.17	0.18	0.33	0.22	0.18
2001	0.12	0.18	0.11	0.17	0.08	0.09	0.14	0.13	0.11	0.16	0.18	0.32	0.17	0.14
2002	0.11	0.16	0.11	0.16	0.10	0.15	0.12	0.13	0.11	0.20	0.17	0.28	0.15	0.13
2003	0.14	0.20	0.13	0.20	0.12	0.12	0.16	0.14	0.13	0.19	0.18	0.22	0.19	0.14
2004	0.16	0.23	0.13	0.22	0.11	0.11	0.17	0.14	0.15	0.23	0.18	0.26	0.15	0.12
2005	0.17	0.25	0.15	0.24	0.09	0.17	0.17	0.10	0.13	0.21	0.15	0.21	0.14	0.14
2006	0.19	0.27	0.15	0.27	0.11	0.11	0.16	0.13	0.13	0.20	0.16	0.25	0.18	0.16
2007	0.18	0.25	0.15	0.24	0.07	0.05	0.15	0.16	0.13	0.20	0.13	0.24	0.12	0.13
2008	0.16	0.23	0.15	0.22	0.10	0.08	0.16	0.18	0.13	0.20	0.14	0.19	0.15	0.14
2009	0.17	0.23	0.16	0.23	0.13	0.05	0.22	0.10	0.16	0.22	0.16	0.28	0.21	0.18
2010	0.16	0.23	0.14	0.22	0.09	0.10	0.15	0.12	0.14	0.23	0.15	0.28	0.16	0.13

Table 11. Striped bass population abundance (January 1) estimates (000s of fish) by age from SCA model.

	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13+	Total	8+
1982	2,087	1,680	1,681	1,450	472	213	165	117	90	89	77	107	58	8,286	538
1983	4,853	1,794	1,156	970	813	264	119	92	65	50	50	43	92	10,362	393
1984	4,117	4,170	1,191	626	508	425	138	62	48	34	26	26	71	11,442	267
1985	4,097	3,540	3,077	779	402	325	272	88	40	31	22	17	62	12,751	259
1986	3,686	3,520	3,010	2,552	624	310	244	199	64	29	22	15	56	14,329	384
1987	4,851	3,168	3,003	2,521	2,083	496	241	187	151	48	21	16	53	16,840	477
1988	5,630	4,172	2,714	2,549	2,113	1,723	406	196	151	122	38	17	56	19,888	580
1989	6,791	4,837	3,547	2,251	2,041	1,633	1,293	298	142	108	87	27	52	23,107	714
1990	9,588	5,839	4,133	2,987	1,857	1,649	1,296	1,014	232	110	83	67	61	28,915	1,566
1991	7,946	8,249	4,968	3,408	2,390	1,459	1,285	1,006	786	179	85	65	98	31,924	2,219
1992	8,326	6,836	7,024	4,109	2,740	1,890	1,145	1,004	785	613	140	66	127	34,805	2,736
1993	10,782	7,164	5,834	5,857	3,350	2,205	1,511	913	800	625	488	111	154	39,794	3,091
1994	21,225	9,276	6,099	4,821	4,703	2,644	1,726	1,179	711	623	487	380	206	54,079	3,585
1995	13,731	18,260	7,885	5,010	3,832	3,665	2,042	1,328	905	545	478	373	449	58,503	4,078
1996	15,664	11,810	15,444	6,360	3,859	2,873	2,712	1,503	975	664	400	350	603	63,216	4,494
1997	17,536	13,456	10,000	12,624	4,978	2,913	2,115	1,968	1,081	698	474	285	679	68,807	5,184
1998	11,054	15,059	11,355	8,087	9,688	3,656	2,076	1,481	1,363	745	479	325	661	66,028	5,054
1999	10,702	9,496	12,752	9,285	6,333	7,318	2,695	1,508	1,066	977	532	342	703	63,711	5,129
2000	8,502	9,197	8,064	10,519	7,390	4,892	5,539	2,015	1,119	789	721	392	770	59,909	5,806
2001	13,174	7,303	7,777	6,563	8,169	5,518	3,556	3,962	1,428	789	555	506	816	60,116	8,056
2002	15,662	11,318	6,188	6,372	5,160	6,203	4,092	2,600	2,873	1,031	569	399	950	63,417	8,422
2003	9,199	13,458	9,602	5,090	5,046	3,958	4,656	3,031	1,912	2,104	753	415	984	60,208	9,199
2004	20,093	7,901	11,375	7,806	3,944	3,755	2,866	3,316	2,139	1,342	1,472	526	977	67,511	9,772
2005	9,937	17,254	6,664	9,186	5,974	2,886	2,665	1,997	2,286	1,466	917	1,005	1,024	63,262	8,695
2006	7,879	8,531	14,531	5,356	6,969	4,319	2,019	1,828	1,354	1,541	985	615	1,359	57,287	7,681
2007	5,368	6,763	7,169	11,594	4,010	4,947	2,957	1,352	1,209	889	1,008	643	1,287	49,196	6,389
2008	9,342	4,608	5,692	5,749	8,763	2,884	3,439	2,014	910	809	593	671	1,283	46,756	6,280
2009	7,151	8,021	3,886	4,593	4,395	6,401	2,042	2,390	1,385	622	551	403	1,328	43,169	6,681
2010	9,099	6,140	6,762	3,133	3,506	3,204	4,523	1,416	1,640	944	423	374	1,174	42,339	5,971

Table 12. Striped bass population biomass (January 1) estimates (MT) by age from SCA model.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
1982	132	887	1,634	1,800	979	798	756	664	487	739	846	1,181	813	11,716
1983	560	480	897	1,185	1,554	744	448	469	385	356	455	455	1,025	9,013
1984	620	1,444	1,148	773	972	1,203	562	287	289	233	216	287	873	8,908
1985	80	1,354	2,466	1,305	756	1,007	1,108	463	246	218	182	159	860	10,205
1986	220	651	2,649	4,089	1,255	811	918	992	347	183	166	140	711	13,133
1987	455	1,040	2,692	4,127	5,103	1,322	810	809	798	285	147	143	698	18,428
1988	1,067	1,780	2,498	4,259	5,421	5,463	1,449	807	752	677	287	154	738	25,353
1989	461	2,453	3,738	3,526	5,025	6,138	6,008	1,557	756	730	614	250	689	31,944
1990	226	2,203	4,020	4,725	4,251	5,645	6,114	5,735	1,381	659	670	600	763	36,992
1991	921	2,238	5,323	5,361	5,539	3,983	5,514	5,295	4,875	1,070	638	507	1,401	42,663
1992	302	2,602	7,711	6,483	6,767	5,859	4,511	5,300	4,921	4,447	1,093	718	1,776	52,489
1993	195	1,975	5,547	9,457	7,746	6,993	6,341	4,994	5,103	4,668	4,299	1,142	2,239	60,698
1994	2,983	2,515	6,912	8,203	11,199	8,234	7,260	6,430	4,583	4,530	4,296	3,831	2,627	73,603
1995	1,985	7,484	9,388	9,617	9,481	11,822	8,861	7,324	6,076	4,234	3,606	3,631	7,487	90,995
1996	1,042	6,404	15,667	11,256	10,241	10,164	13,099	9,293	6,760	5,428	3,632	3,061	8,260	104,307
1997	937	3,965	11,131	24,007	12,711	9,988	9,550	11,199	7,476	5,905	4,532	2,784	10,037	114,223
1998	2,838	4,764	9,794	11,181	22,792	10,526	8,580	7,482	8,017	5,122	4,043	3,219	7,841	106,198
1999	7,045	5,626	11,789	12,205	11,141	17,391	8,485	7,325	6,498	7,150	4,161	2,978	8,424	110,217
2000	3,104	5,371	8,023	13,345	12,415	11,293	17,307	8,332	6,695	5,483	6,292	3,784	10,434	111,877
2001	1,514	2,738	6,104	9,106	14,624	13,926	12,058	17,508	8,124	5,875	4,427	4,540	8,865	109,411
2002	840	2,521	3,927	8,287	10,078	16,418	15,101	12,355	15,809	7,148	4,784	3,663	10,946	111,877
2003	506	3,611	5,346	6,201	9,197	10,453	16,785	14,150	11,054	13,863	6,038	3,835	10,821	111,860
2004	2,861	1,435	8,075	9,236	7,274	9,822	10,430	15,266	12,015	8,843	11,300	4,611	10,459	111,628
2005	444	6,410	3,828	10,649	10,485	8,048	9,401	9,615	12,944	9,350	6,920	8,571	11,985	108,650
2006	1,051	1,908	10,067	6,107	12,467	10,720	7,314	8,093	7,979	10,151	7,254	5,216	15,084	103,410
2007	340	2,029	4,992	12,226	6,594	12,277	9,845	6,146	6,906	6,201	8,165	5,842	16,865	98,429
2008	2,240	1,047	3,760	6,889	15,463	7,769	13,154	9,450	5,170	6,002	4,988	6,352	16,232	98,515
2009	978	3,426	2,523	5,352	7,523	17,612	8,030	12,185	8,352	4,248	4,643	3,734	15,858	94,463
2010	1,591	2,374	5,379	3,696	5,867	7,873	17,082	6,564	9,573	6,624	3,378	3,308	14,462	87,771

Table 13. Striped bass female spawning stock biomass estimates (mt) by age from SCA model.

	Age													
Year	1	2	3	4	5	6	7	8	9	10	11	12	13+	Total
1982	0	0	0	34	66	213	448	461	391	619	732	1,044	741	4,749
1983	0	0	0	22	104	197	264	323	307	296	391	399	928	3,232
1984	0	0	0	15	67	325	337	202	235	198	190	257	807	2,632
1985	0	0	0	26	53	276	674	330	202	188	161	144	802	2,857
1986	0	0	0	81	88	223	561	710	287	158	148	128	667	3,051
1987	0	0	0	81	358	366	498	582	664	248	132	131	659	3,720
1988	0	0	0	84	378	1,500	882	575	618	582	255	140	689	5,702
1989	0	0	0	69	352	1,695	3,680	1,117	626	632	549	228	648	9,597
1990	0	0	0	93	297	1,556	3,741	4,112	1,144	571	599	548	719	13,380
1991	0	0	0	105	387	1,098	3,377	3,800	4,043	928	571	464	1,320	16,092
1992	0	0	0	128	474	1,619	2,768	3,811	4,089	3,863	980	658	1,677	20,066
1993	0	0	0	186	542	1,928	3,883	3,583	4,231	4,046	3,848	1,044	2,109	25,399
1994	0	0	0	161	782	2,267	4,439	4,606	3,794	3,921	3,839	3,496	2,472	29,778
1995	0	0	0	188	659	3,241	5,394	5,223	5,008	3,648	3,208	3,299	7,012	36,881
1996	0	0	0	221	713	2,786	7,962	6,614	5,558	4,665	3,222	2,773	7,714	42,228
1997	0	0	0	470	882	2,729	5,784	7,941	6,123	5,055	4,006	2,512	9,337	44,839
1998	0	0	0	219	1,586	2,885	5,216	5,326	6,592	4,402	3,587	2,916	7,324	40,054
1999	0	0	0	240	777	4,779	5,173	5,230	5,360	6,165	3,704	2,707	7,893	42,027
2000	0	0	0	261	863	3,091	10,505	5,921	5,496	4,705	5,574	3,422	9,729	49,569
2001	0	0	0	179	1,018	3,819	7,335	12,472	6,686	5,053	3,932	4,117	8,286	52,896
2002	0	0	0	163	703	4,508	9,198	8,813	13,027	6,157	4,255	3,326	10,246	60,395
2003	0	0	0	121	639	2,860	10,184	10,052	9,071	11,890	5,346	3,467	10,085	63,714
2004	0	0	0	181	505	2,682	6,314	10,820	9,836	7,566	9,982	4,158	9,724	61,768
2005	0	0	0	208	727	2,194	5,682	6,803	10,579	7,986	6,102	7,716	11,123	59,121
2006	0	0	0	119	862	2,917	4,410	5,712	6,504	8,647	6,380	4,684	13,963	54,198
2007	0	0	0	239	457	3,345	5,947	4,346	5,640	5,292	7,195	5,255	15,641	53,356
2008	0	0	0	135	1,073	2,121	7,961	6,696	4,231	5,134	4,405	5,727	15,087	52,570
2009	0	0	0	105	522	4,807	4,859	8,631	6,834	3,633	4,099	3,366	14,736	51,591
2010	0	0	0	72	407	2,150	10,343	4,653	7,838	5,668	2,985	2,984	13,448	50,548

Table 14. Likely direction of bias associated with various sources of uncertainty in the striped bass SCA assessment results (+ indicates that the potential error leads to an overestimation of the parameter, - indicates that the potential error leads to an underestimation of the parameter, +/- indicates that the potential error could lead to either an overestimation or underestimation of the parameter, 0 indicates that the potential error should not have an effect on the estimation of the parameter).

Source of Uncertainty

Assessment Result	Higher Recent M	Scales vs. Otolith Bias	Overestimate Catch	Underestimate Catch	Dome Shaped Selectivity	Stock Mixing
Full F	+	+	+	-	-	+/-
Current F	+	+	+	-	-	+/-
Biomass	-	-	-	+	+	+/-
SSB	-	-	-	+	+	+/-
Recruitment	+	<Variation	+/-	+/-	+	+/-
Retrospective	+?	+	+	-	0	+/-
Fmsy	+/-	+/-	+/-	+/-	+	+/-
SSB Threshold	+/-	-	+/-	+/-	+	+/-

* If scales underestimate age compared to otoliths

Statistical Catch-at-Age Model Report for Atlantic Striped Bass

Report of the ASMFC Atlantic Striped Bass Stock Assessment Subcommittee
November 2011

A forward-projecting age-structured statistical catch-at-age (SCA) model for the Atlantic coast migratory stocks of striped bass was constructed in 2007 and is used to estimate fishing mortality, abundance, and spawning stock biomass during 1982-2010 from total removals-at-age and fisheries-dependent and fisheries-independent survey indices.

Model Structure

The structure of the population model is aged-based and projects the population numbers-at-age forward through time given model estimates of recruitment and age-specific total mortality. The population numbers-at-age matrix has dimensions Y x A, where Y is the number of years and A is the oldest age group. The time horizon for striped bass is 1982-2010 since complete catch data are only available back to 1982. However, there are relative abundance data (e.g., Maryland young-of-the-year indices) available for earlier years. To use those earlier data, the dimensions of population numbers-at-age are expanded to Y+A-1 x A matrix (Figure 1.1). The number of year classes in the model was 13, representing ages 1 through 13+.

Population numbers-at-age ($a<A$) are calculated through time by using the exponential cohort survival model

$$\hat{N}_{y,a} = \hat{N}_{y-1,a-1}\, exp^{-\hat{F}_{y-1,a-1}-M} \qquad (1)$$

where $\hat{N}_{y,a}$ is abundance of age a in year y, $\hat{N}_{y-1,a-1}$ is abundance of age $a-1$ in year $y-1$, $F_{y-1,a-1}$ is the instantaneous fishing mortality rate for age $a-1$ in year $y-1$, and M is the instantaneous natural mortality (assumed constant across years and ages). For the plus group (A), numbers-at-age are the sum of survivors of $A-1$ in year $y-1$ and survivors from the plus group in year $y-1$:

$$\hat{N}_{y,A} = \hat{N}_{y-1,A-1}\, exp^{-\hat{F}_{y-1,A-1}-M} + \hat{N}_{y-1,A}\, exp^{-\hat{F}_{y-1,A}-M} \qquad (2)$$

Recruitment (numbers of age-1 bass) in year y ($N_{y,1}$) is estimated and it is modeled as a log-normal deviation from average recruitment:

$$\hat{N}_{y,1} = \hat{\bar{N}}_1 \cdot exp^{\hat{e}_y} \qquad (3)$$

where $N_{y,1}$ is the number of age 1 fish in year y, $\hat{N}_1$ is the average recruitment parameter, and e_y are independent and identically distributed normal random variables with zero mean and constant variance and are constrained to sum to zero over all years. A penalty function is used to help constrain the recruitment deviations and is included in the total likelihood:

$$P_{rdev} = \lambda_R \sum_y e_y^2 \tag{4}$$

where λ_R is a user-specified weight. The initial population abundance-at-age for 2-13+ in 1970 is calculated by using $\hat{N}_{1970,1}$ and assuming $F_{1982,a-1}$:

$$\hat{N}_{1970,a} = \hat{N}_{1970,a-1}\, exp^{-\hat{F}_{1982,a-1} - M} \tag{5}$$

Estimation of fishing mortality-at-age is accomplished by assuming that fishing mortality can be decomposed into yearly and age-specific components (separability):

$$\hat{F}_{y,a} = \hat{F}_y \cdot \hat{s}_a \tag{6}$$

where F_y is the fully-recruited fishing mortality in year y and s_a is the average selectivity value of fish of age a. The dimensions of the F-at-age matrix are Y x A. Similar to recruitment, F_y is modeled as a log-normal deviation from average fishing mortality:

$$\hat{F}_y = \hat{\bar{F}} \cdot exp^{d_y} \tag{7}$$

where F_y is the fishing mortality in year y, $\hat{F}$ is the average recruitment parameter, and d_y are independent and identically distributed normal random variables with zero mean and constant variance and are constrained to sum to zero over all years. For years earlier than 1982, the fishing mortality-at-age is assumed equal to the values for 1982. A penalty function is used to help constrain the fishing mortality deviations and is included in the likelihood function:

$$P_{fdev} = \lambda_F \sum_y d_y^2 \tag{8}$$

where λ is a user-specified weight. Following Brodziak (2002), a fishing mortality penalty is imposed to ensure that extremely small Fs are not produced during the early phases of the estimation process:

$$P_{f_{add}} = \begin{cases} \text{phase} < 3, & \lambda_F \cdot 10 \cdot \sum_y (F_y - 0.15)^2 \\ \text{phase} \geq 3, & \lambda_F \cdot 0.001 \cdot \sum_y (F_y - 0.15)^2 \end{cases} \tag{9}$$

Selectivity for ages $a<A$ is modeled by using the Gompertz equation, and to ensure at least one age had a maximum selectivity of 1, s_a is calculated as

$$s_a = \frac{exp^{(-exp^{-\hat{\beta}(a-\hat{\alpha})})}}{max_a(exp^{(-exp^{-\hat{\beta}(a-\hat{\alpha})})})} \tag{10}$$

where α and β are estimates. Selectivity patterns are estimated for 4 periods: 1982-1984, 1985-1989, 1990-1995, and 1996-2010. s_a for the plus group (*A*) is assumed equal to s_a of age *A-1*.

For ease of computation, total mortality-at-age (Z) is calculated as

$$Z_{y,a} = F_{y,a} + M \tag{11}$$

and fills a matrix of dimension Yx A. For years earlier than 1982, Z is assumed equal to the Z values of 1982.

For total catch and survey indices data, lognormal errors are assumed throughout and the concentrated likelihood, weighted for variation in each observation, was calculated. The generalized concentrated negative log-likelihood ($-L_l$)(Parma 2002; Deriso et al. 2007) is

$$-L_l = 0.5 * \sum_i n_i * \ln\left(\frac{\sum_i RSS_i}{\sum_i n_i}\right) \tag{12}$$

where n_i is the total number of observations and RSS_i is the weighted residual sum-of-squares from dataset *i*. Equations for the weighted residual sum-of-squares are shown following the description (given below) of each dataset.

For the catch and survey age compositions, multinomial error distributions are assumed throughout and the negative log-likelihoods are calculated using the general equation

$$-L = \sum_y -n_y \sum_a P_{y,a} \cdot \ln\left(\hat{P}_{y,a}\right) \tag{13}$$

Specific equations for each dataset are shown following the description of each dataset.

Total catch (recreational and commercial harvest numbers plus number of discards that die due to handling and release) and the proportions of catch-at-age of striped bass fisheries are the primary data from which fishing mortalities, selectivities, and recruitment numbers are estimated. Given estimates of F, M, and population numbers, predicted catch-at-age is computed from Baranov's catch equation (Ricker, 1975):

$$\hat{C}_{y,a} = \frac{\hat{F}_{y,a}}{\hat{F}_{y,a} + M} \cdot (1 - exp^{-\hat{F}_{y,a} - M}) \cdot \hat{N}_{y,a} \tag{14}$$

where $\hat{C}_{y,a}$ is the predicted removals of age *a* during year *y* and other variables are as defined above. All predictions are stored in a matrix of dimension *Y* x *A*. Predicted catch-at-age data are then compared to the observed total catch and proportions of catch-at-age through the equations:

Predicted Total Catch

$$\hat{C}_y = \sum_a \hat{C}_{y,a} \tag{15}$$

Predicted Proportions of Catch-At-Age

$$\hat{P}_{y,a} = \frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \tag{16}$$

where $\hat{C}_y$ is the predicted total catch in year y and $P_{y,a}$ is the predicted proportions of age a in the catch during year y.

The weighted lognormal residual sum-of-squares (RSS_c) for total catch is calculated as

$$RSS_c = \lambda_c \sum_y \left(\frac{\ln\left(C_y + 1e^{-5}\right) - \ln\left(\hat{C}_y + 1e^{-5}\right)}{CV_y} \right)^2 \tag{17}$$

where C_y is the observed catch in year y, $\hat{C}_y$ is the predicted catch in year y, CV_y is the coefficient of variation for observed catch in year y, and λ_c is the relative weight (Parma 2002; Deriso et al. 2007). Total catch CVs are assumed equal to the PSEs of MRFSS total catch estimates for the entire Atlantic coast (less South Carolina, Georgia and East Florida records) since it is assumed that only the estimates of recreational kill and dead discards have error.

In addition, the predicted proportions of catch-at-age are compared to the observed proportions of catch-at-age through a multinomial probability model. The proportions of catch-at-age negative log-likelihood (L_p) is

$$-L_p = \lambda_p \sum_y - n_y \sum_a P_{y,a} \cdot \ln\left(\hat{P}_{y,a} + 1e^{-7}\right) \tag{18}$$

where n_y is the effective number of fish aged in year y, $P_{y,a}$ is the observed proportion of catch-at-age, and λ_p is the relative weight. The multinomial probability assumes that the number of aged fish used to apportion the catch into age classes are sampled randomly and independently of each other. This is truly not the case because gear and fishing practices collect fish in groups or clusters; thus, the effective sample size is much smaller than the actual number of fish aged. Therefore, the effective sample size was estimated by using the manual, iterative method of McAllister and Ianelli (1997). The effective sample size for each year is the average over all years and it is set to 354 fish in this model.

The observed total catch and catch age compositions were generated from all state reported landings-at-age, recreational dead discards-at-age, and commercial dead discards-at-age. Total catch by year was calculated by summing catch across age classes. The catch age composition was calculated by dividing the catch-at-age for a given year by yearly total catch.

Young-of-the-year (YOY) and yearling indices from New York (Hudson River YOY: 1980-2010; West Long Island Sound Age 1: 1986-2010), New Jersey (Delaware Bay YOY: 1981-2010), Maryland (Chesapeake Bay YOY and Age 1: 1970-2010), and Virginia (Chesapeake Bay YOY: 1983-2010) were incorporated into the model by linking them to corresponding age abundances and time of year:

$$\hat{I}_{t,y,\mathrm{a}} = \hat{q}_t \cdot \hat{N}_{y,a} \cdot \exp^{-p_t \cdot Z_{y,a}} \qquad (19)$$

where $\hat{I}_{t,y,a}$ is the predicted index of survey *t* for age *a* in year *y*, q_t is the catchability coefficient of index *t*, $N_{y,a}$ is the abundance of age *a* in year *y*, *p* is the fraction of total mortality that occurs prior to the survey, and $Z_{y,a}$ is the total instantaneous mortality rate. All *q*s are estimated as free parameters. Because age 0 striped bass are not modeled, the YOY and yearling indices were advanced one year and are linked to age 1 and age 2 abundances, respectively, and are tuned to January 1st (p=0;Table 1.1). All YOY and yearling indices are geometric means and corresponding CVs as recommended by the SAW reviewers. More information on these surveys can be found in ASMFC (1996).

The aggregate indices (no or borrowed age data or other reasons) from the Marine Recreational Fisheries Statistics Survey (MRFSS: 1988-2010), Connecticut (Recreational CPUE: 1982-2010 ;bottom trawl survey: 1984-2010), and Northeast Fisheries Science Center (NEFSC spring bottom trawl survey: 1991-2008) are incorporated into the model by linking them to aggregate age abundances and the time of year (Table 1.1):

$$\hat{I}_{t,y,\Sigma a} = \hat{q}_t \cdot \sum_a \hat{N}_{y,a} \cdot \exp^{-p_t \cdot Z_{y,a}} \qquad (20)$$

All aggregate indices are geometric means of the survey estimate except for the Connecticut CPUEs. The annual CVs for the MRFSS index were calculated by dividing model estimates of standard errors by the index. The CVs for the Connecticut Recreational CPUE index were assumed equal to the CVs of the total recreational catch values for Connecticut generated by MRFSS. CVs for the remaining surveys were estimated from survey data.

The age-aggregated indices and age composition data from New York (ocean haul seine: 1987-2006), New Jersey (bottom trawl: 1989-2010), Maryland (gillnet: 1985-2010), and Delaware (electrofishing: 1996-2010) surveys are incorporated into the model by linking them to age abundances and the time of year:

$$\hat{I}_{t,y} = \hat{q}_t \sum_a \hat{s}_{t,a} \cdot \hat{N}_{y,a} \cdot \exp^{-p_t \cdot \hat{Z}_{y,a}} \qquad (21)$$

where $s_{t,a}$ is the selectivity coefficient for age *a* in survey *t*. The fraction of the year and ages to which each survey is linked is listed in Table 1.1. The weighted residual sum of squares for survey *t* is given by:

$$RSS_t = \lambda_t \sum_y \left(\frac{\ln\left(I_{t,y} + 1e^{-5}\right) - \ln\left(\hat{I}_{t,y} + 1e^{-5}\right)}{CV_{t,y}} \right)^2 \qquad (22)$$

The Gompertz equation is used to estimate the selectivity pattern for the Delaware spawning stock survey because theory indicates that vulnerability to electric fields increases with surface area of the fish (Reynolds, 1983). Because MD survey estimates are corrected for mesh-size selectivity, it was determined by trail-and-error that only the selectivity value for age 2 had to be estimated; for ages $\geq$ 3, selectivity was set to 1. For the New York ocean haul survey, the Thompson's exponential-logistic model (Thompson 1994) is used to estimate the selectivity pattern

$$\hat{s}_a = \frac{1}{1-\gamma} \cdot \left(\frac{1-\gamma}{\gamma}\right)^{\gamma} \frac{\exp^{\alpha\gamma(\beta-a)}}{1+\exp^{\alpha(\beta-a)}} \qquad (23)$$

For the New Jersey survey, a gamma function is used to estimate the selectivity pattern:

$$\hat{s}_a = \frac{a^{\alpha} \exp^{\beta \cdot a}}{\max_a (a^{\alpha} \exp^{\beta \cdot a})} \qquad (24)$$

Total aggregate index by year is calculated by summing age-specific indices across age classes. The survey age composition is calculated by dividing the age-specific indices by the total aggregate index for a given year. The predicted age composition (proportions-at-age) of each survey is modeled and compared to the observed proportions-at-age through a multinomial probability model. The predicted survey indices-at-age are calculated as

$$\hat{I}_{t,y,a} = \hat{q}_t \cdot \hat{s}_{t,a} \cdot \hat{N}_{y,a} \cdot \exp^{-p_t \cdot \hat{Z}_{y,a}} \qquad (25)$$

and predicted age composition is calculated as

$$\hat{U}_{t,y,a} = \frac{\hat{I}_{t,y,a}}{\sum_a \hat{I}_{t,y,a}} \qquad (26)$$

The age composition negative log-likelihood for survey *t* is

$$-L_t^U = \lambda_t \sum_y - n_{t,y} \sum_a U_{t,y,a} \cdot \ln\left(\hat{U}_{t,y,a} + 1e^{-7}\right) \qquad (27)$$

where $n_{t,y}$ is the effective sample size of fish aged in year *y* from survey *t*, and $U_{t,y,a}$ and $U_{t,y,a}$ are the observed and predicted proportions of age *a* in year *y* from survey *t*.

The effective sample sizes for the catch and survey age composition data are estimated by using the manual, iterative method of McAllister and Ianelli (1997). Predicted average effective sample size ($\hat{\bar{t}}$) is calculated as:

$$\hat{\bar{t}} = \frac{\sum_y \hat{t}_y}{d_y} \qquad (28)$$

and $\hat{t}_y$ is defined as

$$\hat{t}_y = \frac{\sum_a \hat{c}_{a,y}(1-\hat{c}_{a,y})}{\sum_a (o_{a,y}-c_{a,y})^2}$$

where $\hat{c}_{a,y}$ is the predicted proportion-at-age *a* in year *y* from the catch or survey, $o_{a,y}$ is the observed proportion-at-age, and d_y is the number of years of data for catch or survey series. The effective sample sizes for catch and survey proportions were repeatedly adjusted until the predicted sample sizes stabilized under equal weighting of all components. The effective sample sizes for NJ trawl, NY ocean haul survey, MD gillnet and DE electrofishing were estimated to be 18, 53, 73, and 77, respectively.

The total log-likelihood of the model is

$$f = -L_l - L_p - L^U_{NYOHS} - L^U_{NTrawl} - L^U_{NYOHS} - L^U_{MDSSN} + P_{rdev} + P_{fdev} + P_{fadd} \qquad (29)$$

The total log-likelihood is used by the autodifferentiation routine in AD Model Builder to search for the "best" selectivity parameters, average recruitment, recruitment deviations, average F, fishing mortality deviations, and catchability coefficients that minimize the total log-likelihood. AD Model Builder allows the minimization process to occur in phases. During each phase, a subset of parameters is held fixed and minimization is done over another subset of parameters until eventually all parameters have been included. In this model, the following parameters were solved over ten phases:

Phase
1 average recruitment
2 average fishing mortality and fishing mortality deviations
3 recruitment deviations
4 catch selectivity parameters
5 catchability coefficients of YOY/Yearling and aggregate survey indices
6 catchability coefficients of survey indices with age composition data
7 NY survey selectivity parameters
8 NJ survey selectivity parameters
9 DE survey selectivity parameters
10 MD survey selectivity parameters

The estimation proceeds by first calculating $F_{a,y}$ using initial starting values for F_y and s_a (initial parameters estimates are used for the selectivity equations) and, with M (which is fixed at 0.15) and initial values of average recruitment by year, the abundance matrix is filled (Figure 1.1). Note that recruitment is actually estimated back to 1970 in order to provide more realistic estimates of N in the first year of data (1982). Also, this allowed the incorporation of indices (e.g., Maryland young-of-the-year index) back to 1970 unlike the ADAPT model. All predicted values were calculated using the equations described above. Initial starting values for all parameters are given in Table 1.2 and were selected based on trial-and-error.

Diagnostics

Model fit for all components was checked by using standardized residuals and qqnorm (where applicable) plots, and root mean square errors. Standardized residuals (*r*) for log-normal errors were calculated as:

$$r_y = \frac{\log I_y - \log \hat{I}_y}{\sqrt{\log_e (CV_y^2 + 1)}} \qquad (30)$$

Root mean square error for lognormal errors was calculated as:

$$RMSE = \sqrt{\frac{\sum_y r_y^2}{n}}$$

For age composition (multinomial) data, standardized residuals were calculated as:

$$r_{y,a} = \frac{P_{y,a} - \hat{P}_{y,a}}{\sqrt{\frac{\hat{P}_{y,a}(1 - \hat{P}_{y,a})}{\hat{\bar{n}}_y}}} \qquad (31)$$

where n_y is the average effective sample size.

Current Configuration

The current model configuration is based on the 2007 model structure that was reviewed in SAW 46. The model contains four catch selectivity periods (using the Gompertz function), the total catch lambda weight=10, and all indices and all survey selectivity functions are used. Initial starting values for all parameters are given in Table 1.2; there were 102 parameters estimated in the model.

Results

Resulting contributions to total likelihood are listed in Table 1.3. The converged total likelihood was 31626.8. Estimates of fully-recruited fishing mortality, recruitment, parameters of the Gompertz functions for the four selectivity periods, catchability coefficients for all surveys, and parameters of the survey selectivity functions are given in Table 1.4 and are shown graphically in Figure 1.2. Graphs depicting the observed and predicted values, and residuals for the catch age composition, survey indices, and survey compositions are given in Appendix 1. The model fit the observed total catch (Figure 1.2) and catch age composition well (Appendix 1), and the YOY, age 1, MRFSS, CTTrawl, NEFSC indices reasonably well (Appendix 1). Except for MD SSN, the predicted trends matched the observed trends in survey indices, and predicted the survey age composition reasonably well (Appendix 1).

Fishing Mortality

Fully-recruited fishing mortality in 2010 was 0.23 (Table 1.4). The 2010 average fishing mortality rate (F) for ages 8 through 11 equaled 0.23. Average fishing mortality on ages 3-8, which are generally targeted in producer areas, was 0.16 (Table 1.5; Figure 1.2). Among the individual age groups, the highest values of F in 2008 (0.23) were estimated for ages 9-13+ (Table 1.6). An average F weighted by N was calculated for comparison to tagging results since the tag releases and recaptures are weighted by abundance as part of the experimental design. The 2010 F weighted by N for ages 7-11 (age 7 to compare with tagged fish >28") was 0.22 (Table 1.5; Figure 1.2). An F weighted by N for ages 3-8, comparable to the direct enumeration estimate for Chesapeake Bay, was equal to 0.14 (Table 1.5; Figure 1.2).

Comparison of fishing mortality estimates between the 2009 and 2011 model runs indicated that fishing mortality for 2007-2008 was slightly under-estimated in 2009 (Figure 1.3).

Population Abundance (January 1)

Striped bass abundance (1+) increased steadily from 1982 through 1997 when it first peaked around 68.8 million fish (Table 1.7, Figure 1.2). Total abundance declined through 2000, increased and peaked in 2004 at 67 million fish, and has since declined (Table 1.7; Figure 1.2). The 2003 cohort remained strong at 4.5 million fish in 2010 (age 7) and exceeded the sizes of the strong 2001 year classes at the same age (Table 1.7). Abundance of striped bass age 8+ increased steadily through 2004 to 9.7 million, but declined to 6.3 million fish in 2008 (Table 1.7, Figure 1.2). Abundance of 8+ fish increased slightly in 2009 but declined in 2010 (Table 1.7; Figure 1.2). Progression of the current age-class abundances through 2017, assuming 2010 F and selectivity pattern, shows age 8+ abundance increasing through 2011 but then declining through 2017 (Figure 1.4A). A second progression trend for ages 8-12 (age 13+ abundance is over-estimated by the current model structure) shows similar trends (Figure 1.4A).

Total Biomass and Spawning Stock Biomass

Weights-at-age used to calculate spawning stock biomass were generated from catch weights-at-age and the Rivard algorithm described in the NEFSC's VPA/ADAPT program. Total biomass grew steadily from 1982 through 1997 and remained at about 101 thousand mt through 2005 (Figure 1.5). Since 2006, total biomass has been declining (Figure 1.5). Female SSB grew steadily from 1982 through 2003 when it peaked at about 63 thousand mt (Table 1.8, Figure 1.5). Since 2006, female SSB has declined to about 50 thousand mt in 2010. Progression of the female spawning stock biomass through 2013, assuming 2010 F, selectivity pattern, and weight-at-age, shows spawning stock biomass decreasing after 2011 (Figure 1.4B).

Retrospective Analysis

Retrospective bias was evident in estimates of fully-recruited F, SSB, and age 8+ abundance of SCA (Figure 1.6). The retrospective pattern suggests that little over or under-estimation of F, SSB and 8+ abundance has occurred since 2008. Experiences from other assessments indicate that it is possible for the magnitude and direction of the retrospective pattern to change in subsequent assessments. For example, the retrospective analysis from the 2003 assessment of striped bass showed an underestimation of the terminal year estimation of fully recruited F while the retrospective analysis from the 2005 assessment suggest and over estimation of F (ASMFC 2003; ASMFC 2005).

Stock Status

The estimated female SSB in 2010 remained above the threshold level of 36 thousand mt and indicates that the migratory striped bass population is not overfished (Figure 1.7). The 2010 average fishing mortality rate (F) for ages 8 through 11 equaled 0.23 and is below the current target (0.30) and well below the F threshold (0.34) (Figure 1.7).

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Table 1.1. The fraction of total mortality (p) that occurs prior to the survey and ages to which survey indices are linked.

	p	Linked Ages
Age-specific		
NY YOY	0	1 (January 1st)
NJ YOY	0	1 (January 1st)
MD YOY	0	1 (January 1st)
VA YOY	0	1 (January 1st)
MD Age 1	0	2 (January 1st)
NY (WLI) Age 1	0	2 (January 1st)
Aggregate		
MRFSS	0.5	3-13+
CTCPUE	0.5	2-13+
NEFSC	0.333	2-9
CT Trawl	0.333	4-6
Indices with age compositions		
NY OHS	0.75	2-13+
NJ Trawl	0.25	2-13+
MD SSN	0.25	2-13+
DE SSN	0.25	2-13+

Table 1.2. Starting values for model parameters.

Average recruitment (log)	10.6	
Average fishing mortality(log)	-2.6	
Catch Selectivity Parameters		
	α	3
	β	1
Survey Selectivity		
NJ Trawl, DE SSN, MDSSN		
	α	3
	β	1
MD SSN		
	s_2	0.3
NYOHS		
	γ	0.95
	α	-1
	β	1
Catchability Coefficients (log)		
YOY/Age1 Indices	q	-20.4
Aggregate Indices	q	-19.7
Survey/Age Comp Indices	q	-20.2

Table 1.3. Likelihood components with respective contributions from final model run.

Likelihood Component	Weight	RSS
Total Catch	10	322.11
YOY/Yearl Surveys		
NY YOY	1	1902.46
NJ YOY	1	226.41
MD YOY	1	600.63
VA YOY	1	470.10
NY Age 1	1	151.90
MD Age 1	1	263.66
Aggregate Surveys		
MRFSS	1	55.42
CT Rec CPUE	1	130.52
NEFSC	1	99.01
CT Trawl	1	197.52
Age Survey Indices		
NYOHS	1	798.58
NJ Trawl	1	112.25
MD SSN	1	231.99
DE SSN	1	109.09
Total RSS		5671.66
No. of Obs		403.00
Conc. Likelihood		532.83
Catch Age Comps	1	22230.00
Survey Age Comps		
NYOHS	1	1774.76
NJ Trawl	1	757.46
MD SSN	1	3721.94
DE SSN	1	2584.45
Recr Devs	1	19.41
F Devs	1	5.90
Total Likelihood		31626.80

Table 1.4. Parameter estimates and associated standard deviations of current configuration.

Year	Full F	SD	CV
1982	0.43	0.026	0.06
1983	0.50	0.157	0.31
1984	0.30	0.066	0.22
1985	0.20	0.040	0.20
1986	0.14	0.034	0.24
1987	0.07	0.014	0.19
1988	0.19	0.075	0.39
1989	0.11	0.026	0.23
1990	0.11	0.012	0.11
1991	0.10	0.012	0.12
1992	0.08	0.007	0.09
1993	0.10	0.010	0.10
1994	0.12	0.010	0.08
1995	0.16	0.012	0.07
1996	0.19	0.014	0.07
1997	0.23	0.014	0.06
1998	0.19	0.012	0.06
1999	0.16	0.010	0.06
2000	0.20	0.012	0.06
2001	0.18	0.010	0.05
2002	0.17	0.009	0.05
2003	0.21	0.013	0.06
2004	0.23	0.015	0.06
2005	0.25	0.017	0.07
2006	0.28	0.020	0.07
2007	0.26	0.021	0.08
2008	0.24	0.021	0.09
2009	0.24	0.024	0.10
2010	0.23	0.026	0.11

Catch Selectivity Parameters

	Estimate	SD	CV
1982-1984			
α	1.80	0.044	0.02
β	2.14	0.137	0.06
1985-1989			
α	4.01	0.208	0.05
β	0.51	0.036	0.07
1990-1995			
α	2.89	0.084	0.03
β	0.89	0.056	0.06
1996-2010			
α	3.42	0.077	0.02
β	0.63	0.025	0.04

Survey Selectivity Parameters

	Estimate	SD	CV
NYOHS			
γ	0.93	0.027	0.03
α	-3.81	1.202	0.32
β	2.32	0.132	0.06
NJ Trawl			
α	1.52	0.410	0.27
β	0.33	0.089	0.27
DESSN			
α	2.93	0.139	0.05
β	0.75	0.103	0.14
MDSSN			
s2	0.28	0.023	0.08

Year	Recruits	SD	CV
1970	1.40E+07	4.97E+06	0.35
1971	3.29E+07	9.99E+06	0.30
1972	1.32E+07	4.01E+06	0.30
1973	8.56E+06	2.41E+06	0.28
1974	4.81E+06	1.30E+06	0.27
1975	3.50E+06	8.42E+05	0.24
1976	2.76E+06	5.54E+05	0.20
1977	1.99E+06	3.60E+05	0.18
1978	2.46E+06	3.50E+05	0.14
1979	4.25E+06	4.96E+05	0.12
1980	2.84E+06	3.35E+05	0.12
1981	1.96E+06	2.35E+05	0.12
1982	2.09E+06	1.92E+05	0.09
1983	4.85E+06	3.20E+05	0.07
1984	4.12E+06	2.59E+05	0.06
1985	4.10E+06	2.46E+05	0.06
1986	3.69E+06	2.21E+05	0.06
1987	4.85E+06	2.64E+05	0.05
1988	5.63E+06	2.94E+05	0.05
1989	6.79E+06	3.38E+05	0.05
1990	9.59E+06	4.36E+05	0.05
1991	7.95E+06	3.98E+05	0.05
1992	8.33E+06	4.22E+05	0.05
1993	1.08E+07	5.03E+05	0.05
1994	2.12E+07	7.70E+05	0.04
1995	1.37E+07	6.01E+05	0.04
1996	1.57E+07	6.61E+05	0.04
1997	1.75E+07	7.17E+05	0.04
1998	1.11E+07	5.50E+05	0.05
1999	1.07E+07	5.48E+05	0.05
2000	8.50E+06	4.91E+05	0.06
2001	1.32E+07	6.78E+05	0.05
2002	1.57E+07	8.18E+05	0.05
2003	9.20E+06	6.07E+05	0.07
2004	2.01E+07	1.24E+06	0.06
2005	9.94E+06	7.92E+05	0.08
2006	7.88E+06	7.49E+05	0.10
2007	5.37E+06	5.99E+05	0.11
2008	9.34E+06	1.14E+06	0.12
2009	7.15E+06	1.16E+06	0.16
2010	9.10E+06	1.87E+06	0.21

Catchability Coefficients

	Estimate	SD	CV
NY YOY	1.29E-06	9.32E-08	0.07
NJ YOY	1.12E-07	1.19E-08	0.11
MD YOY	4.35E-07	4.08E-08	0.09
VA YOY	9.49E-07	7.97E-08	0.08
NY Age 1	1.41E-07	2.19E-08	0.15
MD Age 1	3.60E-08	5.26E-09	0.15
MRFSS	3.57E-08	4.39E-09	0.12
CTCPUE	1.72E-07	2.45E-08	0.14
NEFSC	1.79E-08	3.02E-09	0.17
CT Trawl	4.63E-08	4.81E-09	0.10
NYOHS	2.33E-07	1.68E-08	0.07
NJ Trawl	1.16E-07	1.84E-08	0.16
MD SSN	1.93E-07	3.60E-08	0.19
DE SSN	9.81E-08	1.43E-08	0.15

Table 1.5. Average and N weighted F estimates for various ages.

	Average F		N weighted F	
Year	8-11	3-8	7-11	3-8
1982	0.43	0.43	0.43	0.42
1983	0.50	0.49	0.50	0.49
1984	0.30	0.29	0.30	0.29
1985	0.19	0.12	0.17	0.06
1986	0.13	0.08	0.12	0.05
1987	0.07	0.04	0.06	0.03
1988	0.18	0.11	0.17	0.09
1989	0.11	0.07	0.10	0.05
1990	0.11	0.09	0.10	0.07
1991	0.10	0.08	0.10	0.07
1992	0.08	0.06	0.08	0.05
1993	0.10	0.08	0.10	0.07
1994	0.11	0.09	0.11	0.08
1995	0.16	0.13	0.16	0.11
1996	0.18	0.13	0.18	0.09
1997	0.22	0.16	0.22	0.12
1998	0.18	0.13	0.18	0.10
1999	0.15	0.11	0.15	0.09
2000	0.20	0.14	0.19	0.13
2001	0.18	0.12	0.17	0.11
2002	0.16	0.11	0.16	0.11
2003	0.20	0.14	0.20	0.13
2004	0.23	0.16	0.22	0.13
2005	0.25	0.17	0.24	0.15
2006	0.27	0.19	0.27	0.15
2007	0.25	0.18	0.24	0.15
2008	0.23	0.16	0.22	0.15
2009	0.23	0.17	0.23	0.16
2010	0.23	0.16	0.22	0.14

Table 1.6. Estimates of fishing mortality by age.

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12	13+
1982	0.00	0.22	0.40	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
1983	0.00	0.26	0.46	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1984	0.00	0.15	0.27	0.29	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
1985	0.00	0.01	0.04	0.07	0.11	0.14	0.16	0.17	0.18	0.19	0.19	0.20	0.20
1986	0.00	0.01	0.03	0.05	0.08	0.10	0.12	0.13	0.13	0.14	0.14	0.14	0.14
1987	0.00	0.00	0.01	0.03	0.04	0.05	0.06	0.06	0.07	0.07	0.07	0.07	0.07
1988	0.00	0.01	0.04	0.07	0.11	0.14	0.16	0.17	0.18	0.19	0.19	0.19	0.19
1989	0.00	0.01	0.02	0.04	0.06	0.08	0.09	0.10	0.11	0.11	0.11	0.11	0.11
1990	0.00	0.01	0.04	0.07	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11
1991	0.00	0.01	0.04	0.07	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1992	0.00	0.01	0.03	0.05	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08
1993	0.00	0.01	0.04	0.07	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1994	0.00	0.01	0.05	0.08	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12
1995	0.00	0.02	0.06	0.11	0.14	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16
1996	0.00	0.02	0.05	0.09	0.13	0.16	0.17	0.18	0.18	0.19	0.19	0.19	0.19
1997	0.00	0.02	0.06	0.11	0.16	0.19	0.21	0.22	0.22	0.23	0.23	0.23	0.23
1998	0.00	0.02	0.05	0.09	0.13	0.16	0.17	0.18	0.18	0.19	0.19	0.19	0.19
1999	0.00	0.01	0.04	0.08	0.11	0.13	0.14	0.15	0.15	0.15	0.16	0.16	0.16
2000	0.00	0.02	0.06	0.10	0.14	0.17	0.19	0.19	0.20	0.20	0.20	0.20	0.20
2001	0.00	0.02	0.05	0.09	0.13	0.15	0.16	0.17	0.18	0.18	0.18	0.18	0.18
2002	0.00	0.01	0.05	0.08	0.12	0.14	0.15	0.16	0.16	0.16	0.17	0.17	0.17
2003	0.00	0.02	0.06	0.11	0.15	0.17	0.19	0.20	0.20	0.21	0.21	0.21	0.21
2004	0.00	0.02	0.06	0.12	0.16	0.19	0.21	0.22	0.23	0.23	0.23	0.23	0.23
2005	0.00	0.02	0.07	0.13	0.17	0.21	0.23	0.24	0.24	0.25	0.25	0.25	0.25
2006	0.00	0.02	0.08	0.14	0.19	0.23	0.25	0.26	0.27	0.27	0.28	0.28	0.28
2007	0.00	0.02	0.07	0.13	0.18	0.21	0.23	0.25	0.25	0.26	0.26	0.26	0.26
2008	0.00	0.02	0.06	0.12	0.16	0.20	0.21	0.22	0.23	0.23	0.24	0.24	0.24
2009	0.00	0.02	0.07	0.12	0.17	0.20	0.22	0.23	0.23	0.24	0.24	0.24	0.24
2010	0.00	0.02	0.06	0.12	0.16	0.19	0.21	0.22	0.23	0.23	0.23	0.23	0.23

Table 1.7 Estimates of population abundance (thousands) by age.

	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13+	Total	8+
1982	2,087	1,680	1,681	1,450	472	213	165	117	90	89	77	107	58	8,286	538
1983	4,853	1,794	1,156	970	813	264	119	92	65	50	50	43	92	10,362	393
1984	4,117	4,170	1,191	626	508	425	138	62	48	34	26	26	71	11,442	267
1985	4,097	3,540	3,077	779	402	325	272	88	40	31	22	17	62	12,751	259
1986	3,686	3,520	3,010	2,552	624	310	244	199	64	29	22	15	56	14,329	384
1987	4,851	3,168	3,003	2,521	2,083	496	241	187	151	48	21	16	53	16,840	477
1988	5,630	4,172	2,714	2,549	2,113	1,723	406	196	151	122	38	17	56	19,888	580
1989	6,791	4,837	3,547	2,251	2,041	1,633	1,293	298	142	108	87	27	52	23,107	714
1990	9,588	5,839	4,133	2,987	1,857	1,649	1,296	1,014	232	110	83	67	61	28,915	1,566
1991	7,946	8,249	4,968	3,408	2,390	1,459	1,285	1,006	786	179	85	65	98	31,924	2,219
1992	8,326	6,836	7,024	4,109	2,740	1,890	1,145	1,004	785	613	140	66	127	34,805	2,736
1993	10,782	7,164	5,834	5,857	3,350	2,205	1,511	913	800	625	488	111	154	39,794	3,091
1994	21,225	9,276	6,099	4,821	4,703	2,644	1,726	1,179	711	623	487	380	206	54,079	3,585
1995	13,731	18,260	7,885	5,010	3,832	3,665	2,042	1,328	905	545	478	373	449	58,503	4,078
1996	15,664	11,810	15,444	6,360	3,859	2,873	2,712	1,503	975	664	400	350	603	63,216	4,494
1997	17,536	13,456	10,000	12,624	4,978	2,913	2,115	1,968	1,081	698	474	285	679	68,807	5,184
1998	11,054	15,059	11,355	8,087	9,688	3,656	2,076	1,481	1,363	745	479	325	661	66,028	5,054
1999	10,702	9,496	12,752	9,285	6,333	7,318	2,695	1,508	1,066	977	532	342	703	63,711	5,129
2000	8,502	9,197	8,064	10,519	7,390	4,892	5,539	2,015	1,119	789	721	392	770	59,909	5,806
2001	13,174	7,303	7,777	6,563	8,169	5,518	3,556	3,962	1,428	789	555	506	816	60,116	8,056
2002	15,662	11,318	6,188	6,372	5,160	6,203	4,092	2,600	2,873	1,031	569	399	950	63,417	8,422
2003	9,199	13,458	9,602	5,090	5,046	3,958	4,656	3,031	1,912	2,104	753	415	984	60,208	9,199
2004	20,093	7,901	11,375	7,806	3,944	3,755	2,866	3,316	2,139	1,342	1,472	526	977	67,511	9,772
2005	9,937	17,254	6,664	9,186	5,974	2,886	2,665	1,997	2,286	1,466	917	1,005	1,024	63,262	8,695
2006	7,879	8,531	14,531	5,356	6,969	4,319	2,019	1,828	1,354	1,541	985	615	1,359	57,287	7,681
2007	5,368	6,763	7,169	11,594	4,010	4,947	2,957	1,352	1,209	889	1,008	643	1,287	49,196	6,389
2008	9,342	4,608	5,692	5,749	8,763	2,884	3,439	2,014	910	809	593	671	1,283	46,756	6,280
2009	7,151	8,021	3,886	4,593	4,395	6,401	2,042	2,390	1,385	622	551	403	1,328	43,169	6,681
2010	9,099	6,140	6,762	3,133	3,506	3,204	4,523	1,416	1,640	944	423	374	1,174	42,339	5,971

Table 1.8 Estimates of female spawning stock biomass (metric tons) at age.

	Age													
Year	1	2	3	4	5	6	7	8	9	10	11	12	13+	Total
1982	0	0	0	34	66	213	448	461	391	619	732	1,044	741	4,749
1983	0	0	0	22	104	197	264	323	307	296	391	399	928	3,232
1984	0	0	0	15	67	325	337	202	235	198	190	257	807	2,632
1985	0	0	0	26	53	276	674	330	202	188	161	144	802	2,857
1986	0	0	0	81	88	223	561	710	287	158	148	128	667	3,051
1987	0	0	0	81	358	366	498	582	664	248	132	131	659	3,720
1988	0	0	0	84	378	1,500	882	575	618	582	255	140	689	5,702
1989	0	0	0	69	352	1,695	3,680	1,117	626	632	549	228	648	9,597
1990	0	0	0	93	297	1,556	3,741	4,112	1,144	571	599	548	719	13,380
1991	0	0	0	105	387	1,098	3,377	3,800	4,043	928	571	464	1,320	16,092
1992	0	0	0	128	474	1,619	2,768	3,811	4,089	3,863	980	658	1,677	20,066
1993	0	0	0	186	542	1,928	3,883	3,583	4,231	4,046	3,848	1,044	2,109	25,399
1994	0	0	0	161	782	2,267	4,439	4,606	3,794	3,921	3,839	3,496	2,472	29,778
1995	0	0	0	188	659	3,241	5,394	5,223	5,008	3,648	3,208	3,299	7,012	36,881
1996	0	0	0	221	713	2,786	7,962	6,614	5,558	4,665	3,222	2,773	7,714	42,228
1997	0	0	0	470	882	2,729	5,784	7,941	6,123	5,055	4,006	2,512	9,337	44,839
1998	0	0	0	219	1,586	2,885	5,216	5,326	6,592	4,402	3,587	2,916	7,324	40,054
1999	0	0	0	240	777	4,779	5,173	5,230	5,360	6,165	3,704	2,707	7,893	42,027
2000	0	0	0	261	863	3,091	10,505	5,921	5,496	4,705	5,574	3,422	9,729	49,569
2001	0	0	0	179	1,018	3,819	7,335	12,472	6,686	5,053	3,932	4,117	8,286	52,896
2002	0	0	0	163	703	4,508	9,198	8,813	13,027	6,157	4,255	3,326	10,246	60,395
2003	0	0	0	121	639	2,860	10,184	10,052	9,071	11,890	5,346	3,467	10,085	63,714
2004	0	0	0	181	505	2,682	6,314	10,820	9,836	7,566	9,982	4,158	9,724	61,768
2005	0	0	0	208	727	2,194	5,682	6,803	10,579	7,986	6,102	7,716	11,123	59,121
2006	0	0	0	119	862	2,917	4,410	5,712	6,504	8,647	6,380	4,684	13,963	54,198
2007	0	0	0	239	457	3,345	5,947	4,346	5,640	5,292	7,195	5,255	15,641	53,356
2008	0	0	0	135	1,073	2,121	7,961	6,696	4,231	5,134	4,405	5,727	15,087	52,570
2009	0	0	0	105	522	4,807	4,859	8,631	6,834	3,633	4,099	3,366	14,736	51,591
2010	0	0	0	72	407	2,150	10,343	4,653	7,838	5,668	2,985	2,984	13,448	50,548

Figure 1.1. Schematic of population abundance-at-age

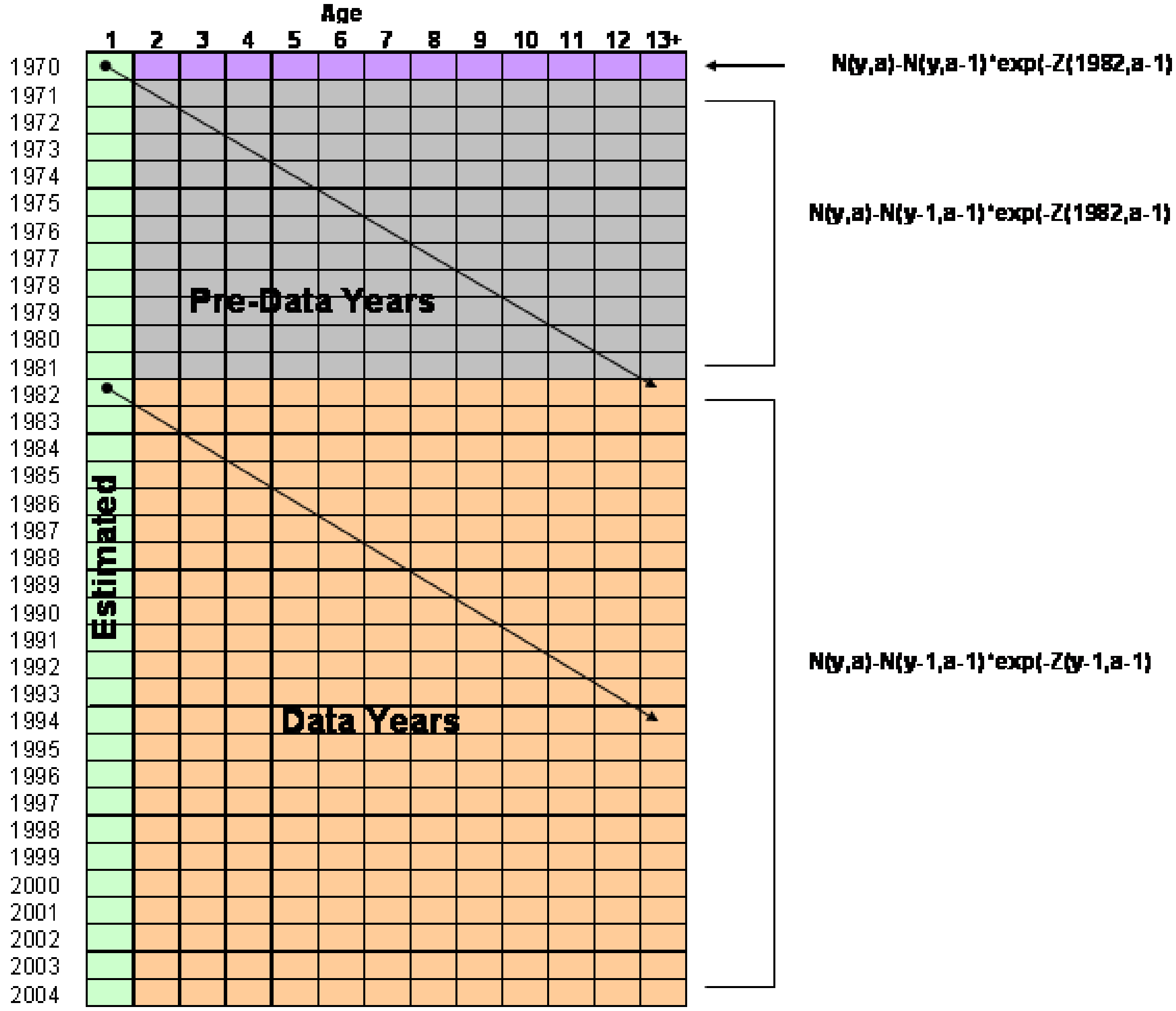

Figure 1.2. Estimates of total landings and residuals, fishing mortality (+95%CI), and period selectivity patterns, recruitment (+95%CI) and abundance of ages 1+ and 8+ from the SCA model.

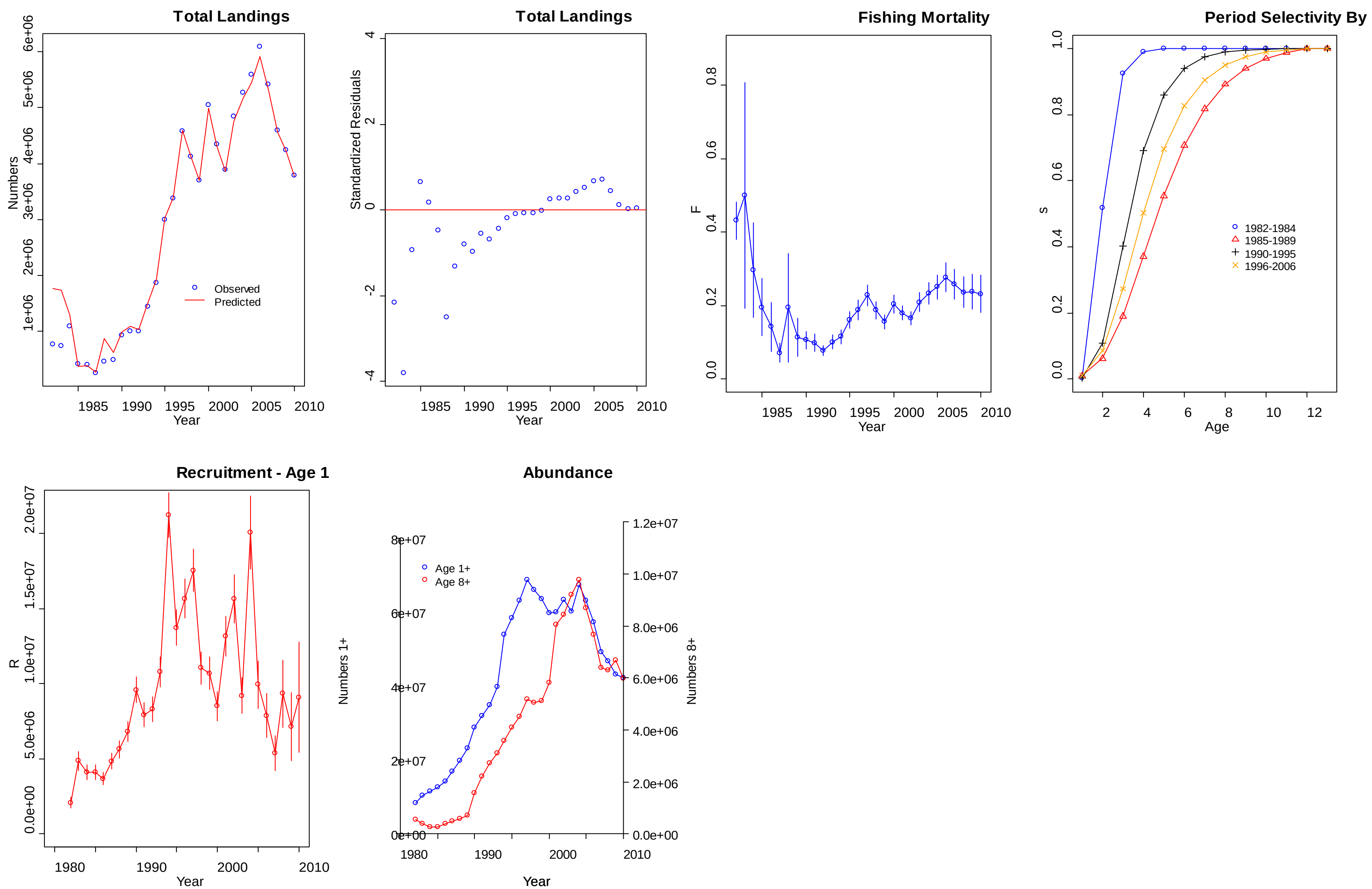

Figure 1.2. Comparison of fishing mortality estimates from the SCA model.

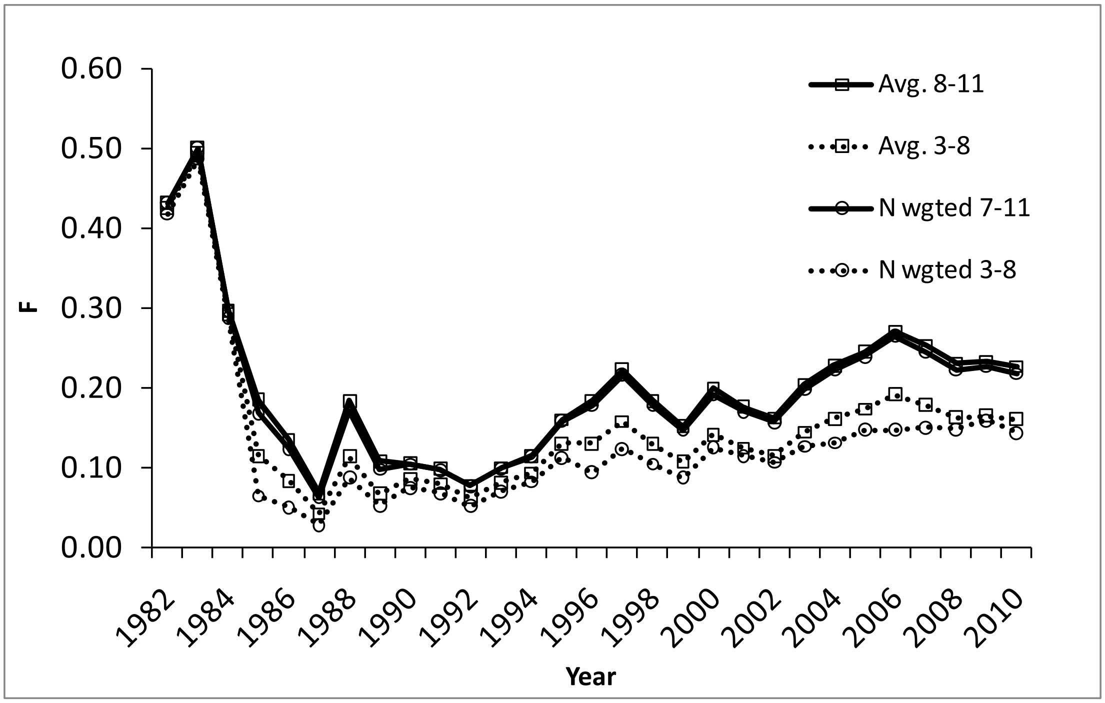

Figure 1.3. Comparison of average fishing mortality (ages 8-11) estimates from the SCA model runs in 2009 and 2011.

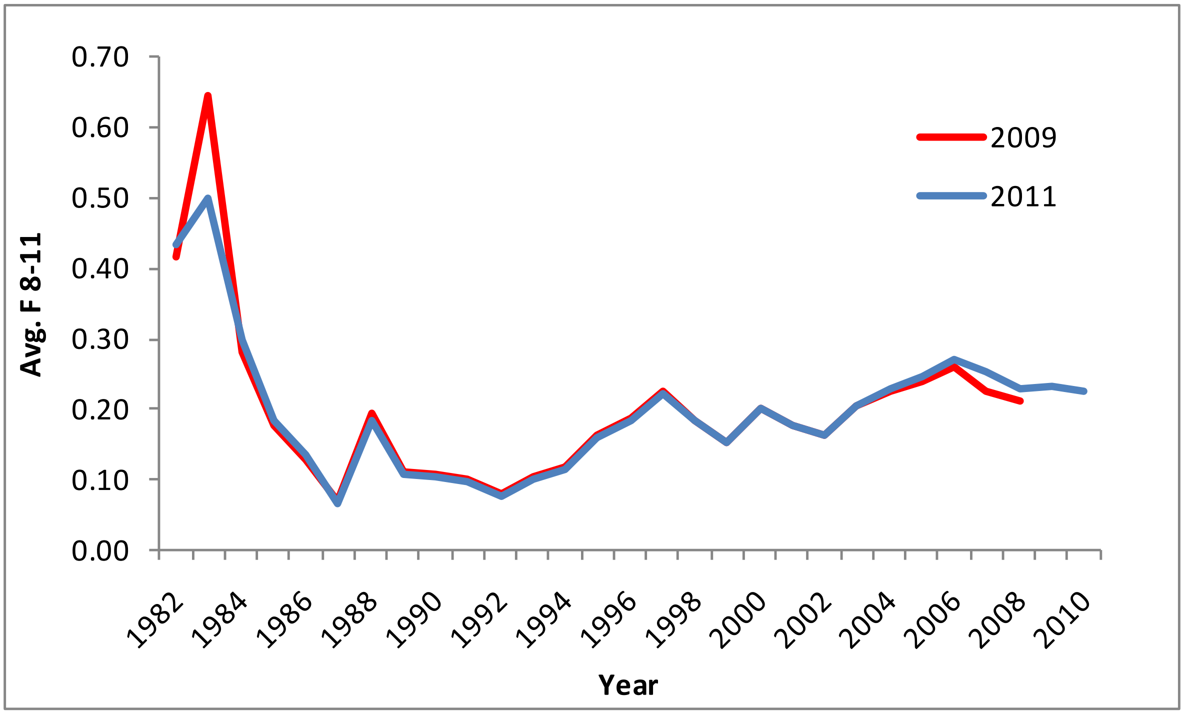

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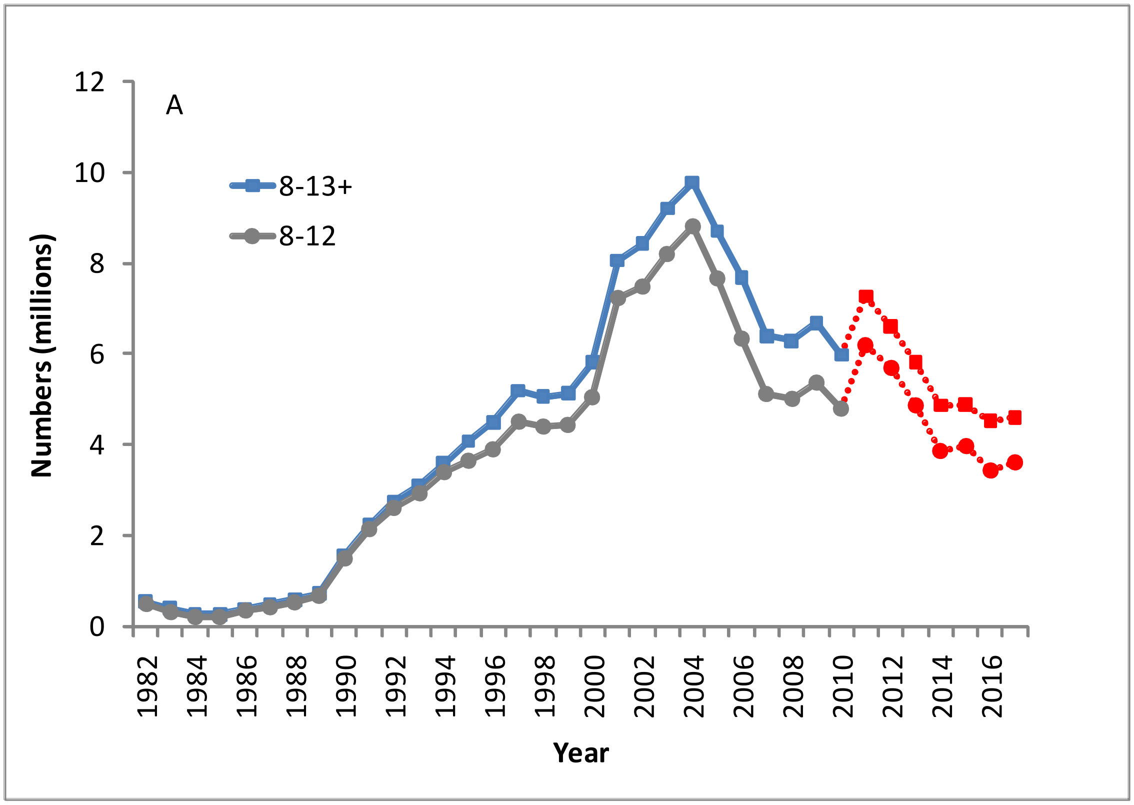
Figure 1.4. Progression of A) 8-13+ abundance and B) spawning stock biomass.



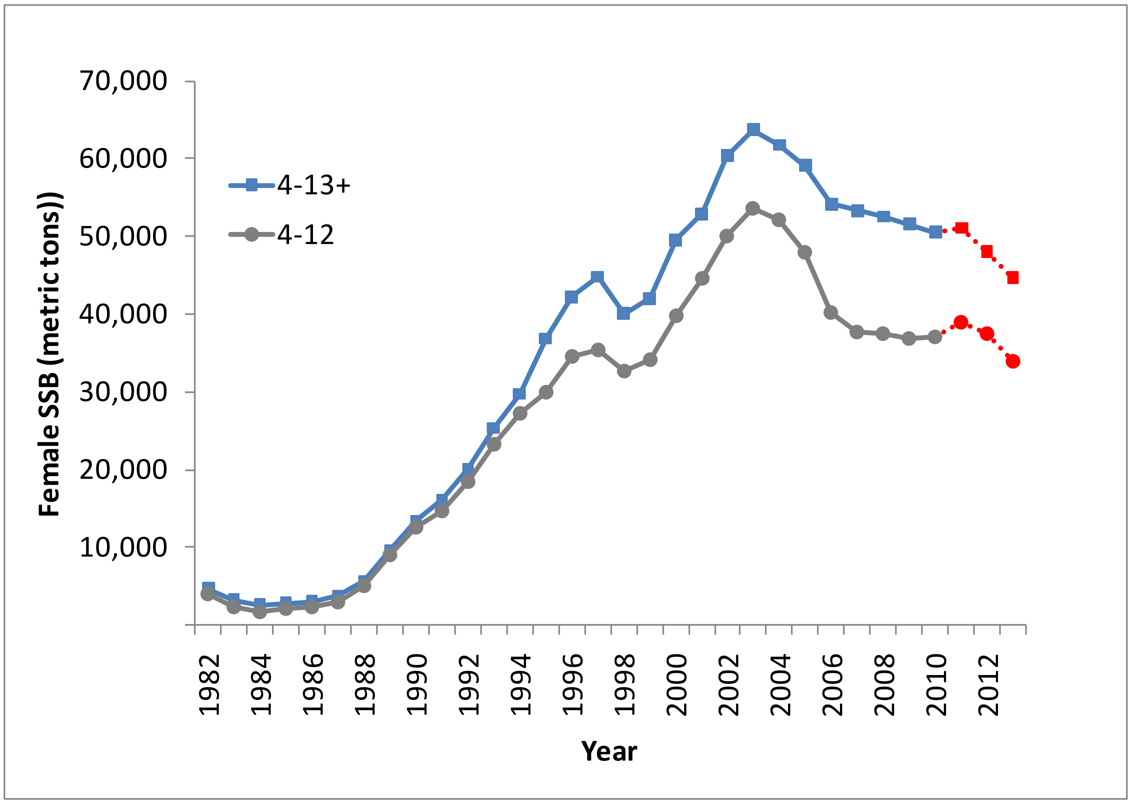


Figure 1.5. Trends in total (Jan-1) and spawning stock biomass (metric tons), 1982-2010.

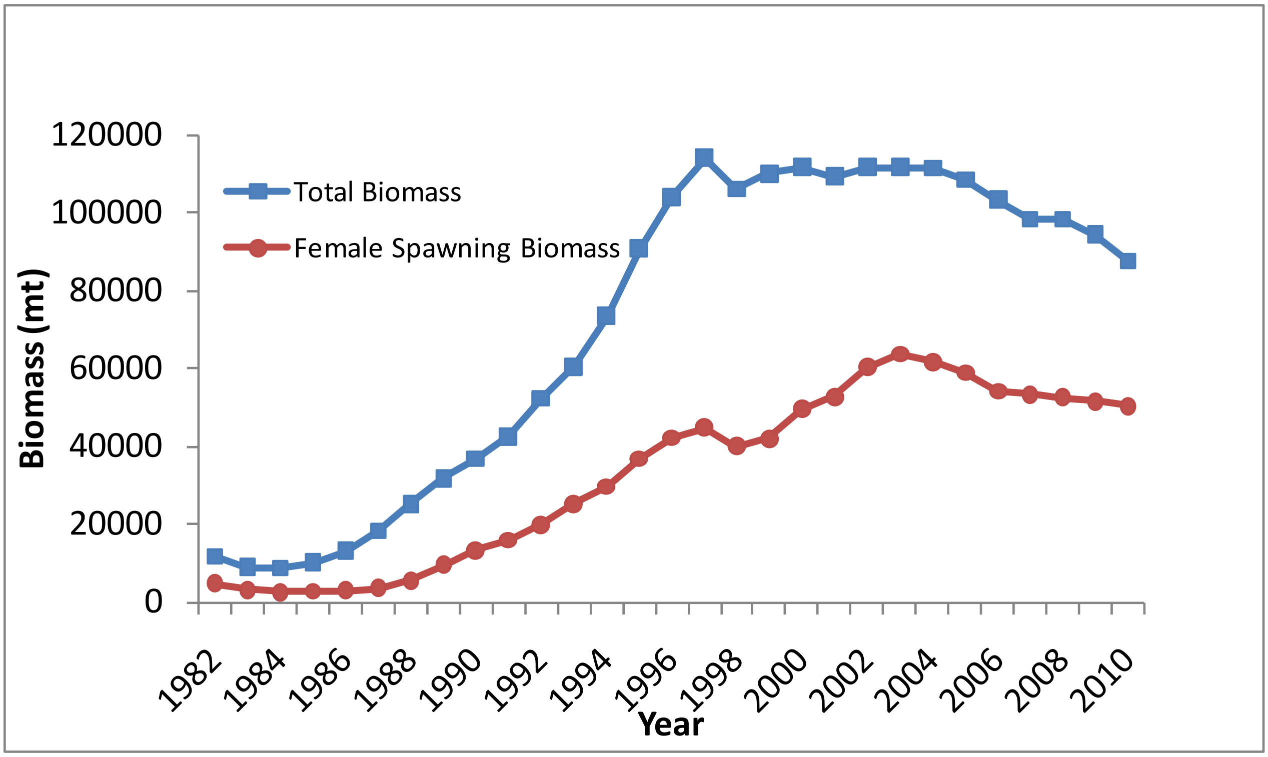


Figure 1.6. Retrospective analysis of fully-recruited fishing mortality, 8+ abundance and spawning stock biomass.

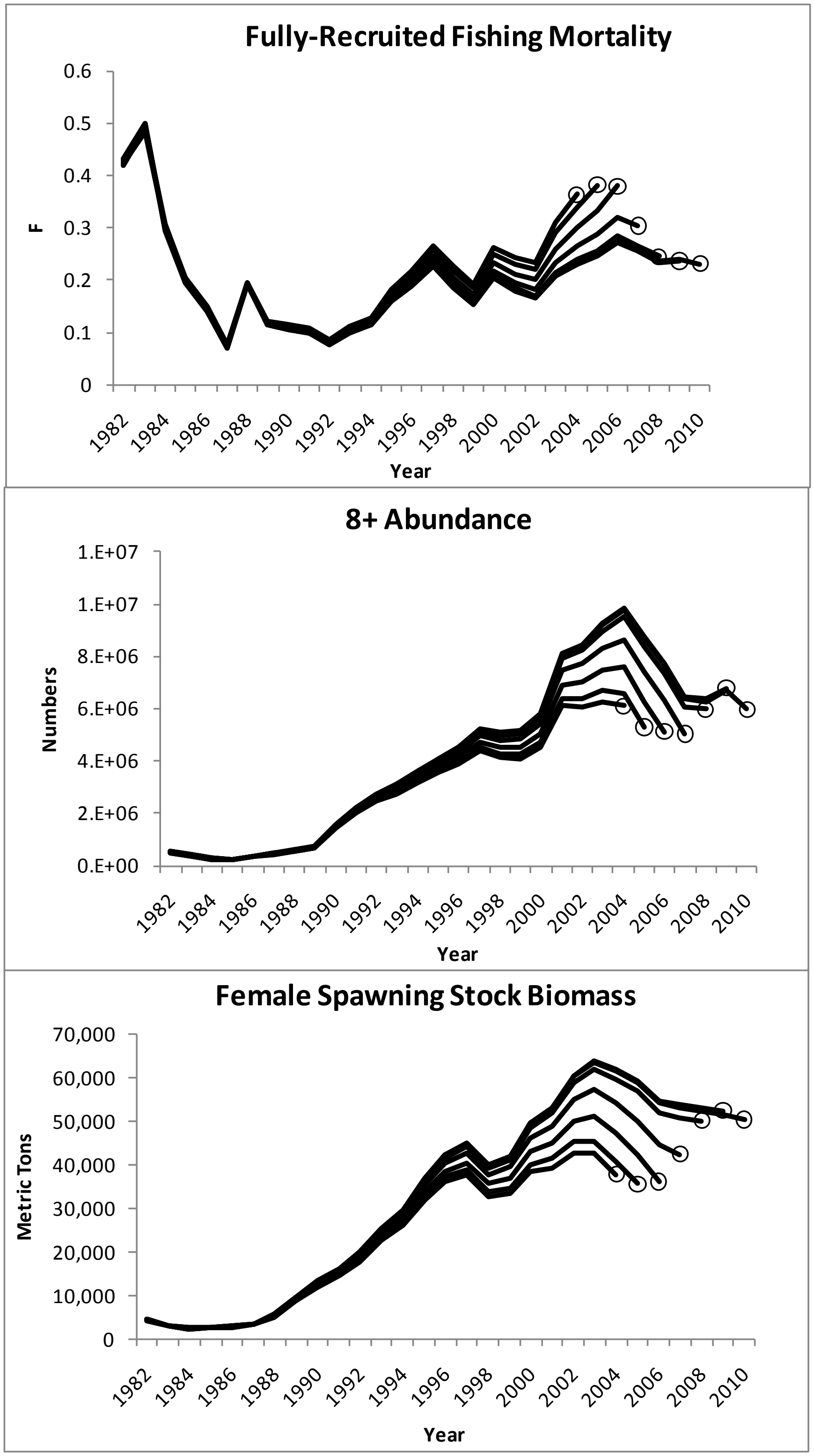
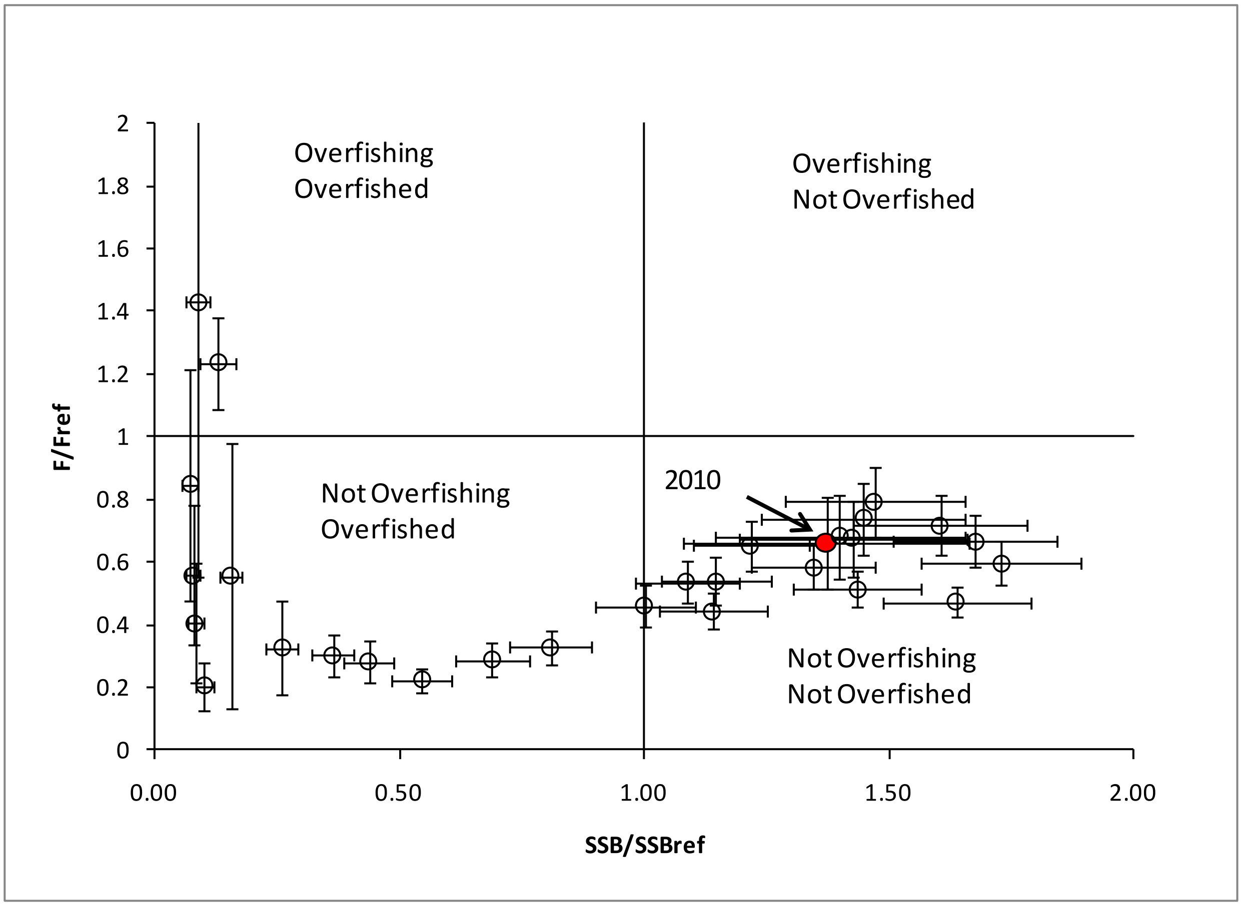
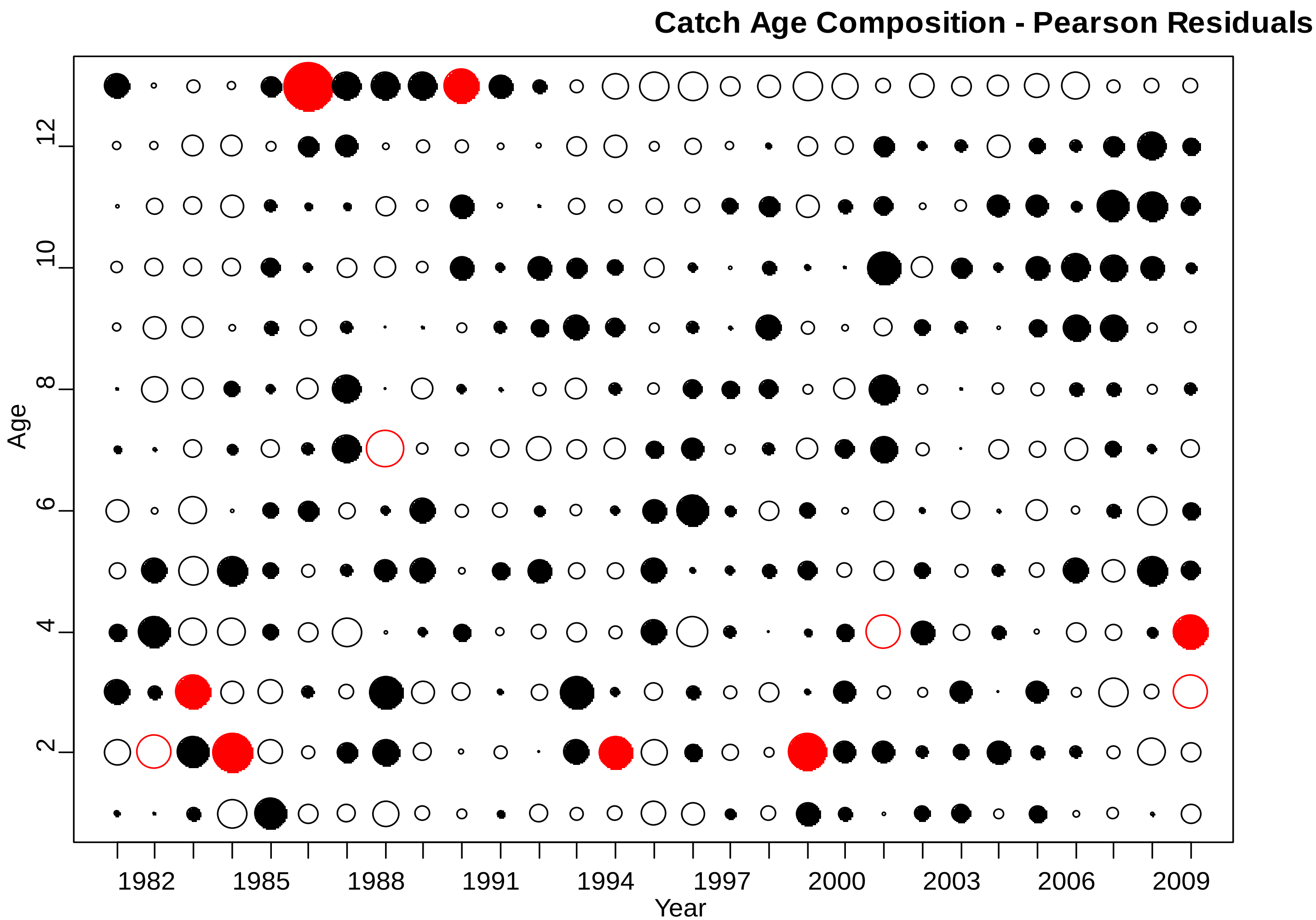


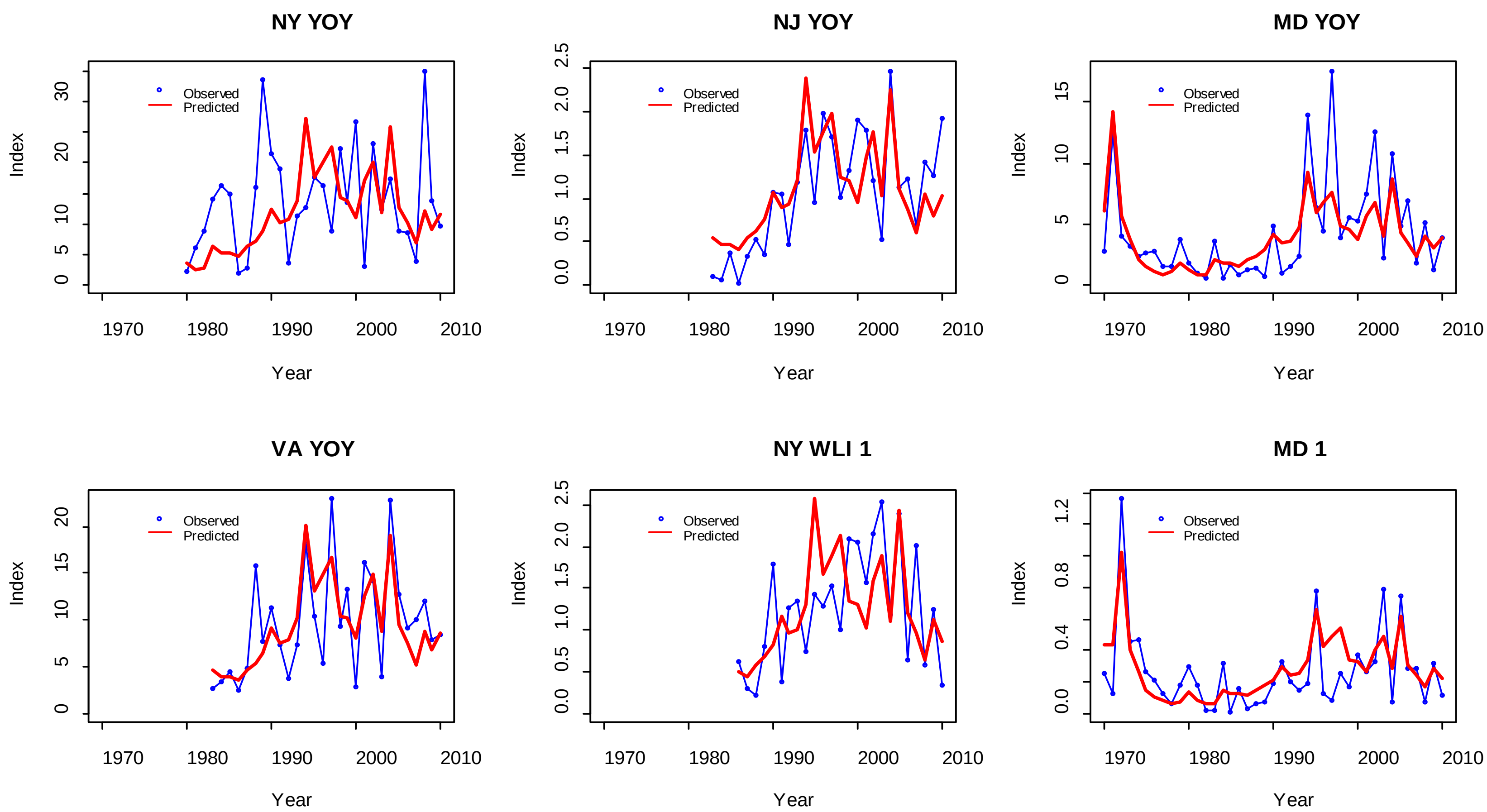
Figure 1.7. Plot of ratios of fishing mortality and female spawning stock biomass levels to their respective reference points . The 2010 value is shown in red. Whiskers are the 95% confidence intervals.



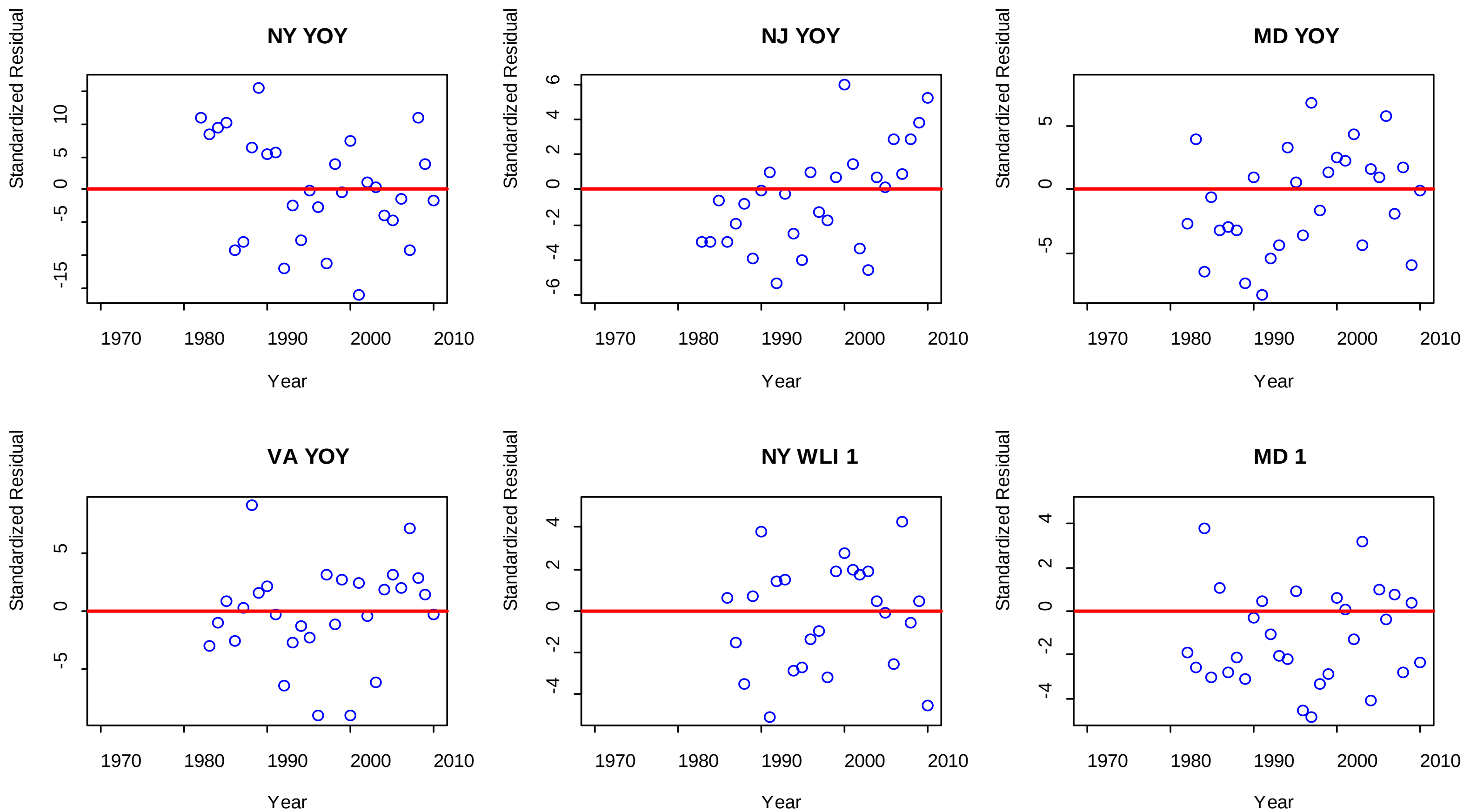
Appendix 1 Figure 1. Standardized residuals for the catch age composition from updated run of the 2011 SCA model.



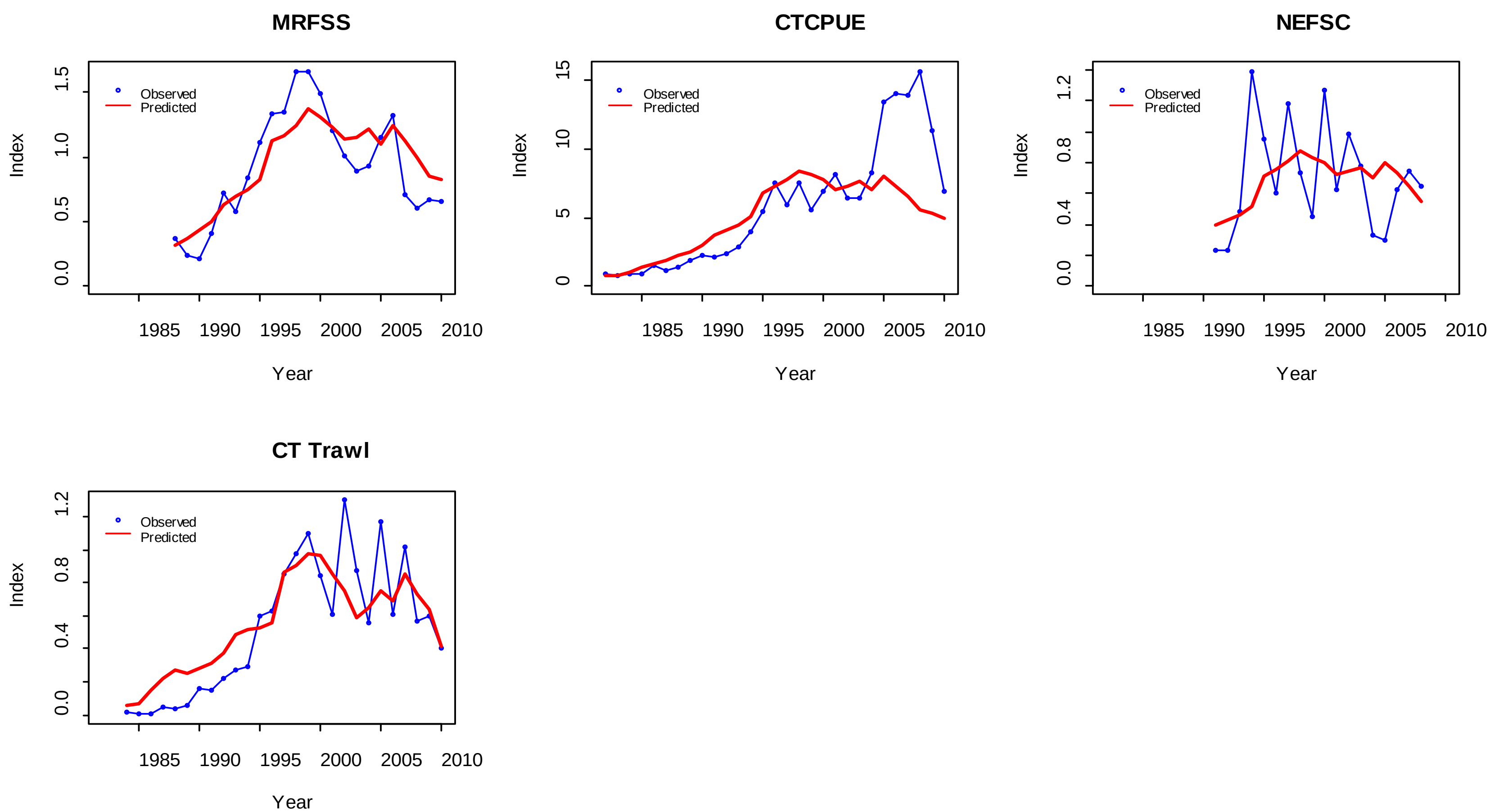
Appendix 1 Figure 2. Comparison of observed versus predicted values of the YOY and age1 indices of relative abundance from updated run of the 2011 SCA model.



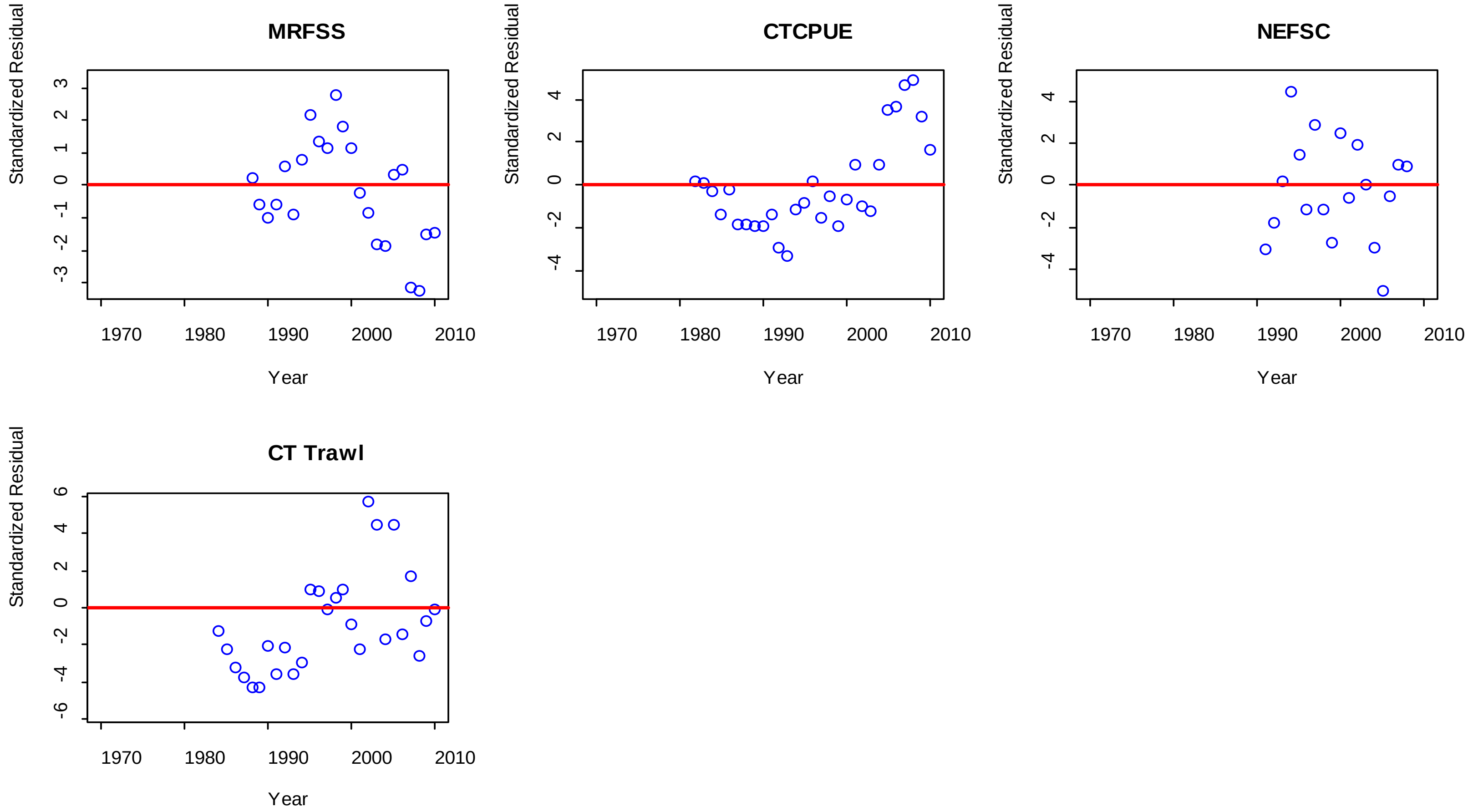
Appendix 1 Figure 3. Standardized residuals for the YOY and age 1 indices from updated run of the 2011 SCA model.



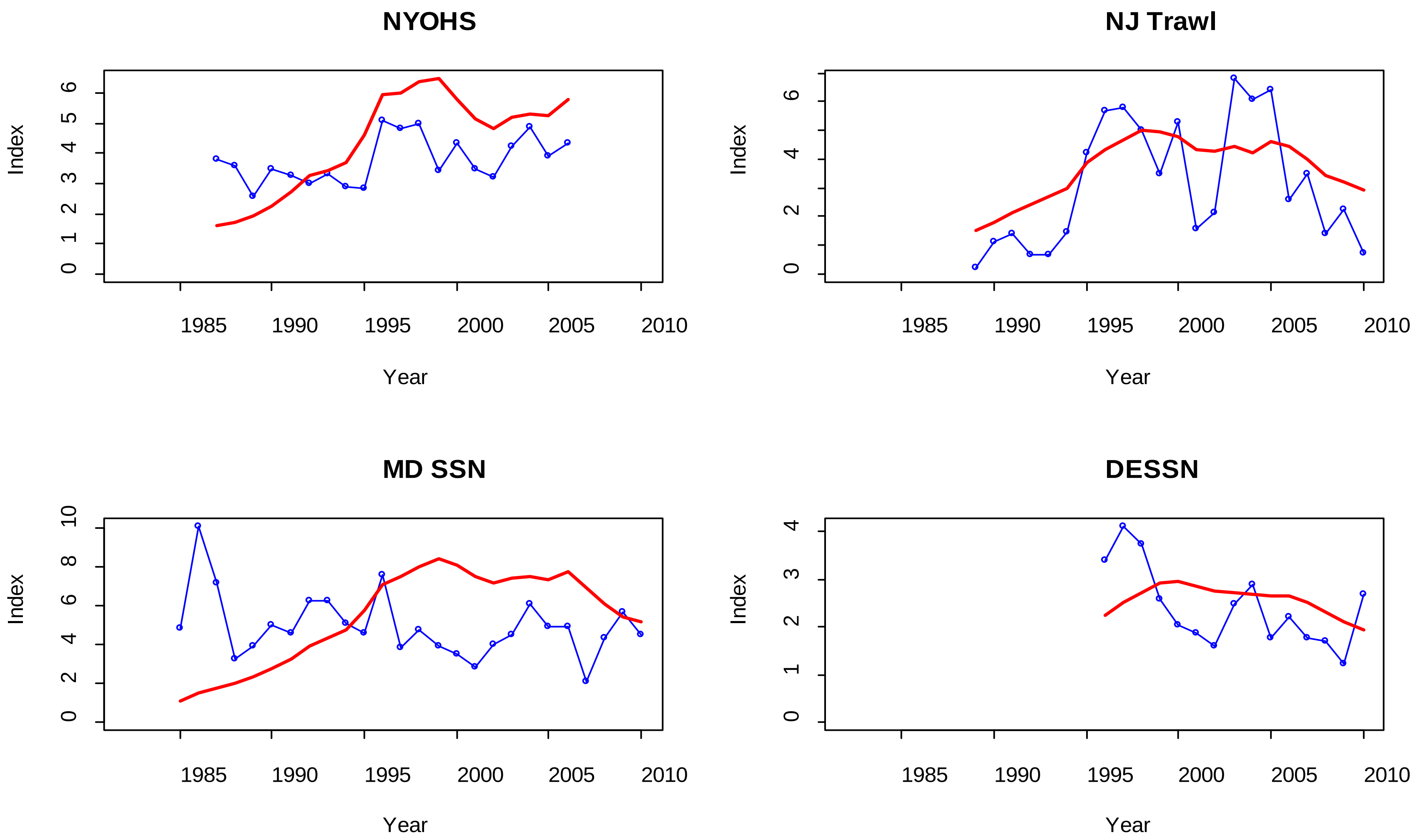
Appendix 1 Figure 4. Comparison of observed and predicted values of the aggregate abundance indices from the 2011 SCA model run.



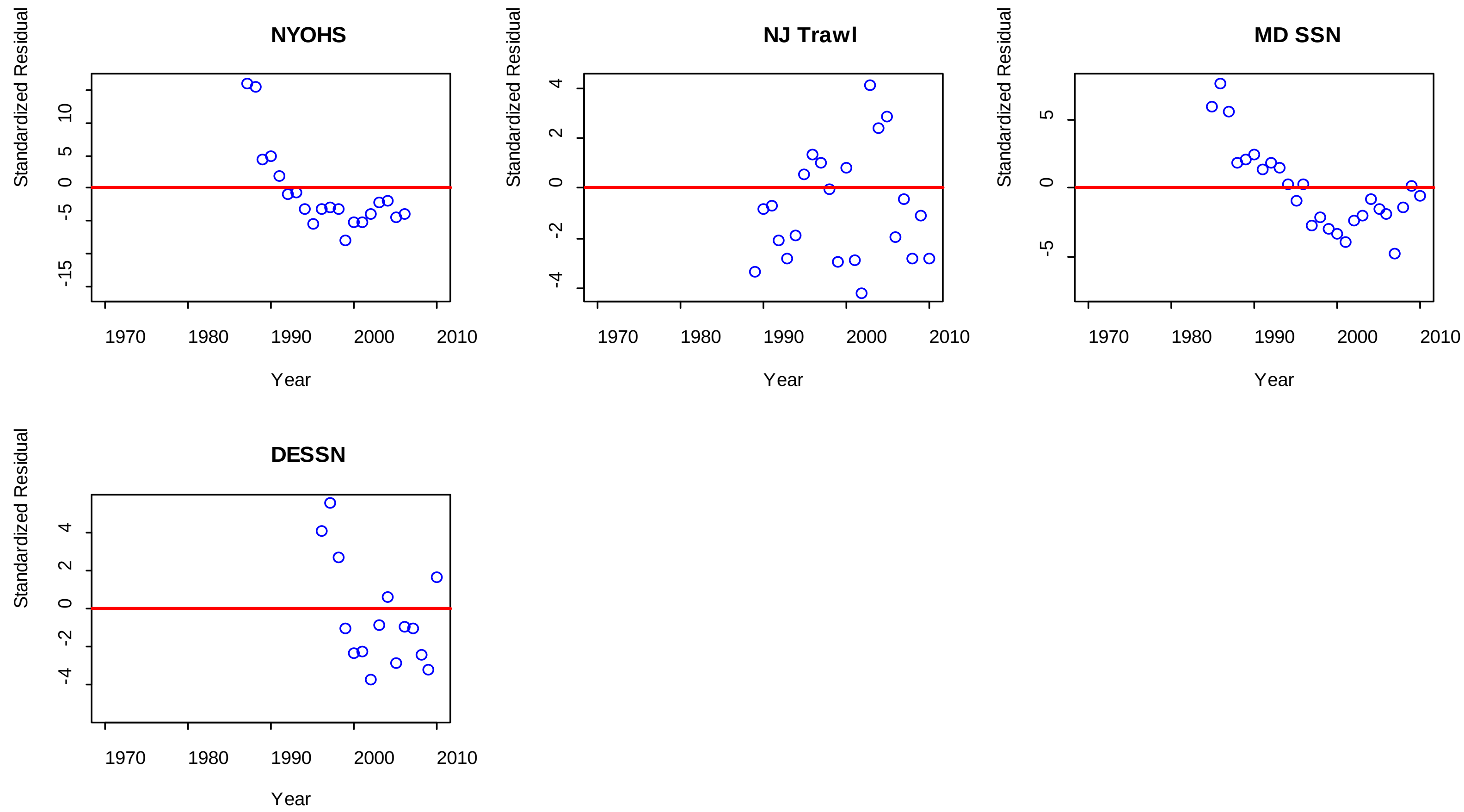
Appendix 1 Figure 5. Standardized residuals for aggregate indices from updated run of the 2011 SCA model.



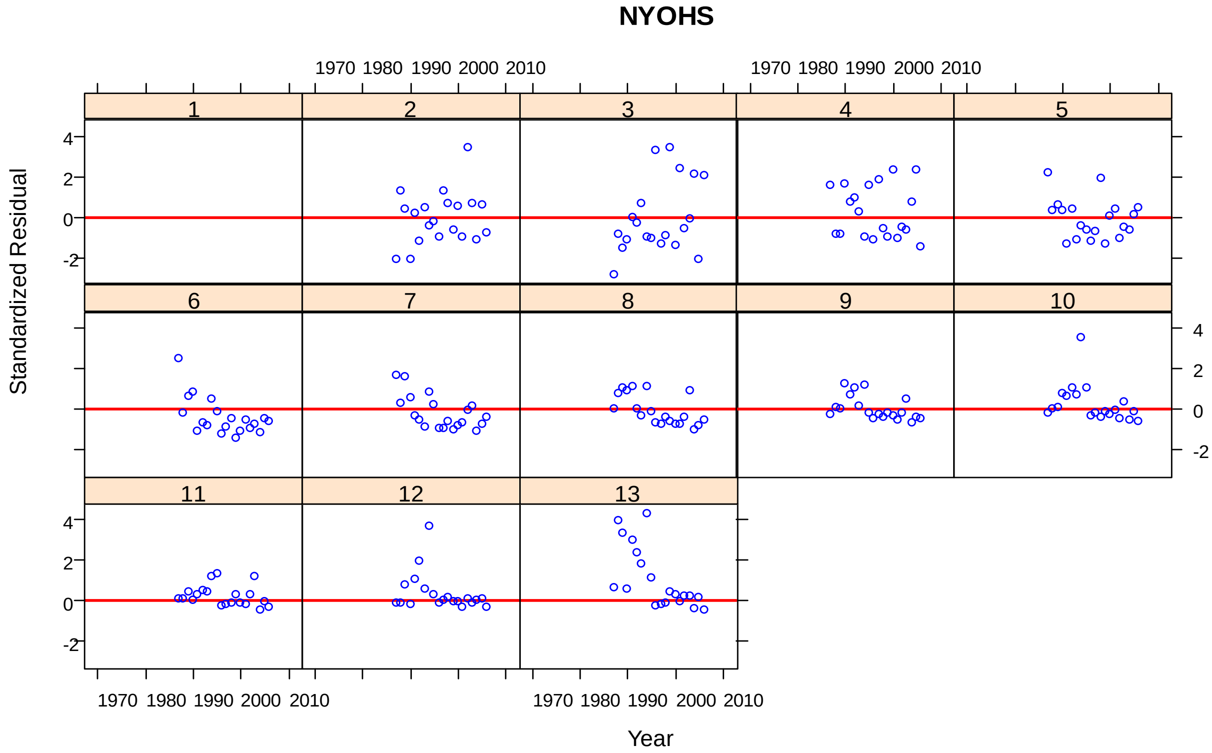
Appendix 1 Figure 6. Comparison of observed and predicted values of the survey indices with age data from updated run of the 2011 SCA model.

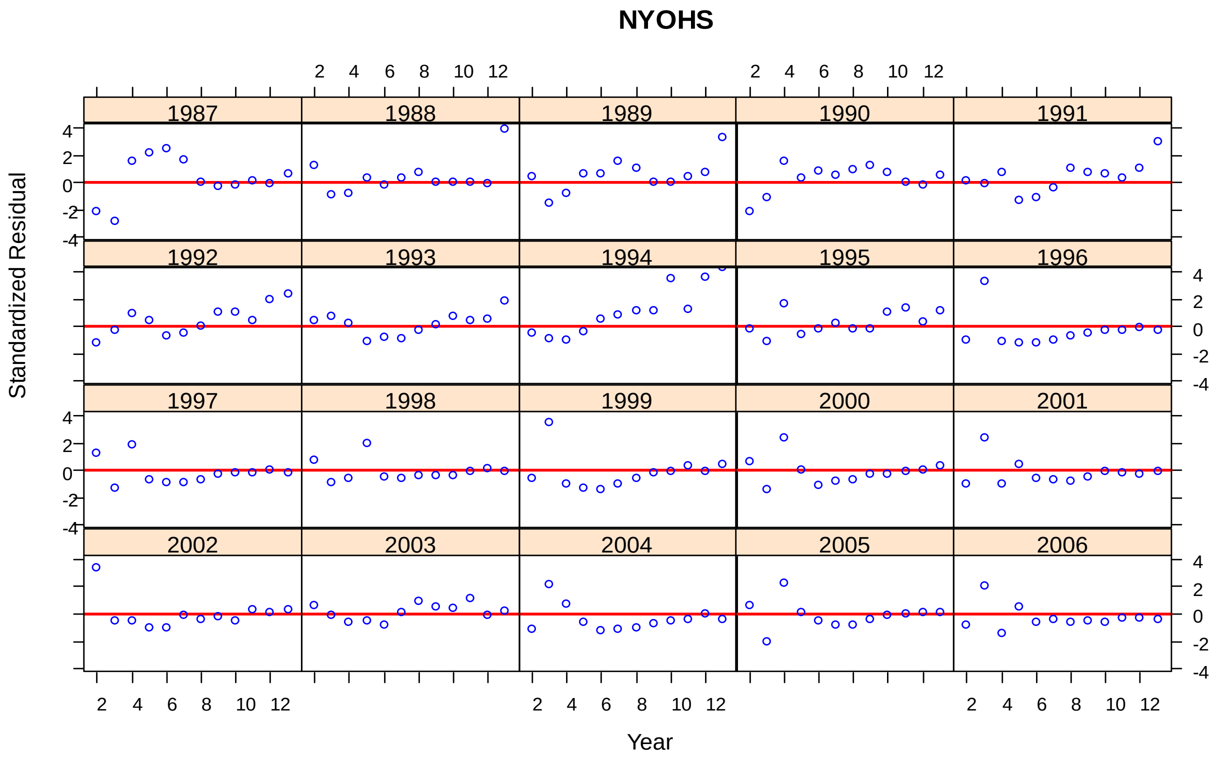


Appendix 1 Figure 7. Standardized residuals for survey indices with age data from updated run of the 2011 SCA model.



Appendix 1 Figure 8. Standardized residuals for the NYOHS age composition from updated run of the 2011 SCA model by year and age.





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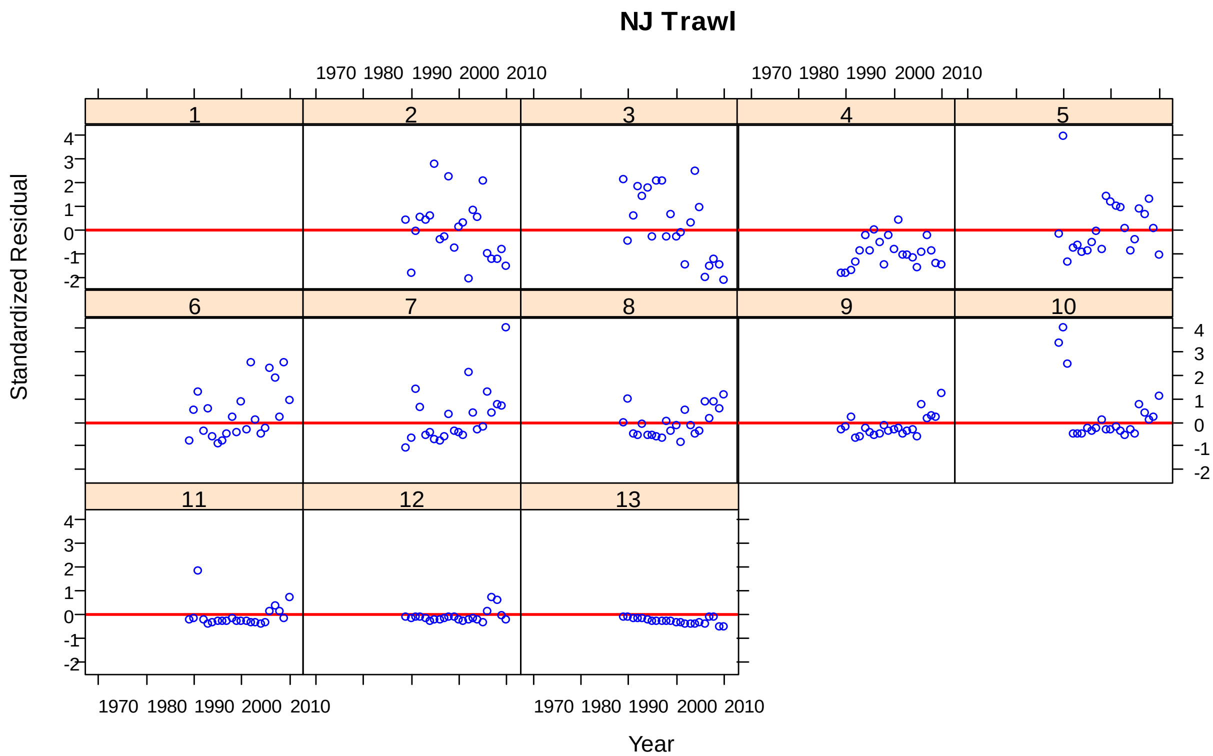

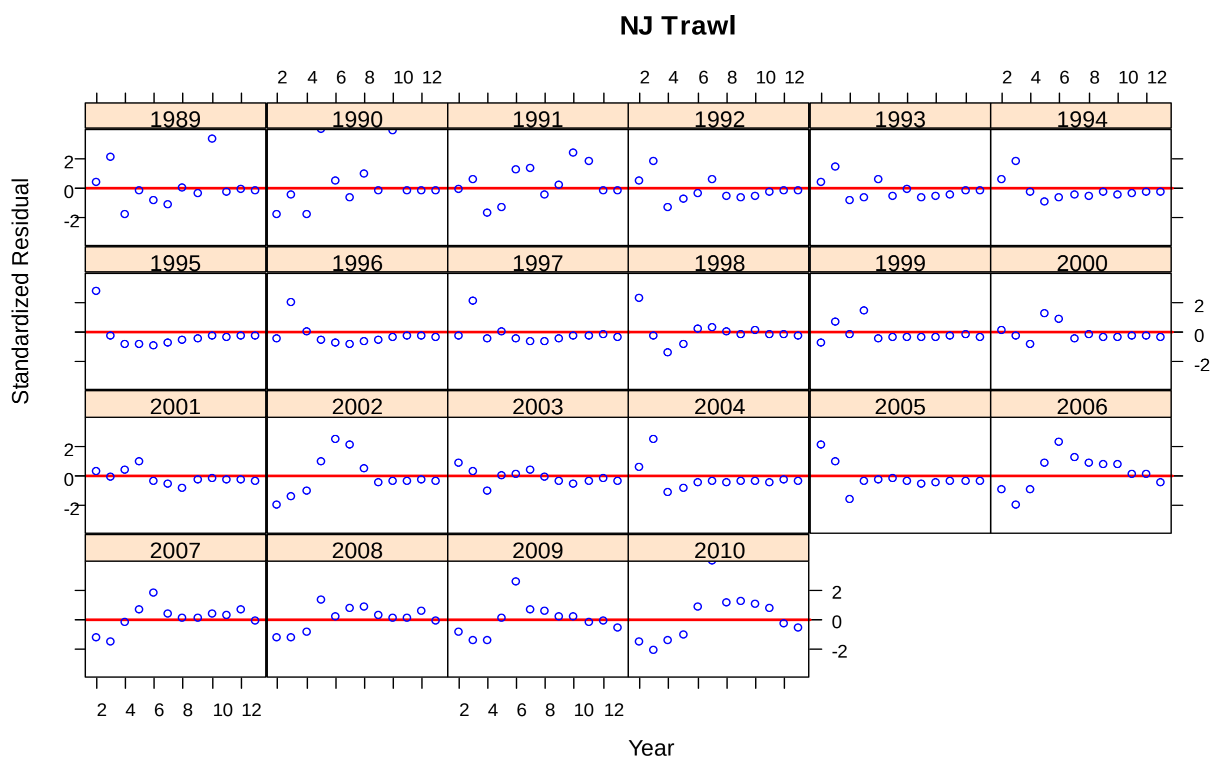

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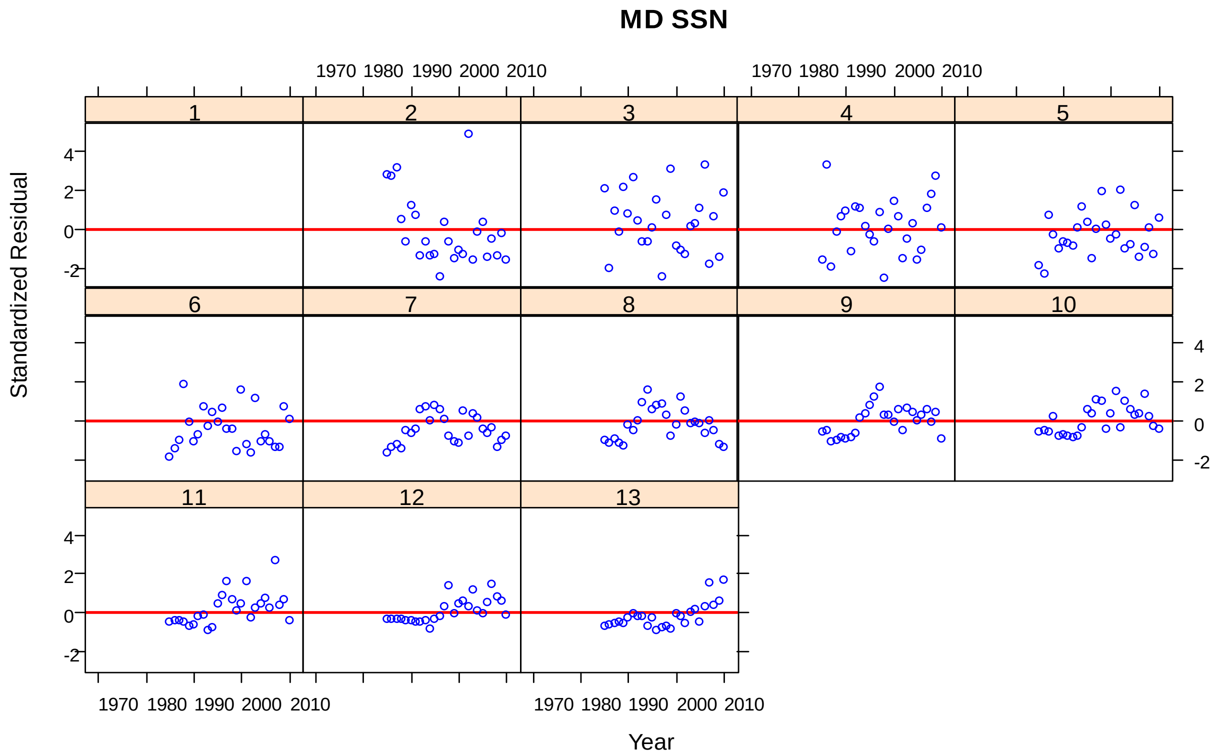

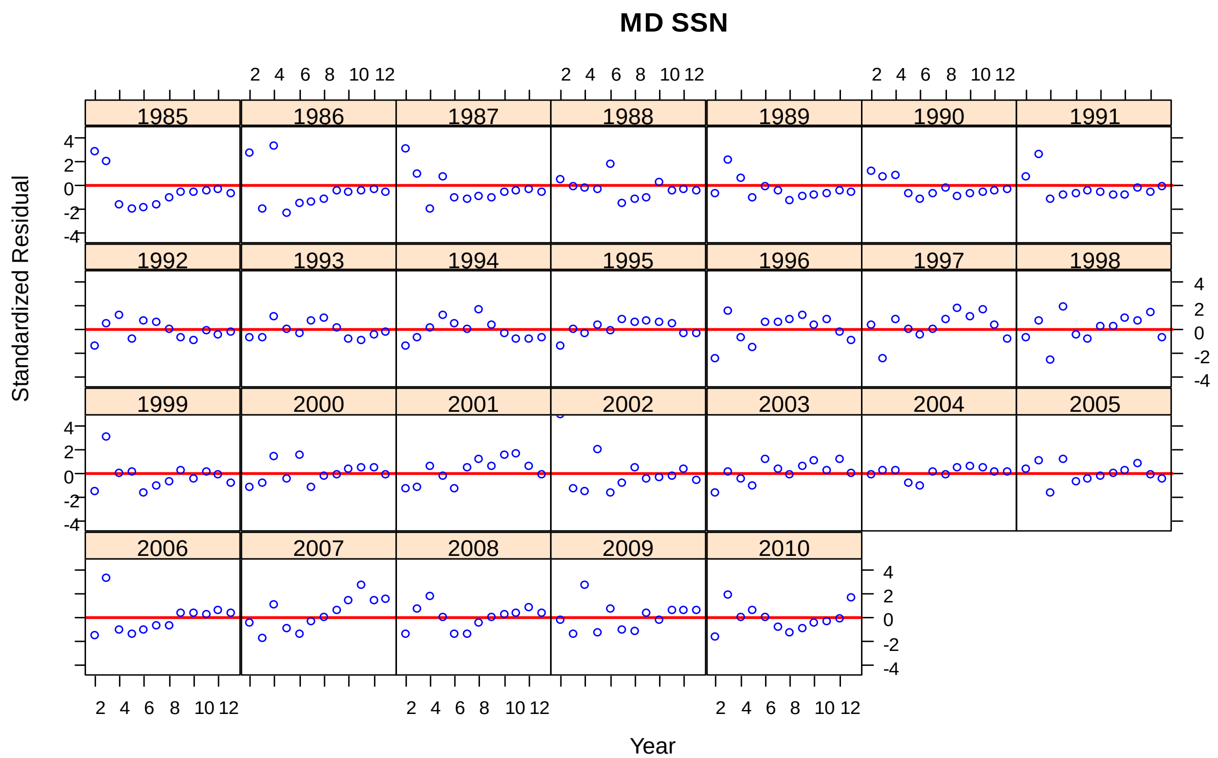

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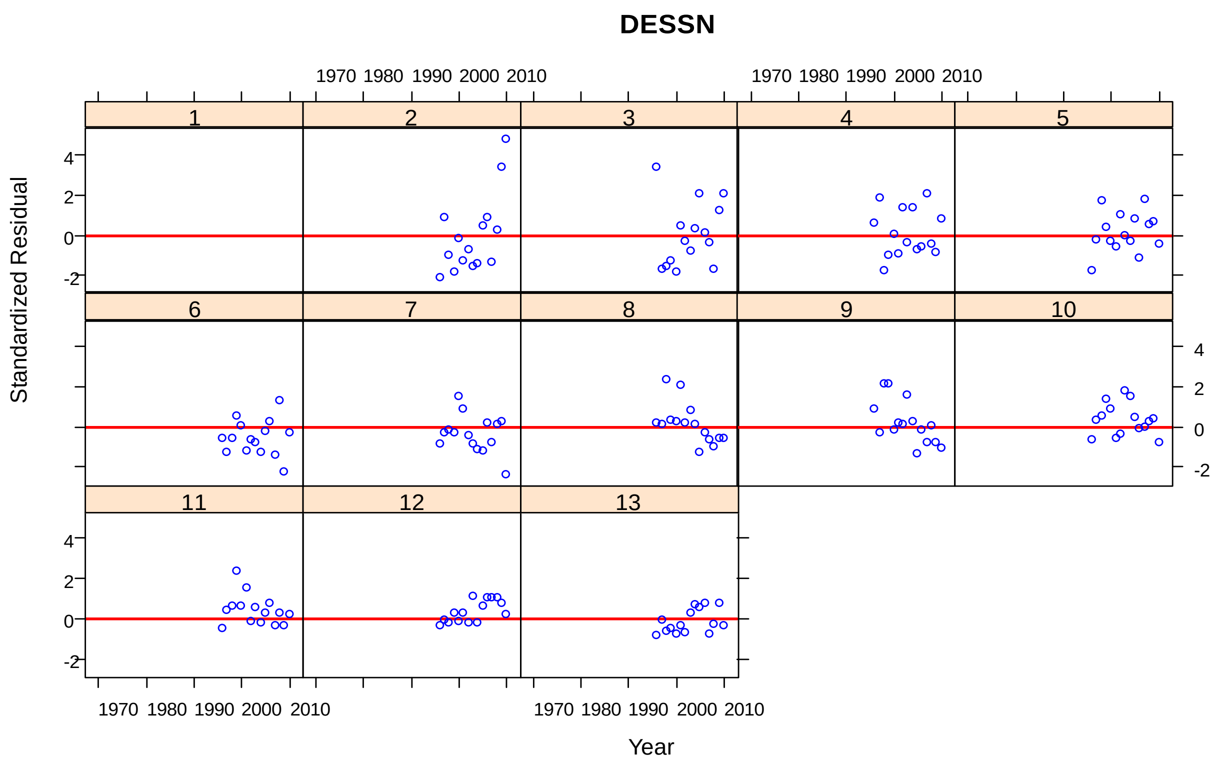

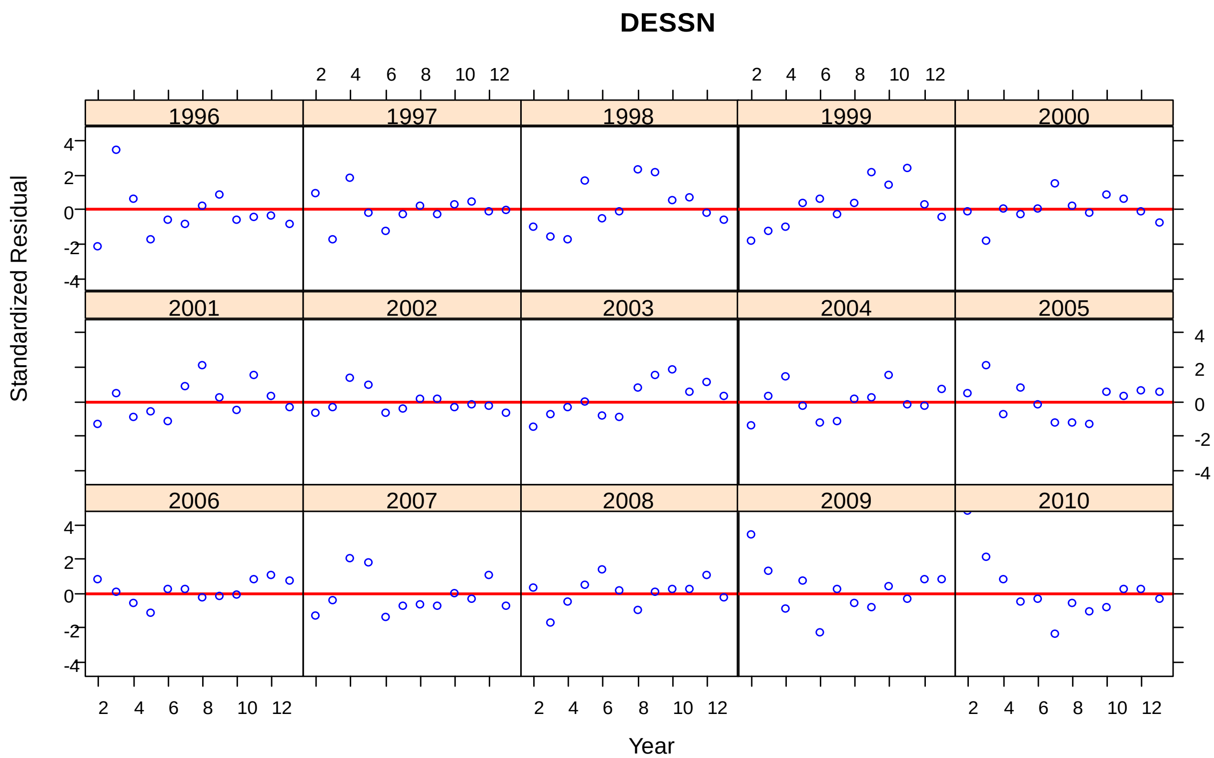

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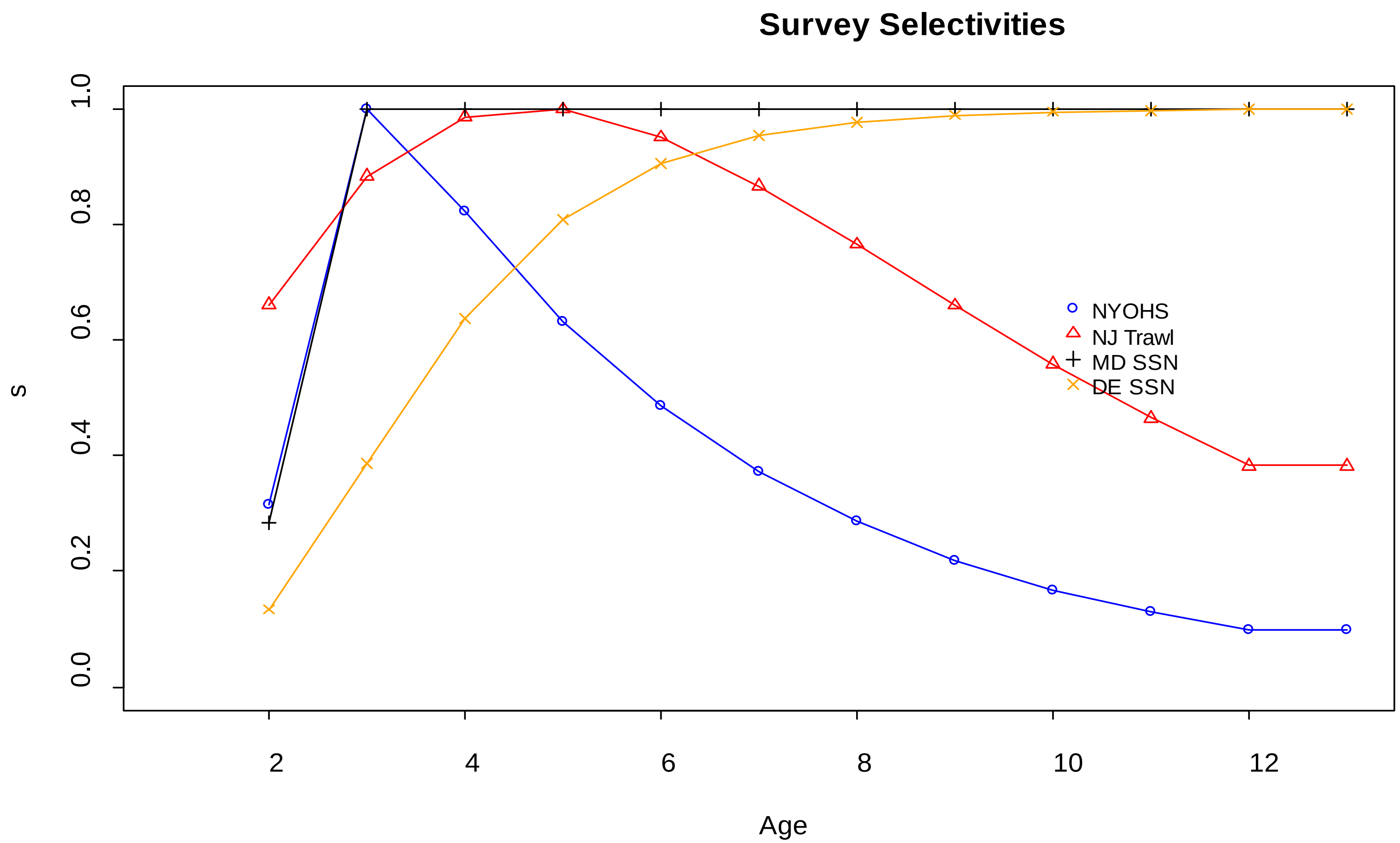

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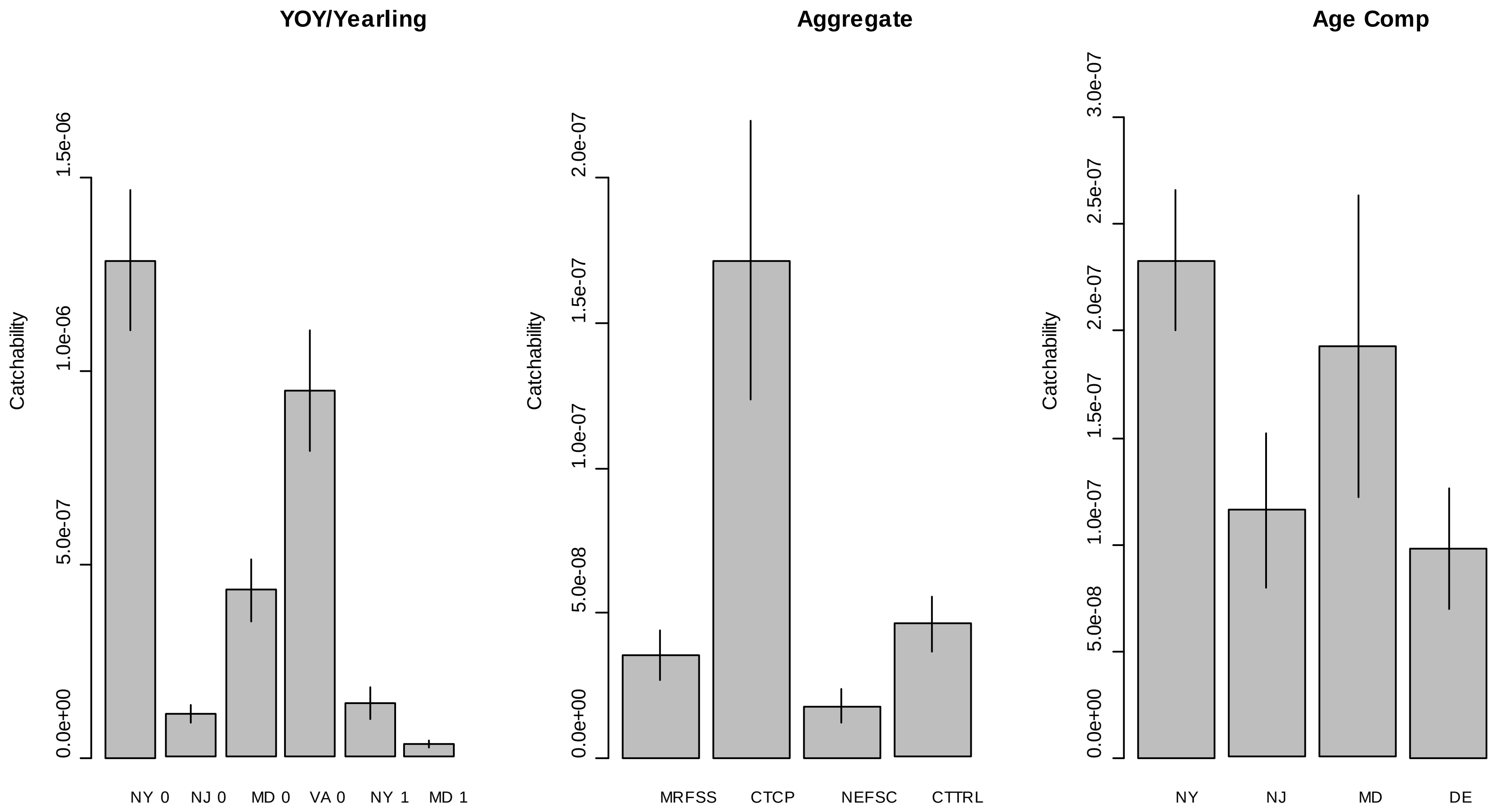
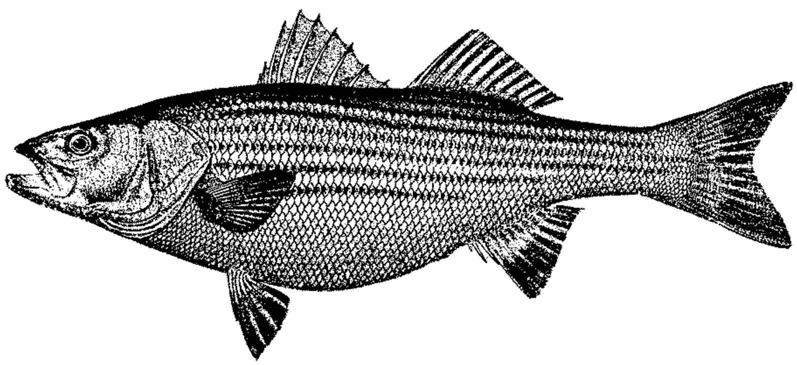


Atlantic States Marine Fisheries Commission
Striped Bass Tagging Subcommittee

Summary of USFWS Cooperative Tagging Program Results



Atlantic States Marine Fisheries Commission Striped Bass Tagging Subcommittee

Heather Corbett (NJ DFW, Chair), Stuart Welsh (USGS, Vice-Chair), Andrea Hoover (MD DNR) Beth Versak (MD DNR), Bob Harris (VIMS), Gary Nelson (MA DMF), Gary Shepherd (NMFS), Ian Park (USFWS), John Hoenig (VIMS), Matt Smith (VIMS), Kathryn Hattala (NY DEC), Andy Kahnle (NY DEC), Chris McShane (NY DEC), Carol Hoffman (NY DEC), Phil Sadler (VIMS), Wilson Laney (USFWS), and Matt Fisher (DE DFW)

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EXECUTIVE SUMMARY

This report summarizes the results of the United States Fish and Wildlife Service's (USFWS) Atlantic coastwide striped bass tagging program through the 2010 tagging year. Data was collected through eight tagging programs which have been in progress for at least 18 years. Producer area tagging programs (Hudson River, DE/PA, MD and VA) primarily operate during spring spawning on the spawning grounds. Coastal area tagging programs (MA, NY, NJ/DE, NC) tag striped bass from mixed stocks during fall, winter, or early spring. Gears include hook & line, seine, gill net, and otter trawl. From 1985 through July 2011, a total of 501,472 striped bass have been tagged and released, with 90,278 recaptures reported and recorded in the USFWS database.

Two approaches were used to analyze the tagging data. The primary method was based on estimates of survival produced by Program MARK and subsequent use of the Baranov's catch equation to parse total mortality (Z) into fishing mortality (F) and natural mortality (M). This approach does not require the assumption that M is constant and known for every year. The tagging subcommittee also explored the use of the previous formulation of the MARK model with constant M, and an alternative methodology, the Instantaneous Rate-Catch and Release (IRCR) model with a single M.

The majority (85%) of tagged coastal fish ranged from 550-799 mm while the majority of producer area tagged fish ranged from 450-649 mm (56%). More fish ≥ 800 mm were caught by the producer areas (25%) than the coastal areas (18%). Coastal ages ranged from 3 to 24 years with the majority (86.5%) aged at 5 to11 years. The producer areas ages ranged from 2 to 22 years with the majority (88%) aged from 4 to 12 years.

Estimates of fishing mortality were calculated as the unweighted average of F estimates from the coastal and producer areas. Coastwide, fishing mortality on both age 3+ and age 7+ fish peaked in 1997 and has declined since then, to a value of 0.11 $year^{-1}$ for age 3+ fish and 0.13 $year^{-1}$ for age 7+ fish in 2010, using the MARK model with the Baranov catch equation. Results from the coastal programs and the producer area programs show similar patterns, with F higher for the producer areas (Figure 1). All areas were below the F=0.3 benchmark.

The magnitude and trends of fishing morality estimates were sensitive to model choice and assumptions about natural mortality. For both age 3+ and age 7+ fish, the IRCR model and the MARK model with the catch equation showed a peak in fishing mortality in the late 1990s with lower levels in recent years, while the MARK model with constant M showed sustained higher levels of exploitation (Figure 2).

The IRCR and catch equation analyses suggested that natural mortality estimates are increasing and are well above the assumed value, especially for the ≥ 18 inch striped bass from the Chesapeake Bay programs. The two period IRCR analyses indicate that the rise in the natural mortality rate occurred as early as 1997 in Chesapeake Bay, but was evident by 2003 for the coastal programs and for the larger (≥ 28 inches) striped bass. Since an increase in natural mortality rates have management implications, the Tagging

Subcommittee will continue to investigate the current value of natural mortality and the direction and magnitude of the change.

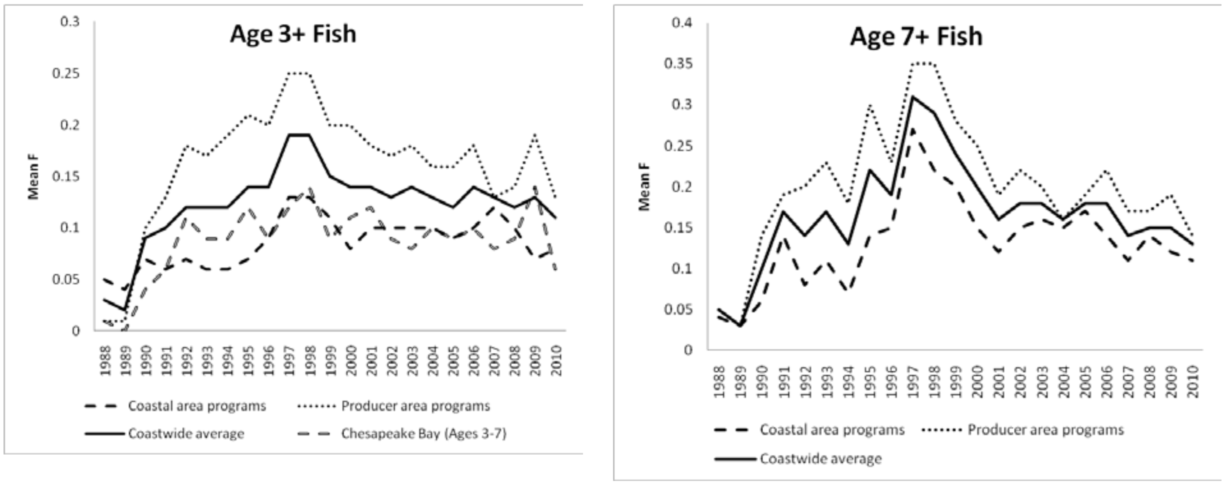

Figure 1: Fishing mortality estimates for age 3+ and age 7+ striped bass from coastal programs, producer area programs, and all programs combined.

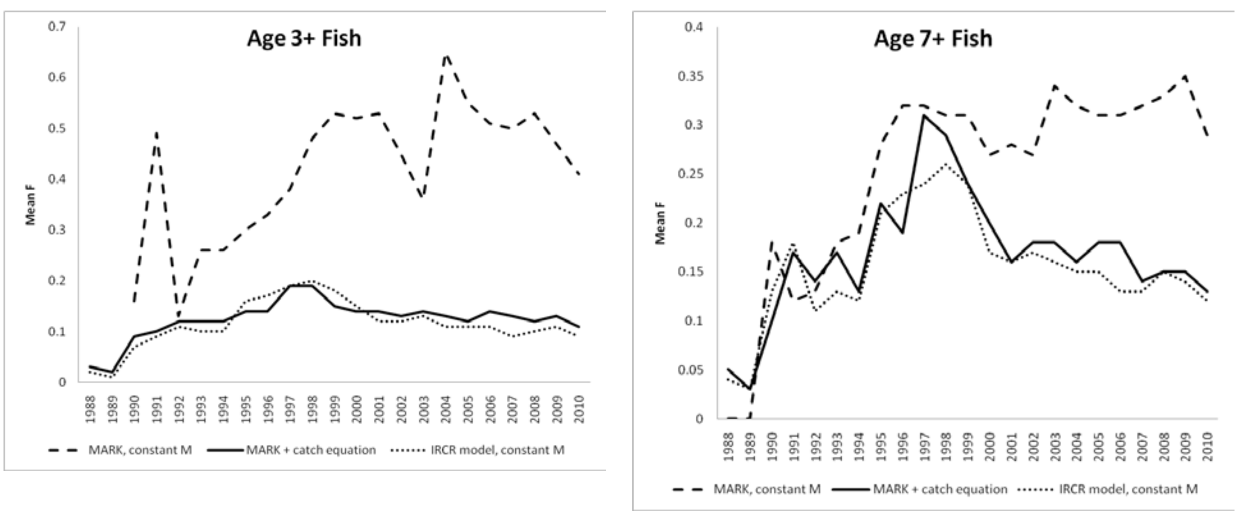

Figure 2: Mean coastwide fishing mortality for age 3+ and age 7+ striped bass from three different tagging models.

1. INTRODUCTION

This report summarizes the results of the United States Fish and Wildlife Service's (USFWS) Atlantic coastwide striped bass tagging program through the 2010 tagging year. The Striped Bass Tagging Subcommittee (SBTS) of the Striped Bass Technical Committee of the ASMFC analyzes the data gathered by the tagging program. The subcommittee is comprised of members from participating state agencies and the USFWS.

Two modeling approaches were used for the 2010 assessment. The SBTS has used Program MARK since 1998 to estimate a time series of annual survival rates (S). Post modeling, instantaneous mortality (Z as $-\log_e S$) was partitioned into instantaneous fishing (F) and natural (M) mortalities using a biologically-based constant value of M. The use of this method produced estimates of F that were sometimes nonsensical and sometimes conflicted with other indicators of stock status. Therefore, in 2004, the post-model partitioning of Z was also accomplished using a formulation of Baranov's catch equation (Ricker 1975) proposed by Pollock et al. (1991), in which the value of M is not assumed *a priori*. However, the catch equation method did not produce completely believable results either. Therefore, the SBTS initiated a new approach for the 2006 assessment – a formulation of Jiang et al.'s (2007) instantaneous (mortality) rates model.

This report presents descriptive statistics and calculations based on the data as well as model results. Data-based results are: length structure of tagged striped bass, age structure of recaptures, geographic distributions of recaptures by month and state, and estimates of catch and exploitation rates by program. Descriptions of the modeling methods, model outputs, and results of post-model calculations are also presented. Time series showing several parameters from model outputs are presented for fish $\geq$ 28 inches (approximating age 7+ fish) and fish $\geq$ 18 inches (approximating age 3+ fish).

2. METHODS

2.1. Description of Atlantic Coastwide Striped Bass Tagging Program

Eight tagging programs have traditionally participated in the USFWS Atlantic coastwide striped bass tagging program, and have been in progress for at least 18 years. As striped bass are a highly migratory anadromous species, the tagging programs are divided into two categories, producer area programs and coastal programs. Most programs tag striped bass (primarily fish $\geq$ 18 inches total length (TL)) during routine state monitoring programs.

Producer area tagging programs primarily operate during spring spawning on the spawning grounds. Several capture methods are used, such as pound nets, gill nets, seines and electroshocking. The producer area programs are:

- Hudson River (HUDSON) - fish tagged in May;
- Delaware and Pennsylvania (DE/PA) - fish tagged in the Delaware River primarily in April and May;

- Maryland (MDCB) - fish tagged in the Potomac River and the upper Chesapeake Bay primarily in April and May; and
- Virginia spawning stock program (VARAP) - fish tagged in the Rappahannock River during April and May.

Coastal programs tag striped bass from mixed stocks during fall, winter, or early spring. Gears include hook & line, seine, gill net, and otter trawl. The coastal tagging programs are:

- Massachusetts (MADFW) - fish tagged during fall months;
- New York ocean haul seine survey (NYOHS) - fish tagged during fall month. This survey changed to a trawl survey (NYTRL) in 2008. When data are combined in the report (NYOHS/TRL). Numbers with * are from the trawl;
- New Jersey Delaware Bay (NJDEL) - fish tagged in March and April; and
- North Carolina winter trawl survey (NCCOOP) - fish tagged primarily in January.

3. DATA

Tag release and recapture data are exchanged between the USFWS office in Annapolis, MD, and the cooperating tagging agencies. The USFWS maintains the tag release/recovery database and provides rewards to fishermen who report the recapture of tagged fish. From 1985 through July 2011, a total of 501,472 striped bass have been tagged and released, with 90,278 recaptures reported and recorded in the USFWS database (Ian Park, personal communication).

Release data, recorded at time of tagging, include:

- tag number,
- fish length,
- sex (if available),
- release date,
- location,
- gear, and
- other physical data.

Recapture data are obtained directly from fishermen and include:

- tag number,
- length,
- disposition,
- date,
- location,
- gear; and
- personal information.

These data were used to develop the following descriptive statistics of reported fish:

- length frequency distributions of releases, measured as total length (TL);
- age frequency distributions of recaptures; and

- annual catch rates.

Annual catch rates were developed for both $\geq$ 18 inch fish and $\geq$ 28 inch fish and were estimated as follows:

$$(R / 0.43) / M \qquad \textit{Eqn 1.}$$

where:

R =	number of fish recovered;
0.43 =	reporting rate; and
M =	number of fish marked.

The data are used in the models as program-specific matrices of releases and recaptures occurring in each year over the time series (FTP site).

4. REPORTING RATE

The reporting rate used throughout these calculations is the proportion of recaptured fish whose tag is reported to the USFWS. Currently, a constant value of 0.43 is used, based on a high-reward tag study conducted on the Delaware River stock, but employing tag returns from the whole Atlantic coast (Kahn and Shirey 2000). This estimate was substantiated by Smith et al. (2000). However, the SBTS recognizes that a constant reporting rate is unlikely. In 2007 and 2008, the four producer area programs participated in a high reward tagging study to obtain a current value for reporting rate. This project is detailed in Appendix G.

5. MODELING

Two approaches were used to analyze the tagging data. The primary method was based on estimates of survival produced by Program MARK (White and Burnham 1999) and subsequent use of Baranov's catch equation to parse Z into F and M. The second method, included in the tagging subcommittee's methodology for the first time in 2007, is an Instantaneous Rates model. Some results from the previous method (assuming constant M) are reported for comparison.

5.1. Program MARK and Baranov's Catch Equation

5.1.1. Assumptions and Structure of the Model

The analysis protocol that has been used by the Striped Bass Tagging Subcommittee since 1998 is based on assumptions described in Brownie et al. (1985) and elaborated for striped bass in Smith et al. (2000). Important assumptions (Brownie et al. 1985) are as follows:

1. The sample is representative of the target population;

2. There is no tag loss;
3. Survival rates are not affected by the tagging itself;
4. The year of tag recoveries is correctly tabulated;
5. The fate of each tagged fish is independent of the fate of other tagged fish;
6. The fate of a given tagged fish is a multinomial random variable; and
7. All tagged individuals of an identifiable class (age, sex) in the sample have the same annual survival and recovery rates.

In this method, Program MARK (White and Burnham 1999) was used to develop estimates of survival. Program MARK is based on Kullback-Leibler information theory and Akaike's information criterion (AICc; Akaike 1973, Burnham and Anderson 1992, 2003). Maximum likelihood estimates of the multinomial parameters of survival and recovery are calculated based on the observed matrix of recaptures. Candidate models are fit to the tag recovery data and arranged in order of goodness-of-fit by a second-order adjustment to the Akaike's information criterion.

Candidate models were selected before analysis and were based on biologically-reasonable hypotheses. Parameters of the models define various patterns of survival and recovery as follows (model formulas are explained more fully in Table 1):

- the global model {S(t)r(t), i.e., fully parameterized model} is a time-saturated model and was used to estimate over-dispersion and model fit statistics (*see Model Diagnostics*);
- models {S(p)r(p), S(p)r(t), S(d)r(p) and S(v)r(p)} parameterize survival as constant within time periods that are based on regulatory changes between 1987 and 2010 (regulatory periods are explained in Table 2);
- one model estimates the terminal year separately {S(d)r(p)} and another estimates the most recent two years separately {S(v)r(p)} in order to provide more exact estimates of recent years for management; and
- constant models {S(.)r(.), S(.)r(p), S(.)r(t)} that hold survival and/or recovery constant over time are also reasonable and were included. Selection of a constant model does not mean *"no"* variation in survival across the time series, but suggests that year-to-year variation in annual survival is "...relatively small in relation to the information contained in the sample data" (Burnham and Anderson 2003).

5.1.2. Model Diagnostics

Model adequacy is a major concern when deriving inference from a model or a suite of models. Over-dispersion, inadequate data (such as low sample size) or poor model structure may cause a lack of model fit. Over-dispersion is expected in striped bass tagging data, given that a lack of independence may result from schooling behavior.

After running the suite of models in Program MARK, an estimate of the variance inflation factor ("c-hat") was used to adjust for over-dispersion, if detected (Anderson et al 1994). Over-dispersion was examined through the goodness-of-fit of the global model.

The goodness-of-fit probability of the global model was quantified as a bootstrap-derived p-value based on model deviance (Burnham and Anderson 2003). A low p-value (< 0.15) and a large estimate of c-hat (> 4) imply inappropriate model structure (Burnham and Anderson 2003). A low bootstrap-derived p-value (< 0.15) and a moderate estimate of c-hat (>1 and < 4) support over-dispersion, with appropriate model structure. C-hat was estimated by dividing the observed Pearson Chi-square value (goodness-of-fit statistic of the global model) by the expected Pearson Chi-square value (derived from a bootstrap analysis of the global model).

5.1.3. Model Averaging

After model diagnostics have been performed, model averaging was performed to estimate program-specific annual survival rates. Survival rates were estimated for two size groups (fish $\geq$ 18 inches TL and fish $\geq$ 28 inches TL). These estimates were calculated as weighted averages across all models, where weight was a function of model fit (Buckland et al. 1997). Model averaging eliminated the need to select the single "best" model, and allowed the uncertainty of model selection to be incorporated into the variance of parameter estimates (Burnham and Anderson 2003). Survival is inestimable for the terminal year in the fully time-saturated {S(t)r(t)} model, so this model was excluded from the model-averaged survival estimate for the terminal year. A weighted average of unconditional variances was estimated for the model-averaged estimates of survival (Buckland et al. 1997).

5.1.4. Bias Adjustment

Because only harvested recoveries are modeled in Program MARK, the practice of catch-and-release fishing causes bias in the survival estimates. Therefore, an adjustment was made to the survival estimates according to the method of Smith et al. (2000).

Live release bias is defined as:

$$bias = -\left[\frac{\theta \cdot P_L \cdot \frac{f}{\lambda}}{(1-(1-\theta \cdot P_L)\frac{f}{\lambda}} \right] \qquad \textit{Eqn. 2}$$

where:

- θ = release survival rate (0.92), based on the 8% hook-and-release mortality rate estimated by Diodati and Richards (1996);
- P_L = annual proportion of tagged striped bass released alive;
- f = annual recovery rate, estimated by a separate MARK run, using a Brownie recovery model (Brownie et al. 1985); and
- λ = reporting rate.

Bias-corrected estimates of survival are then obtained by:

$$\text{bias-corrected S} = \frac{\text{uncorrected S}}{(1+bias)} \qquad \textit{Eqn. 3}$$

Accurate adjustment for live-release bias should also include estimates of tagging mortality and tag loss. Gear-specific tagging mortality was not included in bias adjustment because estimates were unavailable for most gears types. However, reported rates of general tag-induced mortality are low (0%, Goshorn et al. 1998; 1.3% Rugolo and Lange 1993), so tag-induced mortality was excluded from the bias adjustment. Reported rates of tag loss are also quite low (0% by Goshorn et al.1998, 2% by Dunning et al. 1987, and 2.6% by Sprankle et al. 1996), so tag loss was also excluded from the bias adjustment.

5.1.5. Estimation of F and M

In prior years' assessments, F was estimated by converting the adjusted survival (S) to Z as follows:

$$Z = -\log_e(S) \qquad \textit{Eqn. 4}$$

and parsing Z into F and M by subtracting a constant value for M. A value of M = 0.15 was assumed (ASMFC 1987). Using this technique, natural mortality was held fixed, and any change in Z resulted in an equal change in F.

There is general agreement among the SBTS that the use of an assumed constant value for M to estimate F is a weakness. Unreasonably high estimates of F seemed to contradict stable high harvests and continued high reproduction. Additionally, there has been concern that Chesapeake Bay may have been experiencing higher natural mortality during the past decade.

Therefore, beginning in 2004, the bias-adjusted value of S has been used with a form of the Baranov's catch equation to estimate program-specific values of F and M. Ricker (1975, p. 11) presented a formulation of Baranov's catch equation to solve for the exploitation rate (μ). He cautioned that it is applicable only for Type 2 fisheries, in which fishing and natural mortalities occur concurrently. This is the case for striped bass, where the fishery operates over much of the year. Pollock et al. (1991) used the same formula to solve for F as follows:

$$F = \mu/A*Z \qquad \textit{Eqn. 5}$$

where:

μ = exploitation rate;
A = annual total mortality rate (1 – S); and
Z = $-\log_e(S)$

and μ is calculated as follows:

$$\mu = ((R_k + R_L(1 - \theta)) / \lambda) / M \qquad \textit{Eqn. 6}$$

where:

R_k = the number of killed recaptures;
R_L = the number of recaptures released alive;
θ = release survival rate (0.92)
M = the number of fish tagged or marked at the beginning of the year; and
λ = reporting rate (0.43).

Once F is estimated, M is estimated by subtracting F from Z (Crecco 2003).

Variances associated with the estimates of F were calculated using the formulas in Pollock et al. (1991). These estimates were developed without inclusion of the covariance terms (because covariance terms could not be estimated from these data, they were assumed to be negligible). 95% confidence intervals were subsequently developed for each program's F.

Area fishing mortalities were calculated as mean values for the coastal and producer areas. Coastal F was calculated as the arithmetic mean of the coastal programs' values. The producer area F was calculated as a weighted mean of the producer area programs' values. The weights were based on each program area's proportional contribution to the coast-wide stock. The values are:

- Hudson (0.13);
- Delaware (0.09); and
- Chesapeake Bay (0.78), subweighted with MD (0.67) and VA (0.33).

Variance associated with the area mean F estimates were calculated as additive variances. The additive variance for the unweighted coastal mean F was calculated as:

$$\text{var}(\bar{x}_{coast}) = \sum w_i^2 \ \text{var}(\bar{x}_{state}) \qquad \textit{Eqn. 7}$$

where:

w_i = (1 / number of coastal programs; will be equal);
var($\bar{x}_{state}$) = individual state's variance of mean F.

The additive variance for the weighted producer area mean F was calculated as:

$$\text{var}(\bar{x}_{producer}) = \sum w_i^2 \ \text{var}(\bar{x}_{state}) \qquad \textit{Eqn. 8}$$

where:

w_i = 0.09 for Delaware;
w_i = 0.13 for Hudson;
w_i = 0.78 for Chesapeake Bay; with 0.67 for Maryland and 0.33 for Virginia;
var($\bar{x}_{state}$) = individual state's variance of the mean F.

95% confidence intervals were subsequently developed for each area's F.

The coast-wide fishing mortality was calculated as the arithmetic mean of the coastal and producer area means. No associated variance was calculated.

Estimation of stock size

Stock size was estimated for fish $\geq$ 18 inches TL, corresponding roughly to 3-year-old and older striped bass for fish $\geq$ 28 inches TL, corresponding to 7-year-old and older fish. A form of Baranov's catch equation was used:

$$\text{average stock size} = \text{catch} / F \qquad \textit{Eqn. 9}$$

Since F was based on an exploitation rate that included discard mortality from released fish, total catch was used.

5.2. Instantaneous Rates Model

Use of Program MARK and the catch equation was intended to provide more reasonable estimates of instantaneous mortality than were seen with the use of Program MARK and a pre-determined value for M. However, like this method, the catch equation method uses the survival estimate produced by MARK and parses Z into its component parts. Therefore, the values of F and M are not independent. Several tagging programs have continued to produce occasional unreasonable values (negative values for M) with this method.

Hoenig et al. published a basic instantaneous rates model in 1998. In this model, observed recovery matrices from harvested fish were compared to expected recovery matrices to estimate model parameters. Jiang et al. (2007) published an expanded version of the instantaneous rates model that accounts for the release of caught, tagged fish. Since many of the tagging programs do not age all tagged fish, the subcommittee elected to use an age-independent form of the "instantaneous rates – catch and release" (IRCR) model by Jiang et al. (2007). The model was programmed in AD Model Builder by Gary Nelson (MA DFW) and tested using data provided in Jiang (2005). Details of model algorithms are provided in Jiang et al. (2007).

Like Program MARK, several biologically-reasonable candidate models were formulated based on historical changes in striped bass management (Table 3). These models are analogous in structure to the models used in program MARK, but estimate instantaneous mortality rates instead of S. The output from the IRCR model consists of estimates of S, F, F' (mortality on tags recaptured and released), M and associated standard errors for each of the candidate models. In order to be consistent with Program MARK, the candidate models all assume M to be constant throughout the time series.

However, there is increasing evidence that natural mortality has increased within striped bass stocks in Chesapeake Bay. In recent years, four different analyses have been published (Crecco 2003, Kahn 2004, Jiang et al. 2007, and Sadler et al. 2008) that conclude that natural mortality has measurably increased, and possibly doubled, since

1997 in Virginia and 1998 in Maryland. The increase in natural mortality has been linked to mycobacterial infections, but declining forage fish populations and water quality may also contribute.

In the 2009 assessment, the SBTS developed an approach for adapting the instantaneous rates model to determine if a time scenario of two natural mortality periods would better fit the data for each of the coastal and producer area programs (Appendix F). When the constant M and two-M suite of models were run concurrently, the suite of two-M models were consistently given the highest weights, while the constant M models almost unanimously received zero weighting. A comparison of the parameter estimates of the two approaches showed that the two-M approach produced slightly higher annual estimates of fishing mortality than the constant M approach. This multiple natural mortality approach was also explored using the MARK analysis of Virginia's data for striped bass greater than 18 inches and also gave superior results. Thus, a separate analysis utilizing both the constant M and two-M suites was conducted to supplement the standard constant M IRCR analysis.

5.2.1. Assumptions and structure of the model

Similar to Hoenig et al. (1998), observed recovery matrices from the harvested and caught and released fish with removed tags are compared to expected recovery matrices to estimate model parameters. The expected number of tag returns from harvested ($R_{i,y}$) and caught-and-released (R'_{iy}) fish follow a multinomial distribution so that the full likelihood is the product multinomial of the cells (Hoenig et al. 1998). Tagged fish are assumed to be fully recruited to the fishery.

The expected number of tag returns from fish tagged and released in year *i* and harvested in year *y* is:

$$\hat{R}_{i,y} = N_i \hat{P}_{i,y} \qquad \textit{Eqn. 10}$$

where:

N = the number of fish tagged and released in year *i*; and
$P_{i,y}$ = the probability that a fish tagged and released in year *i* will be harvested and its tag reported in year *y*.

$P_{i,y}$ is defined as:

$$\hat{P}_{i,y} = \begin{cases} \left(\prod_{v=i}^{y-1} \hat{S}_v\right)(1-\hat{S}_y)\dfrac{\hat{F}_y}{\hat{F}_y + \hat{F}'_y + M}\hat{\lambda} & (\textit{when } y > i) \\ (1-\hat{S}_y)\dfrac{\hat{F}_y}{\hat{F}_y + \hat{F}'_y + M}\hat{\lambda} & (\textit{when } y = i) \end{cases} \qquad \textit{Eqn. 11}$$

where

$$S_y = e^{-\hat{F}_y - \hat{F}'_y - M}, \qquad \textit{Eqn. 12}$$

and:

F_j = instantaneous rate of fishing mortality on fish in year;
M = instantaneous rate of natural mortality;
λ = tag reporting given that a tagged fish is harvested; and
S_y = annual survival rate in year *y* for tags on fish alive at the beginning of year *y*.

The expected number of tag returns from fish tagged and released in year *i* and recaptured and released without a tag in year *y* is:

$$\hat{R}'_{i,y} = N_i \hat{P}'_{i,y} \qquad \textit{Eqn. 13}$$

where:

N_i = number of fish tagged and released in year *i*; and
$P'_{i,y}$ = probability that a fish tagged and released in year *i* will be caught and released and its tag reported in year *y*.

$P'_{i,y}$ is defined as:

$$\hat{P}'_{i,y} = \begin{cases} \left(\prod_{v=i}^{y-1} \hat{S}_v\right)\left(1-\hat{S}_y\right)\dfrac{\hat{F}'_y}{\hat{F}_y + \hat{F}'_y + M}\hat{\lambda}' & (when\ \ y > i) \\ \left(1-\hat{S}_y\right)\dfrac{\hat{F}'_y}{\hat{F}_y + \hat{F}'_y + M}\hat{\lambda}' & (when\ \ y = i) \end{cases} \qquad \textit{Eqn.14}$$

where:

$$\hat{S}_y = e^{-\hat{F}_y - \hat{F}'_y - M} \qquad \textit{Eqn.15}$$

and:

F'_j = instantaneous rate of fishing mortality in year *y* on the tags taken from fish that are caught and released; and
λ = tag reporting given that a tagged fish is recaptured, the tag is clipped off, and the fish is released alive.

5.2.2. Model diagnostics

The post-model calculations of F and M for each program followed the same procedures used in the MARK modeling. Over-dispersion was corrected with the same c-hat adjustment used in MARK modeling. The pooled Pearson chi-square statistic was used in the c-hat estimate, and was calculated by pooling expected cells (observed cells were pooled to match the expected cells) until the value was >1.

5.2.3. Estimation of F and M

Estimates of fishing mortality and associated standard errors from each IRCR run were imported into an EXCEL spreadsheet where fishing mortality was calculated as a weighted average across all models and its corresponding variance was calculated as a weighted average of unconditional variances (conditional on the set of models).

5.2.4. Estimation of stock size

Stock size was estimated using the IRCR model results for F and the same methodology used with Program MARK and the catch equation.

6. RESULTS

6.1. Data

The data input for both Program MARK and the IRCR model are the observed recovery matrices from harvested fish. The number of twice-recaptured fish was examined to ensure that this phenomenon did not cause a bias in model results. Of 90,278 recaptured fish in the database, only 3,460 fish were recorded as twice recaptured. Since this was less than 5%, it was considered inconsequential.

Length frequencies (total length) of fish tagged in 2009 and 2010 were tabulated by program (Table 4). Length represents the length of fish at the time of tagging. The majority (85%) of tagged coastal fish ranged from 550-799 mm while the majority of producer area tagged fish ranged from 450-649 mm (56%). More fish ≥ 800 mm TL were caught in the producer areas (25%) than the coastal areas (18%).

Age distributions of fish recaptured in 2009 and 2010 were tabulated by program (Table 5). Age distributions are based on a subsample of the total number of tagged fish (all programs do not age all tagged fish). Ages are read from scales taken at time of tagging and are adjusted to the recovery date. Coastal ages ranged from 3 to 24 years with the majority (87%) aged at 5 to11 years. The producer area ages ranged from 2 to 22 years with the majority (88%) aged from 4 to 12 years.

Geographic distributions of 2009 and 2010 recaptures (from fish tagged and released during the full time series) were organized by state and month for each tagging program (Appendix A). Striped bass tagged in the coastal programs were primarily recaptured in May through July along the Northeast coast. The recaptures generally increase again in November when fish were caught in New York, New Jersey and Maryland. Striped bass tagged by the producer programs were a mixture of resident and migratory stocks. Thus, resident striped bass tagged in Maryland and Virginia are recaptured year-round in Chesapeake Bay with coastal recaptures in New England in summer and North Carolina in winter. Producer area recaptures follow a similar monthly pattern but tend to have more recaptures off the southern coast.

Annual catch rates (R/M) for fish ≥ 28 inches show considerable variability among the programs over the time series, with values for most programs between 0.1 and 0.4 since the late 1990's (Table 6). However, VARAP has shown high (up to 0.6) and erratic values. From 1999-2010, all programs have shown a steady decline in their estimated annual catch rate and the overall mean has declined from a peak of 0.35 in 1997 to the current value of 0.16.

Annual catch rates for ≥ 18 inches fish have less variability than the ≥ 28 inches fish (Table 7), but also show a very slight steady decrease since the mid 1990's, with all values for all programs between 0.1 and 0.3. The overall mean has declined from a peak of 0.26 in 1997 to the current value of 0.14.

6.2. Model Diagnostics

6.2.1. Program MARK

The Akaike weights assigned to the candidate models are presented in Appendix B. For fish ≥ 28 inches, multiple models were used by all programs. The constant survival models generally received low weights with the exception of NYTRL, where the majority of weight was assigned. The period models received the majority of the weight for both the producer area and coastal programs.

For fish ≥ 18 inches, the model selection and weighting was entirely different. One model received essentially all weight for the NJDEL and NCCOOP coastal programs and both Chesapeake Bay programs (Appendix B). The models used for the MADFW and HUDSON programs were similar to the ≥ 28" suite, but as previously noted, those programs tag predominantly larger striped bass than the other programs.

6.2.2. Instantaneous Rates Model

The Akaike weights assigned to the candidate models are presented in Appendix C for fish ≥ 28 inches and fish ≥ 18 inches. For fish ≥ 28 inches multiple models were averaged for every program except MADFW and HUDSON. The weighting of the coastal programs was dominated by the time-specific F models while the producer programs were dominated by the various period based F models. The ranking and weighting of the models amongst both the coastal and producer programs were quite different from the 2009 assessment.

However, for fish ≥ 18 inches, the model selection was very different than for the ≥ 28 inch fish. The model rankings were consistent with the ≥ 28 inch fish for MADFW and somewhat for NCCOOP, but the NYTRL became dominated by the period-based f models, and the NJDEL scattered over 5 models. The producer program results were consistent with the ≥ 28 inch analysis except for Maryland, with the year-specific model receiving the full weight.

It is the opinion of the Tagging Subcommittee that the evidence for a substantial change in natural mortality warrants a multiple natural mortality period suite of models for the instantaneous rates model. The results from these exploratory analyses are detailed in Appendix F.

6.3. Estimates of Exploitation Rates

The exploitation rates for fish ≥ 28 inches are presented by program and as an unweighted coastwide mean (Table 8). The 2010 estimates of exploitation ranged from a maximum of 0.23 (DE/PA) down to 0.05 (VARAP). The annual estimates of exploitation rate have declined for every program since an overall peak of 0.27 in 1997. The 2010 overall coastwide mean exploitation rate was 0.12, which continued the downward trend but remained essentially flat since 2007.

The exploitation rates for fish ≥ 18 inches (Table 9) were slightly lower than those for fish ≥ 28 inches, ranging from 0.04 (VARAP) to 0.13 (MDCB). The temporal pattern of the annual exploitation estimates are similar to the ≥28 inches estimates with every program trending downwards, and on average, fairly flat. The mean exploitation rate peaked in 1997 (0.15) and has declined to the current value of 0.08.

6.4. Estimates of S

6.4.1. Program MARK and Bias-Corrected Estimates

Program MARK produces estimates of survival that are biased low due to the practice of catch-and-release fishing (uncorrected S). These uncorrected and the bias-corrected estimates of survival are presented by program in Appendix D. The 2010 bias-corrected estimates of S for fish ≥ 28 inches ranged from 0.64 (NCCOOP) to 0.93 (NYTRL) among the coastal programs. The survival estimates from coastal programs were quite stable over the past few years. Estimates from the NY trawl (2008-2010) were much higher than estimates from the NYOHS that ended in 2007. The bias-corrected survival estimates from the producer programs ranged from 0.53 (DE/PA) to 0.73 (VARAP). The annual estimates for increased in recent years while the VARAP estimate was its highest since 2002.

The 2010 bias-corrected estimates of S for fish ≥ 18 inches ranged from 0.56 (NCCOOP) to 0.75 (MADFW) among the coastal programs and from 0.56 (MDCB) to 0.74 (VARAP) among the producer programs.

6.4.2. Instantaneous Rates Model

The 2010 estimates of the annual survival rate produced by the Instantaneous Rates model for striped bass ≥ 28" ranged from 0.71 (NCCOOP) to 0.84 (NYTRAWL) among the coastal programs (Table 10). The unweighted average of these survival estimates was 0.78 and has varied from only 0.72-0.78 since 2000. The 2010 survival estimates for the producer areas ranged from 0.69 (DE/PA) to 0.76 (MDCB) and the weighted average of 0.73 has varied from only 0.70-0.73 since 2000.

The 2010 estimates of the annual survival rate for striped bass ≥ 18" ranged from 0.67 (NCCOOP) to 0.80 (MADFW) among the coastal programs (Table 11). The unweighted average of these survival estimates was 0.74 and has varied from only 0.72-0.74 since 2000. The 2010 survival estimates for the producer areas ranged from 0.59 (VARAP) to 0.73 (HUDSON and MDCB) and the weighted average of 0.69 has varied from only 0.63-0.69 since 2000.

6.5. Estimates of F and M

6.5.1. Program MARK and Constant M

Estimates of instantaneous mortality rates produced by using a constant assumed value of M (0.15) are presented to illustrate the problems associated with this method and provide justification for the change in protocol. Several programs show negative values of F, show erratic values among years, and some show F estimates above the target (0.30) and threshold (0.41) values throughout the time series. All negative values were not included in any averages or in the results.

Using constant M, the 2010 estimates of F for fish ≥ 28 inches among the coastal programs ranged from 0.14 (MADFW) to 0.30 (NCCOOP) with an unweighted average of 0.24 (Table 12). The F estimates from the Massachusetts program were much lower than the other coastal programs while the annual estimates from the New York program were highly erratic and often negative, especially since the change from haul seine to trawl in 2008. The 2010 estimates of F for the producer area programs ranged from 0.01 (VARAP) to 0.49 (DE/PA) and had a weighted average of 0.29. These average values are approaching the target value of 0.30.

Using constant M, the 2010 estimates of F for fish ≥ 18 inches among the coastal programs ranged from 0.13 (MADFW) to 0.44 (NCCOOP) with an unweighted average of 0.29 (Table 13). The estimates from the Massachusetts program were again much lower than the other coastal programs. The 2010 estimates of F from the producer area programs ranged from 0.15 (VARAP) to 0.43 (MDCB) and had a weighted average of 0.41. The producer area average was the lowest since 2003 while the coastal average was the lowest since 2002.

6.5.2. Program MARK and Baranov's catch equation

Results for each program are presented in Appendix E, which provide the catch equation input values of annual mortality (A), total instantaneous mortality (Z) and annual exploitation rate (u), as well as estimates of F and M for each program.

The 2010 catch equation estimates of F for fish ≥ 28 inches among the coastal programs ranged from 0.09 (MADFW and NCCOOP) to 0.16 (NJDEL). All values are well below the 0.30 target value for F (Table 14). The F estimates for the producer programs ranged from 0.11 (VARAP) to 0.31 (DEL/PA). The Maryland estimates were relatively stable. The Hudson and Delaware estimates increased in recent years while the Virginia of F decreased in recent years.

The 2010 catch equation estimates of F for fish ≥ 18 inches among the coastal programs were consistent, ranging from ranged 0.08 (MADFW) to 0.09 (NY, NJDEL and NCCOOP, Table 15). The F estimates for the producer area programs were in a narrow range from 0.04 (VARAP) to 0.18 (MDCB). Each program has shown a recent decline in their respective F estimates.

The unweighted mean fishing mortality in 2010 for fish ≥ 28 inches among the coastal programs was 0.11 (Table 14). The mean F estimate peaked at 0.27 in 1997 and has generally declined since. The weighted mean F in 2010 for fish ≥ 28 inches among the producer area programs was 0.11. The mean F peaked at 0.35 in 1997 and 1998, and has also generally decreased to 0.14 in 2010.

The unweighted mean fishing mortality in 2010 for fish ≥ 18 inches among the coastal programs was 0.08, which was slightly higher than in 2009. The mean F has varied from 0.04 to 0.13 during the timeseries, reaching its peak in 1996 and 1997.

6.5.3. Instantaneous Rates Model

The 2010 IRCR estimates of F for fish ≥ 28 inches among the coastal area programs ranged from 0.07 (NYTRAWL) to 0.16 (NJDEL) for an unweighted average F of 0.11 (Table 16). The annual estimates of F peaked at 0.26 in 1998, but have varied from only 0.12-0.19 since 2000. The 2010 F estimates for the producer area programs ranged from 0.06 (VARAP) to 0.23 (DE/PA) and a weighted average of 0.12. The Delaware River F values were the lowest reported among the producer areas in 2008, but they were incorrectly estimated. The updated values in this assessment are consistent with the Hudson River program. The mean fishing mortality estimates from both the coastal and the producer area programs were well below the target value of 0.30.

The 2010 IRCR estimates of F for fish ≥ 18 inches among the coastal areas showed little variation, ranging from 0.06 (NYTRAWL) to 0.13 (NJDEL) for an unweighted average of 0.09 (Table 17). The average F value has declined from 0.14 in 1997-1999 to 0.09-0.10 since 2004. The estimates of F for the producer area programs showed more variation, ranging from 0.05 (VARAP) to 0.16 (DE/PA) for a weighted average of 0.09. The average F value has declined from a peak of 0.25 in 1998 to 0.09-0.11 since 2005.

6.6. Estimates of stock size

6.6.1. Program MARK and constant M

Stock size estimates based on constant M for fish ≥ 18 inches (age 3+) was 9.0 million fish (Table 18), which was slightly higher than 2009 and 3.8 million less than the peak estimate in 2003 of 12.8 million fish. The stock size estimate has varied from 1.9-12.8 million fish during the time series.

The stock size estimates based on a constant M for fish ≥ 28 inches (age 7+) show a gradual increase to a peak of 7.7 million fish in 2002 (Table 18). The 2010 estimate for fish ≥ 28 inches was 6.5 million fish, an increase of 1.3 million from the estimated stock size in 2009.

6.6.2. Program MARK and Baranov's catch equation

Stock size estimates based on the catch equation method for fish ≥ 18 inches ranged from 7.6 to 42.1 million fish during the time series, reaching a peak of 42.0 million fish in 2006. The 2010 stock size estimate was 34.1 million fish which was the lowest stock size since 2003 (Table 19).

The stock size estimates based on the catch equation method for fish ≥ 28 inches peaked at 15.3 million fish in 2003 (Table 19) and decreased to 14.8 million fish in 2010.

6.6.3. Instantaneous Rates Model

The stock size estimates based on the instantaneous rates method for fish ≥ 18 inches also exhibit a rapid increase from 32.3 million fish in 2000 to a peak of 63.1 million fish in 2007 (Table 20). However, the estimate of stock size decreased to 41.2 million fish in 2010.

The stock size estimates based on the instantaneous rates method for fish ≥ 28 inches steadily increased from 8.7 million fish in 2000 to a peak of 17.1 million fish in 2006 (Table 20). The 2010 estimate of stock size was 16.3 million fish.

7. CHESAPEAKE BAY RESIDENT STOCK

The striped bass fishery in Chesapeake Bay exploits the pre-migratory/resident striped bass population that consists of smaller fish (TL < 28 inches), mostly ages 3 through 6. Fishing mortality in Chesapeake Bay was calculated using data from the same Maryland and Virginia tagging programs described above. The migratory rates reported by Dorazio et al. (1994) suggest that striped bass between 18 and 28 inches TL are predominantly resident fish. MDDNR data have shown that males comprise 80-90% of the resident fish population. Therefore, the data were limited to male striped bass in this size range to estimate fishing mortality on resident fish.

Fishing mortality for resident striped bass in Chesapeake Bay was estimated using the catch equation and IRCR, using the same methods previously described. Prior to conducting the analysis, release and recapture data from Maryland and Virginia were combined to produce Baywide input matrices for Program MARK and the IRCR, and to estimate a Baywide exploitation rate.

Two high-reward tagging studies have been conducted in the Chesapeake Bay to determine a Bay-specific reporting rate. In 1993, a rate of 0.75 was estimated by Rugolo et al. (1994). The study was repeated in 1999 and resulted in a slightly lower estimate of 0.64 (Hornick et al. 2000). Although the current coastwide assessment uses a value of 0.43, a value of 0.64 is used for the Chesapeake Bay analysis because it is the most recent area-specific value.

7.1. Program MARK and constant M

The year-specific (time-saturated) model received nearly 100% (0.997) of the weight in the Program MARK analysis of the 18-28 inch, resident stock of striped bass in Chesapeake Bay (Table 21). This produced an adjusted survival estimate for 2010 of 0.44 (Table 22). The annual estimates of survival peaked in 1989 during the moratorium at 1.01, but decreased to 0.63-0.74 from 1990-1996, decreased further to 0.24-0.54 since (with the exception of 2003). The resulting estimates of fishing mortality were very high and occasionally exceeded 1.0.

7.2. Program MARK and Baranov's catch equation

The combined (Virginia and Maryland) estimate of the catch rate for 2010 was 0.05 (Table 23). The estimate of catch rate peaked at 0.18 in 1996, but has varied without trend since 2002. The estimate of exploitation rate for 2010 was 0.04. The estimates of exploitation rate have varied from only 0.04-0.08 since 2002.

The estimate of instantaneous fishing mortality resulting from using the estimates of survival and exploitation rate in Baranov's catch equation for 2010 was 0.06 with instantaneous natural mortality estimated as 0.75 (Table 24). The estimates of F have been low but stable, varying from only 0.06-0.10 since 2002, with the exception of 2009 when F was 0.14. Estimates of M were consistently high and variable, and since 2000 have often exceeded 1.0

7.3. Instantaneous Rates Model

The IRCR model can be structured to estimate natural mortality as a constant for the entire period of the study or estimate different natural mortality values within time periods. Some studies have suggested that natural mortality of striped bass in Chesapeake Bay has increased since 1997 due to disease (mycobacteriosis) and reduced forage base (Ottinger 2006, Panek and Bobo 2006, Pieper 2006). Following these assumptions, estimates of fishing mortality were calculated using the IRCR model for two natural mortality scenarios – constant natural mortality for the entire period, and separate estimates of natural mortality for two periods (1987-1996 and 1997-2010). The years of the time periods were determined by the lowest AIC value of multiple model runs (this methodology is described in Appendix F).

The year-specific (time-saturated) model received 100% of the weight in the constant M IRCR model analysis (Table 21). The model produced an estimate of constant instantaneous natural mortality of 0.38 and survival estimates that varied from 0.58-0.68. Since 1999, the estimates of survival have varied from only 0.63-0.66. The estimate of instantaneous fishing mortality for 2010 was 0.03 and has varied from only 0.03-0.06 since 2001.

When two mortality periods are specified, the two-M suite received 100% of the weight, with the majority going to the year-specific F model (Table 21). The two estimates of instantaneous natural mortality differ greatly between the two periods, 0.30 and 0.90 respectively (Table 25). The estimates of survival decreased slowly from 0.74 in 1987 to 0.67 in 1998, then decreased further from 0.36-0.38 during 1999 to 2010. The estimates of instantaneous fishing mortality peaked at 0.13 in 1992 and 2003, but have declined to an estimate of 0.06 in 2010.

8. DISCUSSION

8.1. Data

The number of striped bass tagged by each program, their respective length frequencies and age distributions were all fairly typical of the past four years, North Carolina’s release total was up from their lowest in 2007 and Virginia’s releases were the second highest of their time series. The geographic distribution was also typical, with striped bass recaptures concentrated in northeastern coastal waters from June through September, off North Carolina in December through February, and year-round in Chesapeake Bay.

The difference between the total catch rate and the exploitation rate suggests that the live release rate was approximately 5%. This rate has been fairly constant since the mid-1990’s. This estimate could be biased low because anglers may be less likely to notice tags on fish they have released. They could also be less likely to report tags they do notice, since they are releasing the fish.

8.2. Model Diagnostics and Assumptions

8.2.1. Program MARK

Violations of the basic assumptions for the MARK model have been investigated in detail for the Virginia tag data set and only very minor violations of the assumption of complete mixing was detected (J. Hoenig, personal communication). The major concern is that the tagged fish be representative of the stocks.

It should be noted that analyses of data aggregated over space, as in the Virtual Population Analyses (VPA) is also problematic because it pertains to no specific area and because data from each constituent region is not weighted according to the abundance of striped bass in that region.

The principal problem with the use of the MARK modeling approach is that estimates are required for the terminal year and estimates for this year can only be obtained if strong assumptions are made, i.e., that the recovery rate, tag reporting rate or survival rate is either constant over the last two (or more) years or follows a known trend over the last three (or more) years. As one looks further back in the time series the estimates of survival tend to become more precise because more years have elapsed in which the data have accrued.

8.2.2. Baranov's Catch Equation

The catch equation method uses both the recovery matrix for the entire time series (calculation of S) and the most recent year's recovery data (calculation of exploitation). Some concern has been expressed about the use of two different time scales of the recovery data in the same equation, but the effect has not been investigated. It can be shown that the R/M ratio is a moment estimator of the tag recovery rate parameters the corresponding maximum likelihood estimator is the f parameter of the Brownie model. In other words, the two methods estimate the same parameter. The estimator R/M is more intuitive while the estimator f may be slightly more precise. Both approaches lead to estimates of the exploitation rate, given that the tag reporting rate is known. Also, given estimates of survival and exploitation rate, it is possible to solve for estimates of fishing and natural mortality rates. The critical issue is the tag reporting rate.

8.2.3. Instantaneous Rates Model

The instantaneous rates approach is a reparameterization of the Brownie models. It has the advantage that it explicitly links the tag recovery rate (f), and annual survival (S) parameters. In the Brownie models, these are allowed to vary independently so that, for one year to the next, the tag recovery rate and the survival rate can both go up. This is unreasonable if the tag reporting rate and the natural mortality rate are constant. An increase in f, and thus exploitation rate, should be accompanied by a decrease in the survival rate, unless the reporting rate or natural mortality rate has changed. In the instantaneous rates, one specifies the tag reporting rate and estimates F and M, or one specifies that M is constant and estimates F and the reporting rate.

It should be noted that the reporting rate is used mainly to apportion the total mortality into its F and M components. Hence, a modest misestimation of the reporting rate leads to little error in the estimated total mortality.

8.3. Reporting Rate

A constant reporting rate of 0.43 is used throughout these calculations, based on a high-reward tag study conducted on the Delaware River stock in 1999. The Delaware Division of Fish and Wildlife and the Pennsylvania Fish and Boat Commission conduct a cooperative survey of the Delaware River spawning stock of striped bass every spring (Kahn and Shirey 2000). Both agencies tag fish at that time as part of the USFWS cooperative striped bass tagging program. In 1999, a high reward tagging study was conducted in conjunction with the standard tagging program releasing 159 high reward tags on fish greater than 20 inches in length and 411 standard tags on fish greater than 18 inches in length. The reward for reporting a high reward tag was $100, a monetary reward believed to be high enough to precipitate a reporting rate response of 100% (Nichols et al. 1991). Total recoveries from the 1999 recovery year were 27 high reward tags and 37 standard tags. Only one high reward tag and 6 standard tags were recovered from the commercial fishery, so the 0.43 estimate of tag reporting rate was based on only the recreational fishery.

In 2007, a new high reward tagging study was initiated in order to determine if the tag reporting rate has changed. This study was conducted by the state agencies of Delaware, Maryland, New York, and Virginia during the 2007 and 2008 tagging seasons. Results from this study are detailed in Appendix G.

However, for continuity to previous assessments, the SBTS chose to continue with current convention and use the 0.43 reporting rate estimated from Kahn and Shirey (2000) for the 2009-2010 analyses until the results and implications of the current high reward tag study have been fully evaluated and approved.

8.4. Estimates of S

The bias-corrected estimates of S (Program MARK) for fish ≥ 28 inches ranged from 0.64 to 0.93 for the coastal programs to 0.53 to 0.73 for the producer area programs. For fish ≥ 18 inches, the values ranged from 0.56 to 0.75 for the coastal programs and 0.56 to 0.74 for the producer area programs. Estimates from North Carolina were consistently lowest for the coast while Virginia consistently had the highest estimates for the producer area programs.

The IRCR model estimates of S produced similar estimates of survival, ranging from 0.69-0.84 for striped bass ≥ 28 inches and 0.59-0.80 for striped bass ≥ 18 inches.

8.5. Estimates of F and M

The F estimates produced using the catch equation method were generally lower than those using constant M for the majority of programs. This is due to two factors. Because M is not held constant, more of the mortality can be partitioned into natural mortality. Also, F estimates reflect exploitation rate, which is generally low for fish between 18 and 28 inches (Tables 8 and 9).

In general, use of the catch equation produces more biologically reasonable F estimates, although not all of the problems seen with the use of constant M were eradicated. Some of the coastal programs results for fish ≥ 18 inches were erratic and lack credibility. As yet, the source of the erratic nature of these estimates has not been determined.

The IRCR model produced similar (≥ 28 inches) or lower (≥ 18 inches) estimates of F to the catch equation. Most programs showed similar results for fish ≥ 28 inches. For fish ≥ 18 inches, the estimates were almost identical for all programs except VARAP.

Coastal and producer area mean F estimates generated from the three methods are compared in Figures 1 and 2. All methods produce similar results through 2002 for the ≥ 28 inch fish. However, the erratic values produced by the constant M method for fish ≥ 18 inches are quite visible in Figure 2.

Natural mortality has been assumed to have remained constant at an assumed value of 0.15 in the MARK analyses. However, the IRCR and catch equation analyses indicate that natural mortality estimates are increasing and are well above the assumed value, especially for the ≥ 18 inch striped bass from the Chesapeake Bay programs. The two period IRCR analyses indicate that the rise in the natural mortality rate occurred as early as 1997 in Chesapeake Bay, but was evident by 2003 for the coastal programs and for the larger (≥ 28 inches) striped bass. Since an increase in natural mortality rates have management implications, the Tagging Subcommittee will continue to investigate the current value of natural mortality and the direction and magnitude of the change.

8.6. Estimates of Stock Size

The estimates of stock size for both age 7+ and age 3+ fish computed from the catch equation F's are lower than those obtained with the IRCR model. Catch equation F's are higher, which results in lower estimates of stock size for the same harvest. Estimates generated assuming a constant M are typically lower than the other two methods.

Stock size estimates from the three methods are compared in Figures 3 and 4. Estimates for age 7+ fish from the three methods are fairly similar through 2000, when the constant M estimates stabilize and catch equation and IRCR estimates continue to increase. Estimates for age 3+ fish from the constant M method show a stable abundance, while estimates from the catch equation and IRCR show continued growth.

8.7. Chesapeake Bay resident stock

Amendment 6 implemented a separate management program for the Chesapeake Bay due to the size availability of striped bass in this area. It also specified a separate fishing mortality target of 0.27 (ASMFC 2003). The striped bass fishery in Chesapeake Bay exploits the pre-migratory/resident striped bass population that consists of smaller fish (TL < 28 inches), mostly ages 3 through 6.

Estimates of F from the catch equation method were well below the target value of 0.27. Fishing mortality was near zero in the late 1980s and early 1990s (when the fishery reopened) and has been relatively flat and stable since then. Values have fluctuated between 0.06 - 0.14 without trend since that time. The 2010 estimate of F for the Chesapeake Bay was 0.06, the lowest value since 1990.

These low values of F in recent years are not consistent with the high levels of harvest in the Chesapeake Bay. The assumption that 18-28 inch males are all resident fish may be incorrect. If the fish are emigrating from the Bay at a smaller size and the tags are not recovered or not used in the analysis (for the Bay estimate of F, only recoveries within the Bay were considered), then emigration will result in an over-inflated estimate of natural mortality. This in turn will lead to an underestimated fishing mortality.

Estimates of natural mortality for Chesapeake Bay fish varied from near-zero values to 1.3. Very large inter-annual variation and large estimates of M are not biologically reasonable and should be viewed with caution. Although the values of M for recent years seem excessively high (between 0.7-1.3), the overall trend of increasing M is supported by some field observations.

A number of studies in recent years have indicated a development of mycobacteriosis, a bacterial disease in Chesapeake Bay striped bass beginning around 1997 (Ottinger 2006, Panek and Bobo 2006, Pieper 2006). The disease is believed to have spread significantly thereafter. It has been suggested that mycobacteriosis might lead to an increase in striped bass mortality. Kahn and Crecco (2006) analyzed MD and VA spring tagging data for two groups of fish (fish $\geq$ 18 inches TL and fish $\geq$ 28 inches TL) using Program MARK and the catch equation. They reported high natural mortality rates similar to those estimated in the present analysis and suggested that their high estimates of natural mortality were related to mycobacteriosis. However, as mentioned above, the natural mortality could be overestimated if migration out of the Bay is not accounted for at least in part or completely.

Baywide IRCR estimates of F were all below the target value of 0.27. Under the assumption of constant natural mortality over the time series, fishing mortality increased from near-zero values during the moratorium period to 0.15 in 1992, fluctuated without trend through 1998, then declined to 0.03 in 2010. When two different periods of M were considered, similar patterns in F were observed and values were higher. The IRCR model estimated levels of natural mortality that were up to six times the previously assumed value of 0.15 and suggested that most of total mortality is due to natural causes.

A significant advantage of the catch equation method and the IRCR model is the ability to estimate natural mortality in addition to fishing mortality, either through the use of external model results (the catch equation uses survival estimates from Program MARK) or internally (IRCR model). As reported above, estimated values of natural mortality from both methods were substantially higher than the life-history-based fixed level of natural mortality traditionally used in the analyses (0.15). A significant increase in natural mortality of striped bass in Chesapeake Bay may have a considerable effect on population dynamics and serious implications for management. An obvious effect of an increase in M is a faster decay of individual cohort size (increase in the catch curve slope) and overall decline of population abundance. A significant decline in population size should in turn affect fish availability and lead to a decline in CPUE and total harvest. However, the Bay landings reached record harvest values in 2006 have remained high and stable since then.

This lack of agreement between model results and observed fishery data suggests a need for careful evaluation of the tagging analysis assumptions (full mixing and equal probability of marked fish to be recovered) and interpretation of the results. What is currently interpreted in the model as total mortality can be more generally described as a rate of disappearance, where disappearance includes total mortality and emigration. Striped bass emigrate from Chesapeake Bay as they age and if the fish are moving to areas that are not fished or very lightly fished (for example, the EEZ) the probability of tagged fish being recovered becomes extremely low. In this case, the decline in the number of recovered tags is interpreted in the model as a decline in survival and increase in natural mortality. A simulation analysis is recommended to investigate the ability of the instantaneous rates model to differentiate natural mortality from emigration to areas with different or no fishing activity/tag returns.

9. SOURCES OF UNCERTAINTY

- The reporting rate is used in the bias adjustment and in the calculation of exploitation rate, which is used to estimate F in the catch equation method. Based on the most recent information, 0.43 is low. A current estimate is being evaluated, but possible violations in assumptions (100% reporting of the high reward tags) have complicated the analyses and have to be resolved.

- Violations of Program MARK assumptions:
  - The sample is representative of the target population;
  - There is no tag loss;
  - Survival rates are not affected by the tagging itself;
  - The year of tag recoveries is correctly tabulated;
  - The fate of each tagged fish is independent of the fate of other tagged fish;
  - The fate of a given tagged fish is a multinomial random variable; and
  - All tagged individuals of an identifiable class (age, sex) in the sample have the same annual survival and recovery rates.

- Model averaging incorporates the uncertainty of model selection into the variance of parameter estimates (Burnham and Anderson 2003).

- Bias adjustment is affected by release survival rate – a constant value of 0.92 is used, whereas studies have shown that survival varies by age, type of hook, and temperature.

- 95% confidence intervals for the area F estimates without inclusion of the covariance terms (because covariance terms could not be estimated from these data, they were assumed to be negligible).

- The catch equation method uses both the recovery matrix for the entire time series (calculation of S) and the most recent year's recovery vector (calculation of exploitation). Some concern has been expressed about the use of two different time scales of the recovery data in the same equation, but the effect has not been investigated.

- Variance associated with the area mean F estimates were calculated as the additive variances and do not include covariance terms.

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Table 1. Candidate models used in the analyses of striped bass tag recoveries in Program MARK.

S(.) r(.)	Constant survival and reporting
S(t) r(t)	Time specific survival and reporting – the global model
S(.) r(t)	Constant survival and time specific reporting
S(p) r(t)	*Regulatory period based survival and time specific reporting
S(p) r(p)	*Regulatory period based survival and reporting
S(.) r(p)	*Constant survival and regulatory period based reporting
S(t) r(p)	*Time specific survival and regulatory period reporting
S(d) r(p)	**Regulatory period based survival with unique terminal year and regulatory period based reporting
S(v) r(p)	***Regulatory period based survival with 2 terminal years unique and regulatory period based reporting
* Periods (p)	1 = {1987-1989}, 2 = {1990-1994}, 3 = {1995- 1999}, 4 = {2000-2002}, 5 = {2003-2010}
** Periods (d)	1 = {1987-1989}, 2 = {1990-1994}, 3 = {1995- 1999}, 4 = {2000-2002}, 5 = {2003-2009}, 6 = {2010}
*** Periods (v)	1 = {1987-1989}, 2 = {1990-1994}, 3 = {1995- 1999}, 4 = {2000-2002}, 5 = {2003-2008}, 6 = {2009-2010}

Table 2. Justification of modeling periods used in candidate model set.

Regulatory Period	Explanation
1987-1989	Partial moratorium and large minimum size limits.
1990-1994	Interim fishery under Amendment 4: Commercial fisheries reopen in some states at 80% of historical harvest. Preferred size limit reduced to 28” on coast and 18” in Hudson and Chesapeake Bay. Combination of size limits, seasons, and bag limits used to attain target fishing mortality rate.
1995-1999	Fully recovered fishery under Amendment 5: Target F=0.33. Recreational fisheries: 20” minimum size, 1 fish creel limit, variable season lengths in the producer areas (Chesapeake Bay, Hudson River,) and 28” minimum size, 2 fish creel limit, 365 day season along the coast. Commercial fisheries: flexible quota, same size limits as the recreational fishery. Establishes quotas based on size limits and has paybacks for quota overages. Target reduced to F=0.31 in 1997, minimum size limits maintained.
2000-2002	Addendum IV to Amendment 5: reduce F on age 8 and older striped bass by 14% through creel and size limits. Credit was given to states already more conservative.
2003-2010	Amendment 6: Target F = 0.30. Coastal commercial quotas increased to 100% of historical harvest. Some states’ minimum size limits increased to 28” on the coast.

Table 3. Candidate models used in the analyses of striped bass tag recoveries in the IRCR.

Model Number	Model Name	Description
1	Fy, F'y, M87-10 (Global Model)	F and F' estimated each year, constant M for entire period
2	F87-89, F90-94, F95-99, F00-02, F03-10, F'y, M87-10	Constant F for each regulatory period, F' estimated each year, constant M for entire period
3	F87-10, F'y, M87-10	Constant F over entire period, F' estimated each year, constant M for entire period
4	Fy, F'87-89, F'90-94, F'95-99, F'00-02, F'03-10, M87-10	F estimated each year, constant F' for each regulatory period, constant M for entire period
5	Fy, F'87-10, M87-10	F estimated each year, constant F' for entire period, constant M
6	F87-89, F90-94, F95-99, F00-02, F03-10, F87-89, F'90-94, F'95-99, F'00-02, F'03-10, M87-10	Constant F for each regulatory period, constant F' for each regulatory period, constant M for entire period
7	F87-10, F'87-10, M87-10	Constant F for entire period, constant F' for entire period, constant M for entire period
8	F87-89, F90-94, F95-99, F00-02, F03-09, F10; F'87-89, F'90-94, F'95-99, F'00-02, F'03-09, F'10, M87-10	Constant F and F' for each regulatory period with separate estimate for terminal year, constant M for entire period
9	F87-89, F90-94, F95-99, F00-02, F03-08, F09-10; F'87-89, F'90-94, F'95-99, F'00-02, F'03-08, F'09-10, M87-10	Constant F and F' for each regulatory period with separate estimate for terminal two years, constant M for entire period

Table 4. Total length frequencies of fish tagged in 2009-2010 by program.

	Coast programs								**Producer Area programs**							
	MADFW		NYTRL		NJDEP		NCCOOP		HUDSON		DE/PA		MDCB		VARAP	
TL (mm)	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
<199	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200-249	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
250-299	0	0	0	0	0	0	0	1	0	0	0	6	0	0	0	0
300-349	0	0	0	0	0	0	0	0	0	0	5	29	0	0	0	0
350-399	0	0	1	0	0	0	0	0	0	0	31	46	0	0	0	0
400-449	0	0	12	0	0	0	0	0	40	86	73	54	0	0	0	0
450-499	0	0	7	0	12	4	0	0	79	82	172	139	130	256	17	50
500-549	0	0	13	9	117	30	0	2	67	81	127	177	173	444	18	85
550-599	6	0	33	13	376	116	2	16	41	72	76	67	205	514	22	74
600-649	2	0	17	80	778	253	3	41	38	43	63	52	103	324	21	78
650-699	27	14	17	106	535	379	15	77	26	25	43	42	11	29	24	87
700-749	68	42	15	107	224	246	22	106	24	31	50	34	19	40	33	58
750-799	75	89	11	44	92	103	28	118	14	32	34	41	29	74	60	76
800-849	85	76	8	14	70	38	25	77	24	26	43	21	49	66	80	100
850-899	87	44	7	7	26	17	27	68	16	21	32	27	45	92	99	86
900-949	76	30	6	4	6	6	10	29	14	18	35	20	47	78	86	79
950-999	48	17	1	3	2	3	6	20	21	11	33	24	32	62	31	44
1000-1049	14	11	0	0	1	0	3	7	8	4	20	17	17	42	13	18
1050-1099	10	4	0	0	0	0	3	5	5	6	16	13	6	12	2	5
>1099	3	0	0	0	0	0	2	0	6	4	3	12	2	17	1	0

Table 5. Total age frequencies of fish recaptured in 2009-2010 by program.

	Coast programs								**Producer Area programs**							
	MADFW		NYTRL		NJDEP		NCCOOP		HUDSON		DE/PA		MDCB		VARAP	
AGE	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
1	0	0	0	0	0	0	NA	NA	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0			0	0	0	1	0	0	0	0
3	0	0	0	2	0	0			5	15	4	2	0	0	0	0
4	0	0	1	0	4	0			20	77	2	4	3	0	18	3
5	0	1	5	2	29	1			29	100	4	6	1	0	19	17
6	5	0	42	4	134	19			37	106	9	12	12	0	8	12
7	4	5	6	24	44	54			59	110	15	5	1	1	3	1
8	5	5	10	3	53	102			83	114	16	6	5	2	2	4
9	5	6	9	6	47	42			89	107	5	5	4	3	2	3
10	3	6	2	4	21	36			76	88	4	4	0	2	4	7
11	5	5	2	1	13	30			54	59	3	5	4	0	4	4
12	4	2	0	3	11	11			32	35	2	3	3	0	4	0
13	10	1	0	0	13	11			15	17	3	5	6	4	10	6
14	5	2	1	1	2	7			4	4	6	6	2	5	5	4
15	1	2	0	1	2	5			3	3	2	5	5	4	3	4
16	4	1	0	0	2	2			1	1	2	1	5	1	2	2
17	0	2	0	0	0	3			0	0	2	3	1	1	2	1
18	1	0	0	0	0	2			0	0	1	1	0	1	0	0
19	0	0	0	0	0	1			0	0	1	0	0	1	0	0
20	0	0	0	0	1	0			0	0	1	0	0	0	0	0
21	0	0	0	0	0	0			0	0	0	0	0	0	0	1
22	0	0	0	0	0	3			0	0	0	1	0	1	0	0
23	0	0	0	0	0	0			0	0	0	0	0	0	0	0
24	0	0	0	0	1	0			0	0	0	0	0	0	0	0
25	0	0	0	0	0	0			0	0	0	0	0	0	0	0

Table 6. R/M estimates of catch rates of ≥28 inch striped bass from tagging programs. Catch rate is the proportion of tagged striped bass that were caught, but may have been released (with reporting rate adjustment of 0.43).

Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP	**MEAN**
1987							0.08		0.08
1988		0.27		0.21	0.21		0.11		0.20
1989		0.24	0.24	0.13	0.25		0.10		0.19
1990		0.22	0.52	0.18	0.32		0.18	0.49	0.32
1991		0.26	0.47	0.2	0.24		0.28	0.58	0.34
1992	0.11	0.33	0.21	0.25	0.29		0.24	0.58	0.29
1993	0.10	0.28	0.20	0.28	0.32	0.22	0.22	0.57	0.27
1994	0.10	0.23	0.20	0.20	0.26	0.20	0.22	0.36	0.22
1995	0.15	0.35	0.23	0.27	0.25	0.26	0.28	0.55	0.29
1996	0.17	0.32	0.32	0.15	0.30	0.38	0.26	0.21	0.26
1997	0.30	0.43	0.41	0.24	0.37	0.35	0.28	0.44	0.35
1998	0.15	0.17	0.39	0.26	0.29	0.36	0.28	0.60	0.31
1999	0.16	0.36	0.21	0.27	0.30	0.22	0.25	0.39	0.27
2000	0.14	0.33	0.22	0.13	0.22	0.38	0.20	0.41	0.25
2001	0.10	0.20	0.23	0.21	0.19	0.33	0.16	0.35	0.22
2002	0.16	0.38	0.17	0.15	0.24	0.23	0.13	0.44	0.24
2003	0.12	0.21	0.24	0.16	0.21	0.27	0.16	0.40	0.22
2004	0.11	0.26	0.26	0.17	0.27	0.26	0.11	0.24	0.21
2005	0.10	0.33	0.30	0.10	0.23	0.25	0.15	0.31	0.22
2006	0.14	0.20	0.26	0.17	0.19	0.26	0.17	0.32	0.21
2007	0.07	0.28	0.20	0.24	0.19	0.26	0.12	0.25	0.20
2008	0.10	0.13*	0.21	0.25	0.21	0.14	0.13	0.19	0.17
2009	0.13	0.18*	0.28	0.08	0.25	0.27	0.19	0.10	0.19
2010	0.11	0.12*	0.18	0.09	0.25	0.33	0.13	0.08	0.16

* = NY TRAWL

Table 7. R/M estimates of catch rates of ≥18 inch striped bass from tagging programs. Catch rate is the proportion of tagged striped bass that were caught, but may have been released (with reporting rate adjustment of 0.43).

Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP	**MEAN**
1987							0.17	0.17	0.17
1988		0.17		0.19	0.15		0.10	0.10	0.15
1989		0.23	0.25	0.11	0.20		0.08	0.08	0.17
1990		0.20	0.38	0.16	0.26		0.14	0.14	0.25
1991		0.18	0.17	0.19	0.25		0.20	0.20	0.21
1992	0.12	0.19	0.19	0.25	0.23		0.24	0.24	0.25
1993	0.09	0.14	0.17	0.21	0.24	0.25	0.18	0.18	0.21
1994	0.11	0.17	0.17	0.17	0.21	0.25	0.23	0.23	0.21
1995	0.13	0.15	0.20	0.23	0.22	0.29	0.29	0.29	0.23
1996	0.17	0.17	0.24	0.14	0.26	0.27	0.28	0.28	0.23
1997	0.25	0.18	0.26	0.21	0.31	0.25	0.30	0.30	0.26
1998	0.16	0.15	0.28	0.24	0.24	0.27	0.33	0.33	0.24
1999	0.11	0.15	0.17	0.27	0.22	0.20	0.24	0.24	0.20
2000	0.10	0.13	0.20	0.15	0.21	0.26	0.27	0.27	0.20
2001	0.09	0.15	0.22	0.17	0.18	0.24	0.19	0.19	0.19
2002	0.15	0.18	0.13	0.18	0.18	0.20	0.17	0.17	0.18
2003	0.11	0.15	0.20	0.15	0.20	0.26	0.19	0.19	0.19
2004	0.11	0.14	0.25	0.17	0.21	0.22	0.16	0.16	0.18
2005	0.10	0.16	0.23	0.08	0.18	0.29	0.15	0.15	0.17
2006	0.13	0.18	0.18	0.16	0.16	0.24	0.20	0.20	0.19
2007	0.07	0.14	0.22	0.21	0.15	0.18	0.13	0.13	0.16
2008	0.10	0.12*	0.19	0.23	0.17	0.21	0.16	0.16	0.16
2009	0.12	0.21*	0.20	0.08	0.23	0.25	0.20	0.20	0.18
2010	0.11	0.18*	0.15	0.09	0.19	0.21	0.18	0.18	0.14

* = NY TRAWL

Table 8. R/M estimates of exploitation rates of ≥28 inch striped bass from tagging programs. Exploitation rate is the proportion of tagged fish that were harvested or killed (with reporting rate adjustment of 0.43, and hooking mortality rate adjustment of 0.08).

Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP	**MEAN**
1987							--		
1988		0.05		0.06	0.10		0.07		0.07
1989		0.04	0.02	0.04	0.07		0.04		0.04
1990		0.07	0.05	0.09	0.11		0.09	0.25	0.11
1991		0.13	0.18	0.07	0.10		0.12	0.36	0.16
1992	0.04	0.11	0.02	0.13	0.13		0.12	0.37	0.13
1993	0.05	0.14	0.09	0.11	0.16	0.14	0.12	0.37	0.15
1994	0.04	0.09	0.05	0.08	0.12	0.12	0.12	0.25	0.11
1995	0.04	0.21	0.11	0.14	0.15	0.16	0.21	0.41	0.18
1996	0.08	0.14	0.20	0.11	0.22	0.30	0.17	0.18	0.18
1997	0.17	0.34	0.25	0.18	0.29	0.31	0.23	0.38	0.27
1998	0.07	0.17	0.35	0.20	0.21	0.30	0.23	0.45	0.25
1999	0.09	0.31	0.08	0.24	0.21	0.18	0.21	0.30	0.20
2000	0.13	0.18	0.14	0.06	0.14	0.32	0.17	0.28	0.18
2001	0.07	0.11	0.15	0.15	0.13	0.30	0.11	0.24	0.16
2002	0.07	0.23	0.11	0.12	0.19	0.23	0.10	0.35	0.18
2003	0.11	0.15	0.15	0.11	0.14	0.17	0.11	0.28	0.15
2004	0.09	0.15	0.15	0.12	0.21	0.23	0.08	0.16	0.15
2005	0.07	0.26	0.17	0.07	0.17	0.16	0.11	0.24	0.16
2006	0.09	0.13	0.15	0.12	0.15	0.21	0.14	0.26	0.16
2007	0.05	0.02	0.13	0.19	0.16	0.20	0.09	0.19	0.13
2008	0.08	0.07*	0.14	0.19	0.15	0.12	0.11	0.19	0.13
2009	0.10	0.01*	0.23	0.04	0.19	0.22	0.17	0.08	0.13
2010	0.07	0.12*	0.13	0.07	0.19	0.23	0.10	0.05	0.12

* = NY TRAWL

Table 9. R/M estimates of exploitation rates of >18" striped bass from tagging programs. Exploitation rate is the proportion of tagged fish that were harvested or killed (with reporting rate adjustment of 0.43, and hooking mortality rate adjustment of 0.08).

Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP	**MEAN**
1987							0.01		0.01
1988		0.03		0.03	0.05		0.01		0.03
1989		0.03	0.03	0.03	0.05		0.01		0.03
1990		0.04	0.07	0.06	0.07		0.07	0.17	0.08
1991		0.06	0.03	0.08	0.07		0.10	0.14	0.08
1992	0.04	0.05	0.04	0.14	0.09		0.13	0.32	0.11
1993	0.04	0.04	0.03	0.11	0.10	0.14	0.11	0.23	0.10
1994	0.04	0.04	0.03	0.08	0.09	0.12	0.12	0.26	0.10
1995	0.03	0.06	0.06	0.14	0.12	0.14	0.19	0.19	0.12
1996	0.06	0.04	0.09	0.11	0.15	0.15	0.17	0.15	0.11
1997	0.12	0.05	0.08	0.15	0.22	0.14	0.21	0.20	0.15
1998	0.08	0.03	0.12	0.14	0.17	0.15	0.22	0.15	0.13
1999	0.06	0.06	0.06	0.22	0.14	0.11	0.17	0.13	0.12
2000	0.08	0.03	0.08	0.08	0.10	0.15	0.17	0.14	0.10
2001	0.05	0.05	0.09	0.11	0.09	0.15	0.12	0.18	0.11
2002	0.08	0.07	0.06	0.12	0.08	0.14	0.12	0.19	0.11
2003	0.08	0.05	0.08	0.11	0.10	0.15	0.13	0.19	0.11
2004	0.09	0.04	0.12	0.12	0.13	0.15	0.10	0.12	0.11
2005	0.06	0.04	0.09	0.06	0.09	0.11	0.11	0.15	0.09
2006	0.08	0.04	0.06	0.10	0.10	0.12	0.14	0.16	0.10
2007	0.04	0.02	0.11	0.16	0.09	0.08	0.09	0.14	0.09
2008	0.07	0.03*	0.09	0.18	0.09	0.08	0.11	0.10	0.09
2009	0.09	0.06*	0.07	0.05	0.15	0.12	0.17	0.09	0.10
2010	0.07	0.07*	0.07	0.07	0.12	0.10	0.13	0.04	0.08

* = NY TRAWL

Table 10. Unweighted average of the annual estimates of survival for the coastal programs, and a weighted average for producer areas, for striped bass ≥28 inches using the Instantaneous Rates model program.

	Coastal Programs					Producer Area Programs				
Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	Unweighted average	HUDSON	DE/PA	MDCB	VARAP	Weighted Average
1987								0.82		**0.82**
1988		0.88		0.78	**0.83**	0.80		0.82		**0.82**
1989		0.86	0.88	0.77	**0.84**	0.79		0.82		**0.81**
1990		0.80	0.79	0.72	**0.77**	0.74		0.73	0.65	**0.71**
1991		0.76	0.60	0.73	**0.70**	0.74		0.73	0.65	**0.71**
1992	0.84	0.77	0.87	0.72	**0.80**	0.74		0.73	0.65	**0.71**
1993	0.82	0.74	0.80	0.72	**0.77**	0.74	0.71	0.73	0.65	**0.71**
1994	0.80	0.78	0.84	0.72	**0.79**	0.74	0.71	0.73	0.65	**0.71**
1995	0.79	0.70	0.80	0.67	**0.74**	0.67	0.66	0.64	0.60	**0.64**
1996	0.72	0.69	0.72	0.68	**0.70**	0.67	0.66	0.65	0.60	**0.64**
1997	0.70	0.66	0.73	0.66	**0.69**	0.67	0.66	0.64	0.60	**0.64**
1998	0.72	0.63	0.64	0.66	**0.66**	0.67	0.66	0.64	0.60	**0.64**
1999	0.70	0.66	0.73	0.67	**0.69**	0.67	0.66	0.64	0.60	**0.64**
2000	0.72	0.72	0.75	0.70	**0.72**	0.73	0.65	0.72	0.66	**0.70**
2001	0.79	0.72	0.73	0.69	**0.73**	0.73	0.65	0.72	0.66	**0.70**
2002	0.76	0.72	0.74	0.70	**0.73**	0.72	0.65	0.72	0.66	**0.70**
2003	0.76	0.70	0.71	0.70	**0.72**	0.71	0.69	0.75	0.67	**0.72**
2004	0.78	0.71	0.73	0.70	**0.73**	0.71	0.69	0.75	0.67	**0.72**
2005	0.78	0.75	0.72	0.70	**0.74**	0.71	0.69	0.75	0.67	**0.72**
2006	0.78	0.78	0.78	0.70	**0.76**	0.71	0.69	0.75	0.67	**0.72**
2007	0.81	0.81	0.76	0.70	**0.77**	0.71	0.69	0.76	0.67	**0.72**
2008	0.78	0.74*	0.74	0.70	**0.74**	0.71	0.69	0.75	0.67	**0.72**
2009	0.77	0.76*	0.73	0.70	**0.74**	0.71	0.69	0.76	0.70	**0.73**
2010	0.81	0.84*	0.76	0.71	**0.78**	0.71	0.69	0.76	0.70	**0.73**

*NY TRAWL

Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 11. Unweighted average of the annual estimates of survival for the coastal programs, and a weighted average for producer areas, for striped bass ≥18 inches using the Instantaneous Rates model.

	Coastal Programs					Producer Area Programs				
Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	Unweighted average	HUDSON	DE/PA	MDCB	VARAP	Weighted Average
1987								0.79		
1988		0.79		0.73	**0.76**	0.80		0.79		**0.79**
1989		0.78	0.81	0.73	**0.77**	0.79		0.79		**0.79**
1990		0.74	0.79	0.67	**0.73**	0.75		0.74	0.57	**0.69**
1991		0.75	0.79	0.67	**0.74**	0.75		0.70	0.57	**0.69**
1992	0.83	0.75	0.80	0.67	**0.76**	0.75		0.66	0.57	**0.69**
1993	0.81	0.75	0.80	0.67	**0.76**	0.75	0.66	0.67	0.57	**0.65**
1994	0.80	0.75	0.80	0.67	**0.76**	0.75	0.66	0.67	0.57	**0.65**
1995	0.80	0.72	0.75	0.63	**0.73**	0.68	0.65	0.62	0.54	**0.61**
1996	0.75	0.72	0.73	0.63	**0.71**	0.69	0.65	0.63	0.55	**0.62**
1997	0.72	0.72	0.73	0.63	**0.70**	0.68	0.65	0.59	0.55	**0.60**
1998	0.74	0.72	0.72	0.63	**0.70**	0.69	0.65	0.56	0.55	**0.58**
1999	0.73	0.72	0.74	0.63	**0.71**	0.69	0.65	0.59	0.55	**0.60**
2000	0.74	0.74	0.73	0.66	**0.72**	0.73	0.65	0.64	0.57	**0.63**
2001	0.80	0.74	0.72	0.66	**0.73**	0.73	0.65	0.67	0.57	**0.63**
2002	0.76	0.74	0.73	0.66	**0.72**	0.73	0.65	0.70	0.57	**0.67**
2003	0.77	0.75	0.72	0.67	**0.73**	0.73	0.66	0.68	0.57	**0.66**
2004	0.78	0.74	0.72	0.67	**0.73**	0.73	0.66	0.71	0.57	**0.67**
2005	0.78	0.74	0.72	0.67	**0.73**	0.73	0.66	0.72	0.57	**0.67**
2006	0.78	0.74	0.73	0.67	**0.73**	0.73	0.66	0.71	0.57	**0.67**
2007	0.81	0.74	0.73	0.67	**0.74**	0.73	0.66	0.74	0.57	**0.69**
2008	0.78	0.75*	0.73	0.67	**0.73**	0.73	0.66	0.74	0.57	**0.69**
2009	0.77	0.75*	0.74	0.67	**0.73**	0.73	0.66	0.71	0.57	**0.67**
2010	0.80	0.75*	0.73	0.67	**0.74**	0.73	0.66	0.73	0.59	**0.69**

*NY TRAWL

Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 12. Unweighted average of the annual estimates of instantaneous fishing mortality for the coastal programs, and a weighted average for producer areas, for striped bass ≥28 inches using program MARK and assuming constant instantaneous natural mortality.

	Coastal Programs					Producer Area Programs				
Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	Unweighted average	HUDSON	DE/PA	MDCB	VARAP	Weighted Average
1987								-0.05		-
1988		-0.18		0.03	0.03	0.03		-0.11		0
1989		-0.14	-0.04	0.10	0.10	-0.06		-0.15		-
1990		0.18	-0.03	0.09	0.14	0.05		0.17	0.18	0.18
1991		0.17	-0.16	0.09	0.13	0.14		0.07	0.17	0.12
1992	0.03	0.08	0.09	0.08	0.07	0.09		0.11	0.12	0.13
1993	0.04	0.19	0.15	0.10	0.12	0.11	-0.08	0.14	0.22	0.18
1994	0.02	0.15	0.08	0.11	0.09	0.11	-0.11	0.15	0.24	0.19
1995	0.07	0.11	0.07	0.19	0.11	0.15	0.21	0.21	0.30	0.28
1996	0.06	0.06	0.10	0.25	0.12	0.18	0.22	0.23	0.37	0.32
1997	0.07	0.17	0.14	0.22	0.15	0.16	0.31	0.23	0.35	0.32
1998	0.06	0.28	0.21	0.22	0.19	0.18	0.26	0.24	0.29	0.31
1999	0.11	0.22	0.06	0.22	0.15	0.16	0.29	0.24	0.32	0.31
2000	0.15	-0.01	0.06	0.21	0.14	0.16	0.22	0.26	0.17	0.27
2001	0.09	0.02	0.08	0.20	0.10	0.18	0.26	0.26	0.20	0.28
2002	0.05	0.00	0.08	0.20	0.08	0.18	0.30	0.25	0.17	0.27
2003	0.18	0.36	0.22	0.30	0.27	0.23	0.17	0.29	0.32	0.34
2004	0.17	0.32	0.21	0.29	0.25	0.26	0.26	0.31	0.19	0.32
2005	0.16	0.36	0.14	0.31	0.24	0.24	0.18	0.29	0.20	0.31
2006	0.15	0.33	0.21	0.29	0.25	0.25	0.25	0.28	0.19	0.31
2007	0.15	0.32	0.23	0.28	0.25	0.26	0.24	0.30	0.20	0.32
2008	0.16	-0.14*	0.23	0.28	0.22	0.24	0.28	0.30	0.21	0.33
2009	0.18	-0.24*	0.27	0.31	0.25	0.23	0.58	0.30	0.18	0.35
2010	0.14	-0.07*	0.27	0.30	0.24	0.27	0.49	0.30	0.01	0.29

*NY TRAWL
Negative values excluded from averages.

Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 13. Unweighted average of the annual estimates of instantaneous fishing mortality for the coastal programs, and a weighted average for producer areas, for striped bass ≥18 inches using program MARK and assuming constant instantaneous natural mortality.

	Coastal Programs					Producer Area Programs				
Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	Unweighted average	HUDSON	DE/PA	MDCB	VARAP	Weighted Average
1987								-0.14		
1988		0.33		-0.24	0.33	0.04		-0.06		0.00
1989		-0.25	-0.27	0.24	0.24	-0.01		-0.05		
1990		0.29	-0.27	0.36	0.33	0.07		0.23	-0.09	0.16
1991		-0.01	0.26	0.18	0.22	0.11		0.20	1.02	0.49
1992	0.03	-0.20	0.17	-0.03	0.10	0.12		0.18	-0.08	0.13
1993	0.05	0.48	0.28	-0.01	0.27	0.13	0.15	0.22	0.25	0.26
1994	0.03	0.12	0.11	0.48	0.19	0.12	0.16	0.19	0.32	0.26
1995	0.05	-0.07	-0.13	-0.17	0.05	0.14	0.31	0.30	0.18	0.30
1996	0.03	-0.08	-0.06	0.37	0.20	0.13	0.31	0.30	0.26	0.33
1997	0.07	0.14	0.33	0.46	0.25	0.15	0.32	0.32	0.36	0.38
1998	0.07	0.53	0.02	0.15	0.19	0.16	0.33	0.32	0.67	0.48
1999	0.11	0.10	0.02	-0.14	0.08	0.16	0.32	0.35	0.76	0.53
2000	0.15	0.28	-0.05	0.96	0.46	0.11	0.30	0.42	0.61	0.52
2001	0.09	0.13	0.07	0.30	0.15	0.15	0.31	0.45	0.54	0.53
2002	0.08	0.21	0.32	0.41	0.26	0.12	0.32	0.46	0.29	0.45
2003	0.16	0.15	0.31	0.21	0.21	0.22	0.43	0.43	-0.01	0.36
2004	0.16	0.36	0.10	-0.14	0.21	0.24	0.44	0.44	0.86	0.65
2005	0.15	0.59	0.24	1.18	0.54	0.24	0.39	0.45	0.55	0.55
2006	0.14	-0.16	0.27	0.71	0.37	0.24	0.42	0.43	0.45	0.51
2007	0.13	2.03	0.17	0.35	0.67	0.25	0.40	0.45	0.40	0.50
2008	0.15	0.27*	0.13	-0.13	0.18	0.24	0.40	0.45	0.48	0.53
2009	0.17	0.25*	-0.14	-0.13	0.21	0.22	0.41	0.46	0.29	0.47
2010	0.13	0.34*	0.23	0.44	0.29	0.28	0.40	0.43	0.15	0.41

*NY TRAWL

Negative values excluded from averages.

Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 14. Unweighted average of the annual estimates of instantaneous fishing mortality for the coastal programs, and a weighted average for producer areas, for striped bass ≥28” using the catch equation.

Coast Programs

Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	Unweighted average	lower 95% CI	upper 95% CI
1988		0.05		0.04	**0.04**	0.03	0.06
1989		0.04	0.02	0.03	**0.03**	0.02	0.04
1990		0.08	0.04	0.07	**0.06**	0.04	0.09
1991		0.15	0.18	0.09	**0.14**	0.05	0.22
1992	0.04	0.13	0.02	0.15	**0.08**	0.05	0.12
1993	0.05	0.16	0.10	0.12	**0.11**	0.06	0.16
1994	0.04	0.11	0.06	0.09	**0.07**	0.05	0.10
1995	0.05	0.24	0.12	0.16	**0.14**	0.09	0.19
1996	0.09	0.16	0.22	0.13	**0.15**	0.09	0.20
1997	0.19	0.40	0.29	0.18	**0.27**	0.16	0.38
1998	0.08	0.21	0.42	0.17	**0.22**	0.13	0.31
1999	0.10	0.37	0.09	0.26	**0.20**	0.11	0.30
2000	0.15	0.19	0.15	0.10	**0.15**	0.08	0.21
2001	0.08	0.12	0.17	0.13	**0.12**	0.08	0.17
2002	0.08	0.24	0.12	0.14	**0.15**	0.09	0.20
2003	0.13	0.19	0.18	0.13	**0.16**	0.10	0.21
2004	0.11	0.18	0.18	0.14	**0.15**	0.10	0.21
2005	0.08	0.33	0.19	0.07	**0.17**	0.08	0.25
2006	0.10	0.16	0.17	0.13	**0.14**	0.08	0.20
2007	0.06	0.03	0.16	0.19	**0.11**	0.07	0.15
2008	0.09	0.07*	0.17	0.22	**0.14**	0.09	0.18
2009	0.12	0.01*	0.28	0.05	**0.12**	0.07	0.17
2010	0.09	0.13*	0.16	0.09	**0.11**	0.08	0.15

Negative values excluded from averages.

* = NY TRAWL

Table 14 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	Weighted average*	lower 95% CI	upper 95% CI
1987					**0.00**	0.00	0.00
1988	0.11		0.08		**0.05**	0.00	0.11
1989	0.07		0.04		**0.03**	0.00	0.06
1990	0.12		0.10	0.18	**0.14**	0.06	0.22
1991	0.12		0.13	0.23	**0.19**	0.09	0.30
1992	0.14		0.14	0.34	**0.20**	0.06	0.34
1993	0.18	0.15	0.14	0.28	**0.23**	0.12	0.33
1994	0.14	0.12	0.13	0.33	**0.18**	0.08	0.27
1995	0.17	0.19	0.25	0.22	**0.30**	0.16	0.44
1996	0.26	0.36	0.21	0.18	**0.23**	0.12	0.34
1997	0.33	0.38	0.28	0.25	**0.35**	0.19	0.50
1998	0.25	0.37	0.27	0.22	**0.35**	0.19	0.52
1999	0.24	0.22	0.26	0.20	**0.28**	0.13	0.43
2000	0.16	0.38	0.21	0.19	**0.25**	0.13	0.37
2001	0.16	0.36	0.13	0.25	**0.19**	0.11	0.28
2002	0.23	0.29	0.12	0.23	**0.22**	0.11	0.34
2003	0.17	0.20	0.13	0.21	**0.20**	0.11	0.30
2004	0.25	0.28	0.11	0.20	**0.16**	0.09	0.23
2005	0.20	0.18	0.14	0.20	**0.19**	0.10	0.29
2006	0.18	0.26	0.17	0.21	**0.22**	0.11	0.34
2007	0.19	0.24	0.12	0.19	**0.17**	0.08	0.26
2008	0.18	0.14	0.14	0.13	**0.17**	0.05	0.29
2009	0.23	0.32	0.21	0.11	**0.19**	0.09	0.30
2010	0.24	0.31	0.12	0.04	**0.14**	0.06	0.21

* Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 15. Unweighted average of the annual estimates of instantaneous fishing mortality for the coastal programs, and a weighted average for producer areas, for striped bass ≥18 inches using the catch equation.

Coast Programs

Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	**Unweighted average**	lower 95% CI	upper 95% CI
1987							
1988		0.03		0.06	**0.05**	0.03	0.06
1989		0.03	0.03	0.05	**0.04**	0.02	0.05
1990		0.05	0.07	0.11	**0.07**	0.05	0.10
1991		0.07	0.03	0.09	**0.06**	0.04	0.08
1992	0.04	0.05	0.04	0.14	**0.07**	0.04	0.09
1993	0.04	0.06	0.03	0.12	**0.06**	0.03	0.09
1994	0.04	0.04	0.04	0.11	**0.06**	0.04	0.08
1995	0.04	0.06	0.06	0.14	**0.07**	0.05	0.10
1996	0.06	0.04	0.09	0.14	**0.09**	0.06	0.12
1997	0.13	0.06	0.10	0.25	**0.13**	0.09	0.18
1998	0.09	0.05	0.13	0.23	**0.13**	0.07	0.18
1999	0.07	0.07	0.06	0.24	**0.11**	0.06	0.16
2000	0.10	0.04	0.08	0.10	**0.08**	0.05	0.12
2001	0.06	0.06	0.10	0.19	**0.10**	0.07	0.13
2002	0.09	0.08	0.07	0.15	**0.10**	0.07	0.13
2003	0.09	0.06	0.09	0.14	**0.10**	0.07	0.13
2004	0.10	0.05	0.13	0.12	**0.10**	0.07	0.13
2005	0.07	0.06	0.11	0.13	**0.09**	0.06	0.12
2006	0.09	0.04	0.08	0.18	**0.10**	0.07	0.13
2007	0.05	0.06	0.13	0.24	**0.12**	0.07	0.16
2008	0.08	0.04*	0.10	0.19	**0.10**	0.07	0.14
2009	0.10	0.07*	0.07	0.05	**0.07**	0.05	0.10
2010	0.08	0.09*	0.09	0.09	**0.08**	0.06	0.11

* = NY TRAWL

Table 15 continued.

Producer Area Programs*

Year	HUDSON	DE/PA	MDCB	VARAP	Weighted Average	lower 95% CI	upper 95% CI
1987			0.01		0.00	0.00	0.01
1988	0.05		0.01		0.01	0.01	0.02
1989	0.05		0.01		0.01	0.01	0.02
1990	0.08		0.08	0.18	0.10	0.05	0.14
1991	0.08		0.12	0.23	0.13	0.07	0.19
1992	0.10		0.15	0.34	0.18	0.08	0.28
1993	0.11	0.16	0.13	0.28	0.17	0.10	0.25
1994	0.10	0.14	0.15	0.33	0.19	0.09	0.28
1995	0.14	0.17	0.23	0.22	0.21	0.12	0.31
1996	0.18	0.18	0.21	0.18	0.20	0.11	0.28
1997	0.25	0.18	0.26	0.25	0.25	0.14	0.36
1998	0.20	0.19	0.28	0.22	0.25	0.13	0.36
1999	0.16	0.14	0.22	0.20	0.20	0.10	0.29
2000	0.11	0.19	0.22	0.19	0.20	0.10	0.29
2001	0.10	0.19	0.16	0.25	0.18	0.10	0.26
2002	0.09	0.18	0.16	0.23	0.17	0.09	0.25
2003	0.12	0.20	0.17	0.21	0.18	0.10	0.26
2004	0.15	0.20	0.14	0.20	0.16	0.09	0.23
2005	0.11	0.14	0.15	0.20	0.16	0.08	0.23
2006	0.12	0.16	0.18	0.21	0.18	0.09	0.27
2007	0.12	0.10	0.12	0.19	0.13	0.07	0.20
2008	0.10	0.11	0.15	0.13	0.14	0.06	0.21
2009	0.18	0.15	0.23	0.11	0.19	0.09	0.28
2010	0.14	0.13	0.18	0.04	0.13	0.06	0.20

* Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 16. Summaries of tag-based estimates of annual instantaneous fishing mortality of striped bass >28 inches based on the Instantaneous Rates Model, along with the unweighted average for coastal programs, the weighted average for producer areas, and 95% confidence intervals.

Coast Programs

Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	**Unweighted average**	lower 95% CI	upper 95% CI
1987							
1988		0.02		0.05	**0.04**	0.02	0.05
1989		0.02	0.00	0.04	**0.02**	0.01	0.03
1990		0.10	0.11	0.11	**0.11**	0.07	0.14
1991		0.16	0.37	0.10	**0.21**	0.13	0.29
1992	0.03	0.14	0.00	0.12	**0.07**	0.06	0.09
1993	0.06	0.18	0.10	0.12	**0.11**	0.09	0.14
1994	0.08	0.13	0.05	0.11	**0.09**	0.08	0.11
1995	0.10	0.24	0.10	0.19	**0.16**	0.14	0.17
1996	0.18	0.26	0.20	0.18	**0.21**	0.18	0.23
1997	0.21	0.31	0.19	0.20	**0.23**	0.20	0.25
1998	0.19	0.35	0.32	0.20	**0.26**	0.23	0.29
1999	0.21	0.30	0.19	0.19	**0.23**	0.19	0.26
2000	0.19	0.22	0.16	0.14	**0.18**	0.15	0.21
2001	0.09	0.22	0.19	0.16	**0.16**	0.14	0.19
2002	0.14	0.21	0.18	0.15	**0.17**	0.15	0.19
2003	0.14	0.24	0.22	0.14	**0.19**	0.16	0.21
2004	0.11	0.23	0.20	0.15	**0.17**	0.15	0.20
2005	0.10	0.18	0.21	0.14	**0.16**	0.13	0.18
2006	0.10	0.14	0.13	0.14	**0.13**	0.11	0.15
2007	0.07	0.11	0.16	0.15	**0.12**	0.11	0.13
2008	0.11	0.19*	0.18	0.15	**0.16**	0.14	0.17
2009	0.12	0.16*	0.20	0.14	**0.16**	0.14	0.17
2010	0.08	0.07*	0.16	0.14	**0.11**	0.10	0.13

*NY TRAWL

Table 16 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	**Weighted average***	lower 95% CI	upper 95% CI
1987			0.02		**0.02**	0.00	0.02
1988	0.09		0.03		**0.04**	0.01	0.05
1989	0.09		0.03		**0.04**	0.01	0.04
1990	0.15		0.13	0.14	**0.14**	0.10	0.15
1991	0.15		0.13	0.14	**0.14**	0.10	0.15
1992	0.15		0.13	0.14	**0.14**	0.10	0.15
1993	0.15	0.20	0.13	0.14	**0.14**	0.12	0.17
1994	0.15	0.20	0.13	0.14	**0.14**	0.12	0.16
1995	0.26	0.27	0.26	0.22	**0.25**	0.23	0.28
1996	0.26	0.27	0.26	0.22	**0.25**	0.22	0.27
1997	0.26	0.27	0.26	0.22	**0.25**	0.22	0.28
1998	0.26	0.27	0.27	0.22	**0.25**	0.22	0.29
1999	0.26	0.27	0.27	0.22	**0.25**	0.22	0.29
2000	0.18	0.29	0.16	0.12	**0.16**	0.13	0.19
2001	0.18	0.29	0.16	0.12	**0.16**	0.13	0.19
2002	0.18	0.29	0.15	0.12	**0.16**	0.13	0.18
2003	0.20	0.23	0.11	0.11	**0.13**	0.11	0.16
2004	0.20	0.23	0.11	0.11	**0.13**	0.11	0.15
2005	0.20	0.23	0.11	0.11	**0.13**	0.11	0.15
2006	0.20	0.23	0.11	0.11	**0.13**	0.11	0.15
2007	0.20	0.23	0.11	0.11	**0.13**	0.11	0.15
2008	0.20	0.23	0.11	0.11	**0.13**	0.11	0.15
2009	0.20	0.23	0.10	0.07	**0.12**	0.10	0.14
2010	0.20	0.23	0.10	0.06	**0.12**	0.09	0.14

* Weighting Scheme: Hudson (0.13); Delaware (0.09); Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 17. Summaries of tag-based estimates of annual instantaneous fishing mortality of striped bass ≥18" based on the Instantaneous Rates Model, along with the unweighted average for coastal programs, the weighted average for producer areas, and 95% confidence intervals.

Coast Programs

Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	**Unweighted average**	lower 95% CI	upper 95% CI
1987							
1988		0.01		0.02	**0.02**	0.01	0.02
1989		0.01	0.01	0.02	**0.01**	0.01	0.02
1990		0.05	0.04	0.10	**0.06**	0.05	0.08
1991		0.05	0.05	0.11	**0.07**	0.05	0.08
1992	0.03	0.05	0.03	0.11	**0.06**	0.05	0.07
1993	0.05	0.05	0.03	0.11	**0.06**	0.05	0.07
1994	0.07	0.05	0.03	0.11	**0.06**	0.06	0.07
1995	0.07	0.09	0.10	0.17	**0.11**	0.09	0.13
1996	0.14	0.09	0.12	0.17	**0.13**	0.12	0.14
1997	0.17	0.09	0.13	0.17	**0.14**	0.13	0.16
1998	0.15	0.09	0.15	0.17	**0.14**	0.12	0.16
1999	0.16	0.09	0.12	0.17	**0.14**	0.12	0.15
2000	0.15	0.07	0.13	0.12	**0.12**	0.10	0.13
2001	0.08	0.07	0.14	0.12	**0.10**	0.09	0.11
2002	0.13	0.07	0.13	0.12	**0.11**	0.10	0.12
2003	0.12	0.06	0.14	0.10	**0.11**	0.09	0.12
2004	0.11	0.06	0.14	0.10	**0.10**	0.09	0.12
2005	0.10	0.06	0.15	0.10	**0.10**	0.09	0.11
2006	0.10	0.06	0.13	0.10	**0.10**	0.09	0.11
2007	0.06	0.06	0.14	0.10	**0.09**	0.08	0.10
2008	0.09	0.06*	0.14	0.10	**0.10**	0.09	0.11
2009	0.11	0.06*	0.12	0.10	**0.10**	0.09	0.11
2010	0.07	0.06*	0.13	0.10	**0.09**	0.08	0.10

*NY TRAWL

Table 17 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	**Weighted average***	lower 95% CI	upper 95% CI
1987			0.00				
1988	0.04		0.01		**0.02**	0.01	0.02
1989	0.04		0.00		**0.01**	0.00	0.01
1990	0.10		0.07	0.09	**0.08**	0.06	0.08
1991	0.10		0.12	0.09	**0.11**	0.09	0.11
1992	0.10		0.19	0.09	**0.15**	0.12	0.15
1993	0.10	0.15	0.17	0.09	**0.14**	0.12	0.15
1994	0.10	0.15	0.16	0.09	**0.14**	0.12	0.15
1995	0.20	0.16	0.25	0.13	**0.20**	0.18	0.22
1996	0.20	0.16	0.22	0.13	**0.20**	0.17	0.21
1997	0.20	0.16	0.29	0.13	**0.23**	0.21	0.25
1998	0.20	0.16	0.34	0.13	**0.25**	0.23	0.28
1999	0.20	0.16	0.27	0.13	**0.21**	0.20	0.25
2000	0.13	0.17	0.22	0.08	**0.17**	0.15	0.19
2001	0.13	0.17	0.16	0.08	**0.14**	0.12	0.16
2002	0.13	0.17	0.12	0.08	**0.12**	0.10	0.13
2003	0.13	0.16	0.16	0.09	**0.14**	0.12	0.15
2004	0.13	0.16	0.12	0.09	**0.12**	0.10	0.13
2005	0.13	0.16	0.10	0.09	**0.11**	0.09	0.12
2006	0.13	0.16	0.11	0.09	**0.11**	0.10	0.13
2007	0.13	0.16	0.07	0.09	**0.09**	0.08	0.11
2008	0.13	0.16	0.08	0.09	**0.09**	0.08	0.11
2009	0.13	0.16	0.11	0.09	**0.11**	0.10	0.13
2010	0.13	0.16	0.09	0.05	**0.09**	0.07	0.10

* Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 18. Coastwide fishing mortality rates, presented as an unweighted average of producer and coastal programs' means, developed assuming a constant M and coastwide stock size estimates for age 3+ and 7+ obtained via "Kill = F * Stock Size".

Year	Fishing Mortality	Age 3+ Kill includes discards	Total Stock Size Thousands	Year	Fishing Mortality	Age 7+ Kill includes discards	Total Stock Size Thousands
1988	0.00	411.4	83,366	1988	0.00	101.4	25,107
1989		443.2	-	1989	-	95.0	-
1990	0.16	873.0	5,345	1990	0.18	222.3	1,255
1991	0.49	913.8	1,880	1991	0.12	296.4	2,455
1992	0.13	938.2	6,951	1992	0.13	262.7	2,053
1993	0.26	1,367.1	5,325	1993	0.18	380.6	2,106
1994	0.26	1,715.5	6,477	1994	0.19	475.9	2,443
1995	0.30	2,562.1	8,427	1995	0.28	740.0	2,641
1996	0.33	3,276.4	9,829	1996	0.32	965.3	3,045
1997	0.38	4,285.3	11,177	1997	0.32	1,371.1	4,280
1998	0.48	3,908.5	8,084	1998	0.31	1,080.5	3,540
1999	0.53	3,587.6	6,749	1999	0.31	1,146.8	3,664
2000	0.52	4,685.0	8,926	2000	0.27	1,481.1	5,429
2001	0.53	4,156.0	7,855	2001	0.28	1,591.8	5,600
2002	0.45	3,667.5	8,221	2002	0.27	2,085.4	7,660
2003	0.36	4,561.2	12,757	2003	0.34	2,169.3	6,292
2004	0.65	5,031.4	7,723	2004	0.32	2,440.0	7,528
2005	0.55	5,126.4	9,396	2005	0.31	2,130.9	6,874
2006	0.51	5,835.1	11,473	2006	0.31	2,218.3	7,166
2007	0.50	5,255.2	10,515	2007	0.32	1,979.9	6,158
2008	0.53	4,505.3	8,566	2008	0.33	2,217.8	6,753
2009	0.47	4,161.2	8,846	2009	0.35	1,816.9	5,257
2010	0.41	3,706.5	8,994	2010	0.29	1,874.3	6,519

Negative values not used to calculate fishing mortality averages.

Table 19. Coastwide fishing mortality rates, presented as an unweighted average of producer and coastal programs' means, using the catch equation, and coastwide stock size estimates for age 3+ and 7+ obtained via "Kill = F * Stock Size".

Year	Fishing Mortality	Age 3+ Kill includes discards	Total Stock Size Thousands	Year	Fishing Mortality	Age 7+ Kill includes discards	Total Stock Size Thousands
1988	0.03	411.4	13,824	1988	0.05	101.4	2,056
1989	0.02	443.2	18,188	1989	0.03	95.0	3,099
1990	0.09	873.0	10,117	1990	0.10	222.3	2,132
1991	0.10	913.8	9,350	1991	0.17	296.4	1,772
1992	0.12	938.2	7,608	1992	0.14	262.7	1,849
1993	0.12	1,367.1	11,604	1993	0.17	380.6	2,276
1994	0.12	1,715.5	14,122	1994	0.13	475.9	3,771
1995	0.14	2,562.1	17,815	1995	0.22	740.0	3,376
1996	0.14	3,276.4	23,286	1996	0.19	965.3	5,080
1997	0.19	4,285.3	22,497	1997	0.31	1,371.1	4,467
1998	0.19	3,908.5	21,084	1998	0.29	1,080.5	3,773
1999	0.15	3,587.6	23,452	1999	0.24	1,146.8	4,737
2000	0.14	4,685.0	33,825	2000	0.20	1,481.1	7,454
2001	0.14	4,156.0	29,628	2001	0.16	1,591.8	9,998
2002	0.13	3,667.5	27,348	2002	0.18	2,085.4	11,299
2003	0.14	4,561.2	33,376	2003	0.18	2,169.3	12,134
2004	0.13	5,031.4	38,218	2004	0.16	2,440.0	15,331
2005	0.12	5,126.4	41,370	2005	0.18	2,130.9	11,780
2006	0.14	5,835.1	42,053	2006	0.18	2,218.3	12,211
2007	0.13	5,255.2	41,630	2007	0.14	1,979.9	14,222
2008	0.12	4,505.3	37,886	2008	0.15	2,217.8	14,492
2009	0.13	4,161.2	31,840	2009	0.15	1,816.9	11,727
2010	0.11	3,706.5	34,126	2010	0.13	1,874.3	14,838

Table 20. Coastwide fishing mortality rates, presented as an unweighted average of producer and coastal programs' means, using the Instantaneous Rates model, and coastwide stock size estimates for age 3+ and 7+ obtained via "Kill = F * Stock Size".

Instantaneous Rates Method

Year	Fishing Mortality	Age 3+ Kill includes discards	Total Stock Size Thousands	Year	Fishing Mortality	Age 7+ Kill includes discards	Total Stock Size Thousands
1988	0.02	411.4	20,570	1988	0.04	101.4	2,535
1989	0.01	443.2	44,320	1989	0.03	95	3,167
1990	0.07	873.0	12,471	1990	0.13	222.3	1,778
1991	0.09	913.8	10,751	1991	0.18	296.4	1,694
1992	0.11	938.2	8,935	1992	0.11	262.7	2,502
1993	0.10	1,367.1	13,671	1993	0.13	380.6	3,045
1994	0.10	1,715.5	17,155	1994	0.12	475.9	4,138
1995	0.16	2,562.1	16,530	1995	0.21	740	3,610
1996	0.17	3,276.4	19,856	1996	0.23	9,65.1	4,196
1997	0.19	4,285.3	23,164	1997	0.24	1,371.1	5,713
1998	0.20	3,908.5	20,044	1998	0.26	1,080.5	4,156
1999	0.18	3,587.6	20,501	1999	0.24	1,146.8	4,778
2000	0.15	4,685.0	32,310	2000	0.17	1,481.1	8,712
2001	0.12	4,156.0	34,633	2001	0.16	1,591.8	9,949
2002	0.12	3,667.5	31,890	2002	0.17	2,085.4	12,639
2003	0.13	4,561.2	36,490	2003	0.16	2,169.2	13,558
2004	0.11	5,031.4	45,743	2004	0.15	2,440.4	16,269
2005	0.11	5,126.4	48,821	2005	0.15	2,131	14,697
2006	0.11	5,835.1	55,570	2006	0.13	2,218.2	17,063
2007	0.09	5,255.2	63,050	2007	0.13	2,121.5	16,972
2008	0.10	4,505.3	44,735	2008	0.15	1,962.3	13,533
2009	0.11	4,161.2	39,630	2009	0.14	1,816.9	12,978
2010	0.09	3,706.5	41,183	2010	0.12	1,874.3	16,298

Table 21. Akaike weights used to derive model averaged parameter estimates using program MARK and the Instantaneous Rates (constant and 2 period M) models for striped bass 18-28 inches in Chesapeake Bay.

MARK

Model	CB 18-28"
{S(.)r(.)}	0
{S(.)r(p)}	0
{S(.)r(t)}	0
{S(p)r(p)}	0
{S(p)r(t)}	0.002
{S(d)r(p)}	0
{S(v)r(p)}	0
{S(t)r(p)}	0.001
{S(t)r(t)}	**0.997**

IRCR (1M)

Model	CB 18-28"
{F(t)F'(t)M(.)}	1.000
{F(p)F'(t)M(.)}	0.000
{F(.)F'(t)M(.)}	0.000
{F(t)F'(p)M(.)}	0.000
{F(t)F'(.)M(.)}	0.000
{F(p)F'(p)M(.)}	0.000
{F(.)F'(.)M(.)}	0.000
{F(d)F'(d)M(.)}	0.000
{F(v)F'(v)M(.)}	0.000

IRCR (2M)

Model	CB 18-28"
{F(t)F'(t)M(.)}	0.000
{F(p)F'(t)M(.)}	0.000
{F(.)F'(t)M(.)}	0.000
{F(t)F'(p)M(.)}	0.000
{F(t)F'(.)M(.)}	0.000
{F(p)F'(p)M(.)}	0.000
{F(.)F'(.)M(.)}	0.000
{F(d)F'(d)M(.)}	0.000
{F(v)F'(v)M(.)}	0.000
{F(t)F'(t)M(p)}	**0.998**
{F(p)F'(t)M(p)}	0.000
{F(.)F'(t)M(p)}	0.000
{F(t)F'(p)M(p)}	0.002
{F(t)F'(.)M(p)}	0.000
{F(p)F'(p)M(p)}	0.000
{F(.)F'(.)M(p)}	0.000
{F(d)F'(d)M(p)}	0.000
{F(v)F'(v)M(p)}	0.000

Table 22. Unadjusted (unadj.) and bias-corrected (adj.) estimates of survival (S) and fishing mortality (F) for striped bass 18-28 inches, from Program MARK and assuming a constant natural mortality, for Chesapeake Bay.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1987	0.86	0.00	0.07	0.93	-0.09	0.95	-0.10	-0.21	0.24
1988	0.76	0.13	0.04	0.86	-0.05	0.79	0.08	-0.04	0.27
1989	0.97	-0.12	0.03	0.93	-0.04	1.01	-0.16	-0.17	-0.14
1990	0.60	0.36	0.05	0.56	-0.04	0.63	0.32	0.17	0.51
1991	0.70	0.21	0.07	0.42	-0.05	0.73	0.17	0.01	0.41
1992	0.61	0.35	0.10	0.40	-0.07	0.65	0.28	0.11	0.50
1993	0.54	0.47	0.08	0.32	-0.04	0.56	0.43	0.26	0.63
1994	0.62	0.33	0.10	0.41	-0.06	0.66	0.26	0.09	0.50
1995	0.50	0.54	0.11	0.39	-0.07	0.54	0.47	0.27	0.72
1996	0.70	0.21	0.10	0.38	-0.06	0.74	0.14	-0.05	0.49
1997	0.47	0.60	0.09	0.34	-0.05	0.50	0.55	0.30	0.87
1998	0.35	0.91	0.09	0.32	-0.05	0.36	0.86	0.57	1.20
1999	0.39	0.79	0.08	0.28	-0.04	0.40	0.76	0.48	1.09
2000	0.29	1.08	0.09	0.38	-0.06	0.31	1.02	0.74	1.34
2001	0.38	0.81	0.09	0.37	-0.05	0.40	0.76	0.46	1.12
2002	0.52	0.51	0.07	0.34	-0.04	0.54	0.47	0.19	0.88
2003	0.60	0.36	0.07	0.26	-0.03	0.62	0.33	0.04	0.85
2004	0.24	1.28	0.06	0.27	-0.02	0.24	1.26	0.83	1.75
2005	0.33	0.95	0.05	0.31	-0.03	0.34	0.92	0.54	1.39
2006	0.37	0.85	0.08	0.33	-0.04	0.38	0.81	0.39	1.36
2007	0.31	1.01	0.05	0.38	-0.03	0.32	0.98	0.54	1.53
2008	0.33	0.96	0.05	0.31	-0.03	0.34	0.93	0.47	1.54
2009	0.33	0.97	0.07	0.23	-0.02	0.33	0.95	0.38	1.74
2010	0.44	0.68	0.03	0.30	-0.02	0.44	0.66	0.21	1.37

Table 23. R/M estimates of expoitation (u) and catch rates of 18-28 inch striped bass from tagging programs in Chesapeake Bay. Catch rate is the proportion of tagged striped bass that were caught, but may have been released (with reporting rate adjustment of 0.43).

Year	u	catch rate
1987	0.01	0.11
1988	0.01	0.07
1989	0.00	0.05
1990	0.03	0.10
1991	0.05	0.12
1992	0.09	0.17
1993	0.07	0.11
1994	0.08	0.14
1995	0.09	0.18
1996	0.08	0.18
1997	0.08	0.15
1998	0.09	0.15
1999	0.06	0.12
2000	0.06	0.15
2001	0.08	0.15
2002	0.07	0.11
2003	0.06	0.11
2004	0.06	0.09
2005	0.05	0.08
2006	0.07	0.12
2007	0.05	0.09
2008	0.05	0.09
2009	0.08	0.11
2010	0.04	0.05

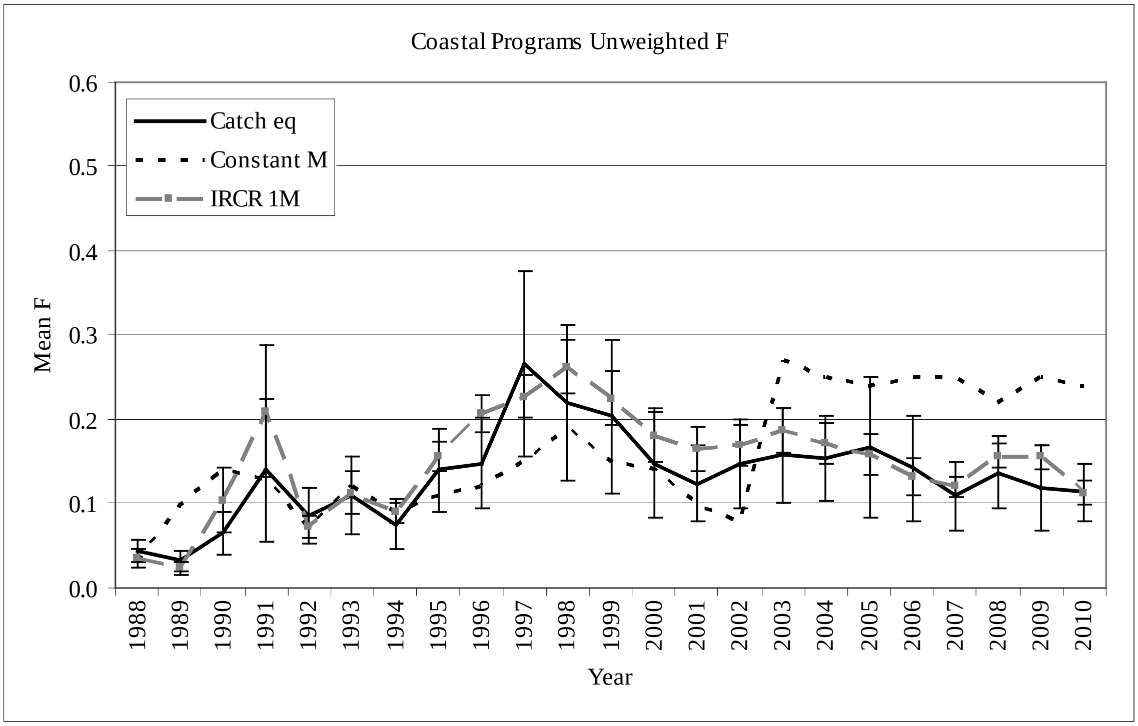
Table 24. Estimates of fishing mortality for 18-28 inch striped bass in Chesapeake Bay obtained without assuming constant natural mortality, based on exploitation rate and Baranov's catch equation, using bias-adjusted estimates of survival from Table 32. Column headings are S: bias-corrected survival rate, Z: total instantaneous mortality, A: annual percentage mortality expressed as a proportion, U: annual exploitation rate, F: instantaneous fishing mortality rate and M: instantaneous natural mortality rate.

Year	Z	A	U	F	M
1987	0.05	0.05	0.01	0.01	0.04
1988	0.23	0.21	0.01	0.01	0.22
1989	-0.01	-0.01	0.00	0.00	-0.01
1990	0.47	0.37	0.03	0.04	0.43
1991	0.32	0.27	0.05	0.06	0.25
1992	0.43	0.35	0.09	0.11	0.32
1993	0.58	0.44	0.07	0.09	0.49
1994	0.41	0.34	0.08	0.09	0.32
1995	0.62	0.46	0.09	0.12	0.50
1996	0.29	0.26	0.08	0.09	0.20
1997	0.70	0.50	0.08	0.12	0.58
1998	1.01	0.64	0.09	0.14	0.87
1999	0.91	0.60	0.06	0.09	0.81
2000	1.17	0.69	0.06	0.11	1.06
2001	0.91	0.60	0.08	0.12	0.78
2002	0.62	0.46	0.07	0.09	0.53
2003	0.48	0.38	0.06	0.08	0.40
2004	1.41	0.76	0.06	0.10	1.31
2005	1.07	0.66	0.05	0.09	0.98
2006	0.96	0.62	0.07	0.10	0.85
2007	1.13	0.68	0.05	0.08	1.05
2008	1.08	0.66	0.05	0.09	0.99
2009	1.10	0.67	0.08	0.14	0.96
2010	0.81	0.56	0.04	0.06	0.75
Average	0.70	0.47	0.06	0.08	0.61

Table 25. Estimates of instantaneous fishing mortality (F), instantaneous natural mortality (M), survival (S) and tag mortality (F') of 18-28 inch striped bass in Chesapeake Bay using a constant (1M) and a two-natural mortality period (2M) (1987-1997 and 1998-2010) Instantaneous Rates model and a tag reporting rate of 0.64.

	1987-2010 (1M)				1987-1997 and 1998-2010 (2M)			
Year	F	M	S	F'	F	M	S	F'
1987	0.00	0.38	0.68	0.04	0.00	0.30	0.74	0.04
1988	0.01	0.38	0.68	0.01	0.01	0.30	0.74	0.01
1989	0.00	0.38	0.68	0.04	0.00	0.30	0.74	0.04
1990	0.05	0.38	0.65	0.06	0.05	0.30	0.71	0.05
1991	0.09	0.38	0.62	0.06	0.08	0.30	0.68	0.05
1992	0.15	0.38	0.58	0.09	0.13	0.30	0.65	0.08
1993	0.13	0.38	0.60	0.05	0.11	0.30	0.66	0.05
1994	0.12	0.38	0.60	0.08	0.10	0.30	0.67	0.07
1995	0.15	0.38	0.59	0.08	0.12	0.30	0.65	0.06
1996	0.11	0.38	0.61	0.07	0.09	0.30	0.68	0.06
1997	0.13	0.38	0.60	0.05	0.10	0.30	0.67	0.04
1998	0.13	0.38	0.60	0.05	0.10	0.30	0.67	0.04
1999	0.08	0.38	0.63	0.03	0.08	0.90	0.38	0.03
2000	0.07	0.38	0.64	0.04	0.09	0.90	0.37	0.06
2001	0.06	0.38	0.65	0.03	0.10	0.90	0.37	0.06
2002	0.05	0.38	0.65	0.02	0.11	0.90	0.36	0.04
2003	0.06	0.38	0.64	0.02	0.13	0.90	0.36	0.04
2004	0.05	0.38	0.65	0.02	0.12	0.90	0.36	0.04
2005	0.04	0.38	0.66	0.02	0.09	0.90	0.37	0.03
2006	0.05	0.38	0.65	0.02	0.12	0.90	0.36	0.05
2007	0.03	0.38	0.66	0.02	0.07	0.90	0.38	0.05
2008	0.03	0.38	0.66	0.01	0.08	0.90	0.38	0.03
2009	0.05	0.38	0.65	0.01	0.12	0.90	0.36	0.03
2010	0.03	0.38	0.66	0.01	0.06	0.90	0.38	0.02

Figure 1. Comparison of coast program and producer area mean fishing mortality estimates from the three methods, for fish > 28 inches. 95% confidence intervals are shown for the catch equation and IRCR methods.



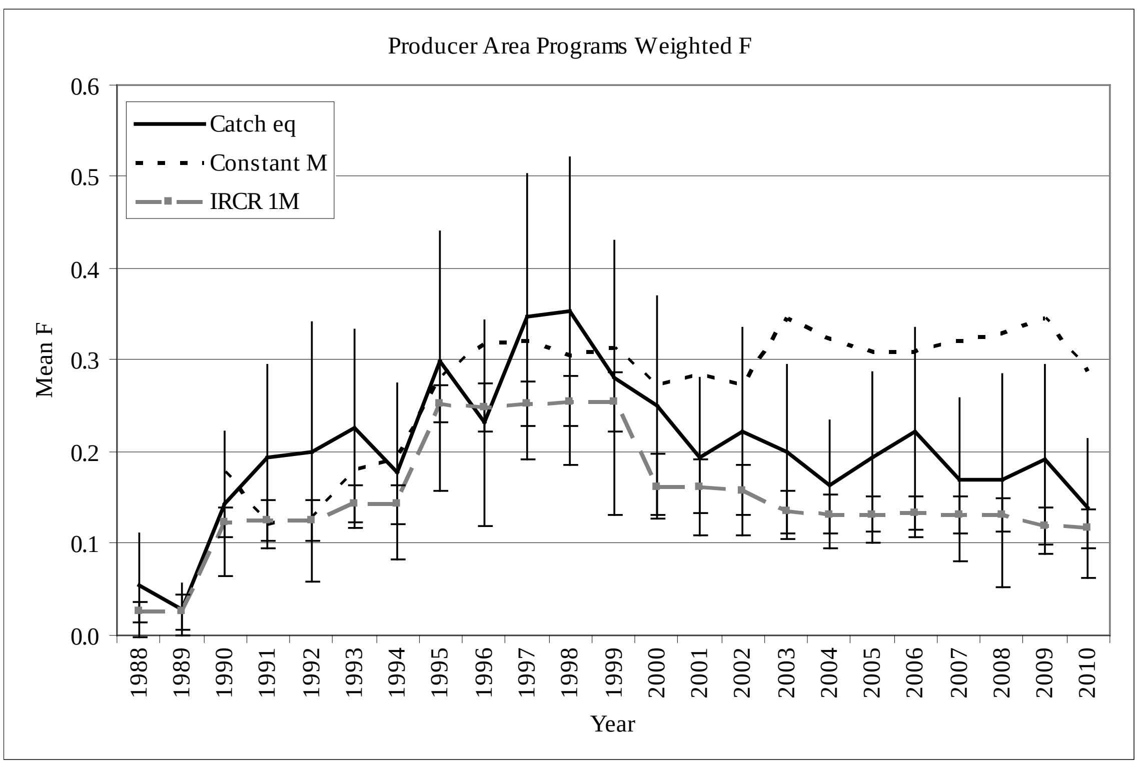


Figure 2. Comparison of coast program and producer area mean fishing mortality estimates from the three methods, for fish ≥ 18 inches. 95% confidence intervals are shown for the catch equation and IRCR methods.

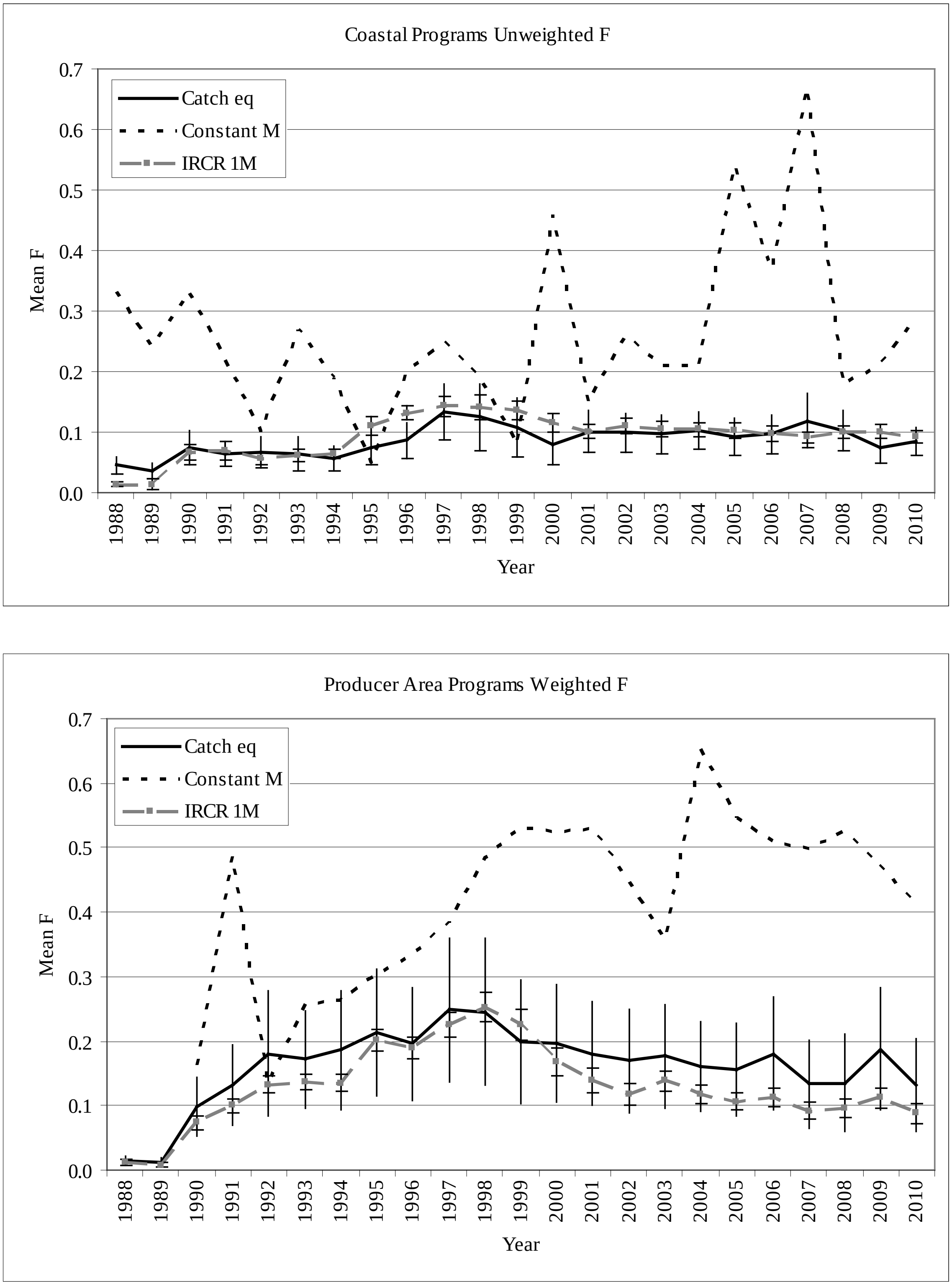


Figure 3. Comparison of stock size estimates from the three methods, for fish age seven and older (comparable to fish ≥ 28 inches). Stock size obtained via "Kill = F * Stock Size".

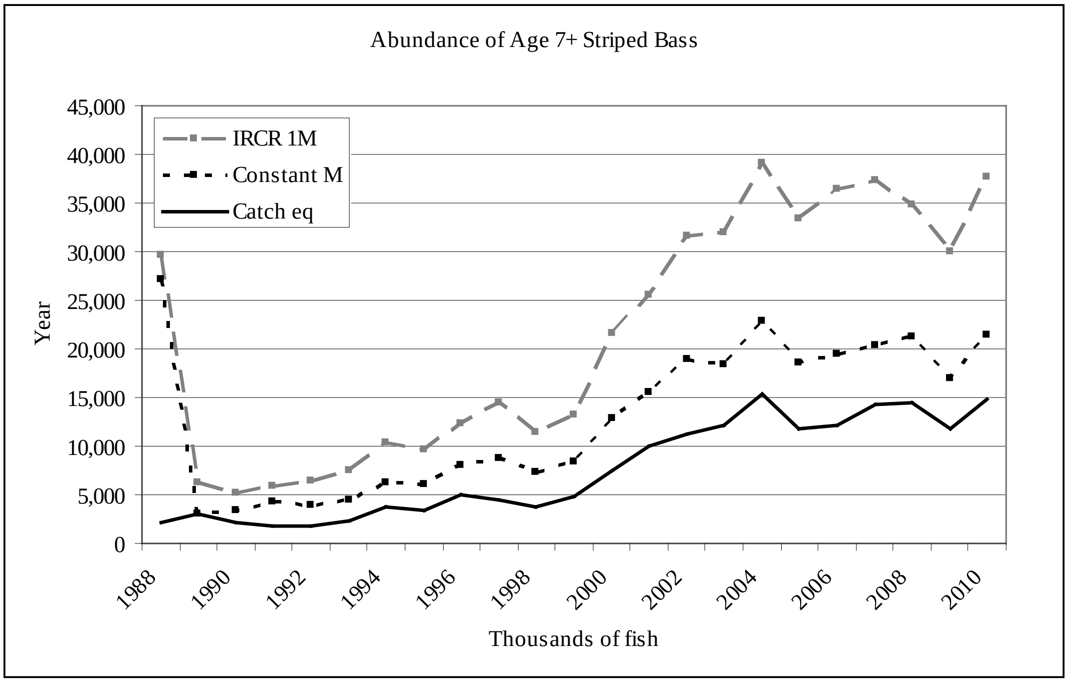
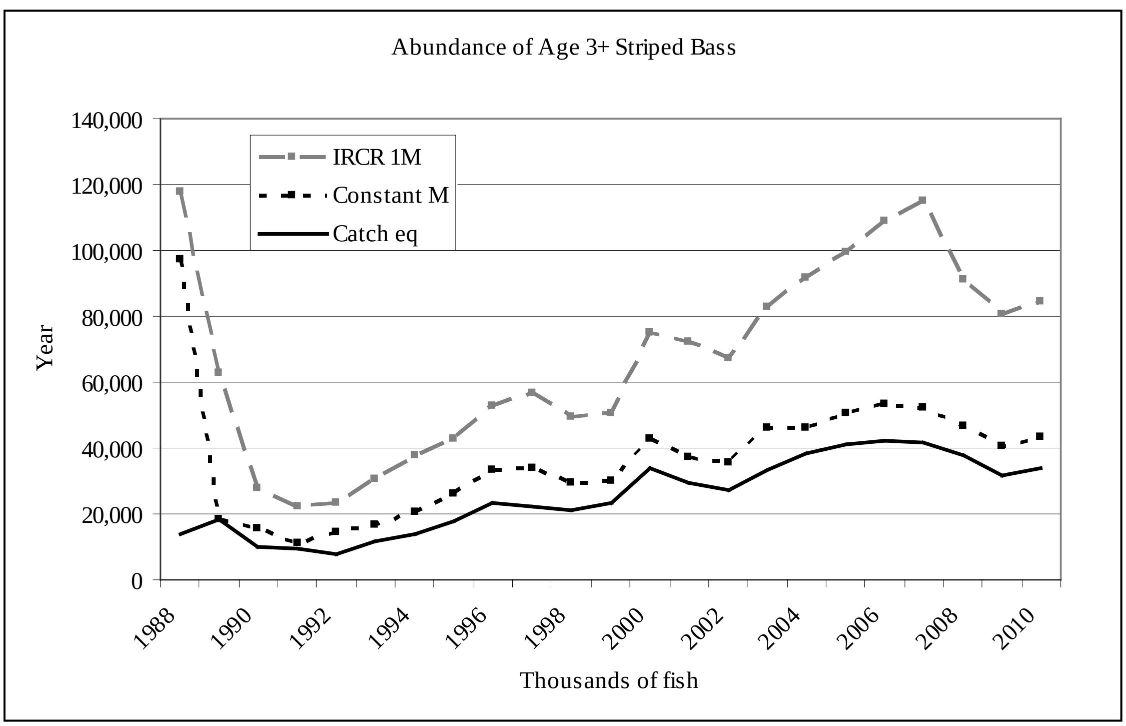


Figure 4. Comparison of stock size estimates from the three methods, for fish age three and older (comparable to fish ≥ 18 inches). Stock size obtained via "Kill = F * Stock Size".



APPENDIX A

Distribution of tag recaptures by state (program) and month.

Coast Programs

Massachusetts (recaptures in 2009 from fish tagged and released during 1992-2009)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA					5	2	8	1	2	1			19
RI						3				1			4
CT					3								3
NY		1			3	1	1	2					8
NJ					1	2				1	9		13
PA													0
DE			2										2
MD		2	3	1	5						2	1	14
VA	2			1	4							3	10
NC													0
UN	1		1					1					3
Total	3	3	6	2	21	8	9	4	2	3	11	4	76

Massachusetts (recaptures in 2010 from fish tagged and released during 1992-2010)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA					2	5	8	7					22
RI						1							1
CT													0
NY				2	6		1	1	1	1	3		15
NJ				2	2	3					9		16
PA													0
DE											1		1
MD			1	3	1						1		6
VA		1	2	1								1	5
NC	1	1										1	3
UN	1		1	1									3
Total	2	2	4	9	11	9	9	8	1	1	14	2	72

Coast Programs (continued)

New York - Trawl (recaptures in 2009 from fish tagged/release during 1988-2009)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME						1	1						2
NH													0
MA					5	7	4	1	2	1			20
RI					2	1		1		1			5
CT						1		1					2
NY				1	2	7	3	1		5		1	20
NJ	1		2	5	2	1				1	12		24
PA													0
DE													0
MD	1			1	1								3
VA													0
NC													0
Total	2	0	2	7	12	18	8	4	2	8	12	1	76

New York - Ocean Haul Seine (recaptures in 2010 from fish tagged/release during 1988-2010)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME						1	1						2
NH													0
MA						3	5						8
RI						3	1	1					5
CT					4	1	1						6
NY				3	5	5	1		1	1	3		19
NJ				1	1	1					4	1	8
PA													0
DE													0
MD				1	1								2
VA													0
NC		1											1
Total	0	1	0	5	11	14	9	1	1	1	7	1	51

Coast Programs (continued)

New Jersey - Delaware Bay (recaptures in 2009 from fish tagged/release during 1989-2009)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME						1	1						2
NH													0
MA						3	5						8
RI						3	1	1					5
CT					4	1	1						6
NY				3	5	5	1		1	1	3		19
NJ				1	1	1					4	1	8
PA													0
DE													0
MD				1	1								2
VA													0
NC		1											1
Total	0	1	0	5	11	14	9	1	1	1	7	1	51

New Jersey - Delaware Bay (recaptures in 2010 from fish tagged/release during 1989-2010)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME						3	1						4
NH					2	1	2	1					6
MA					9	35	30	19	6				99
RI				1	1	7	4	2	3	3			21
CT				1	7	8	4	1	2				23
NY				3	15	9	16	4	5	11	13		76
NJ			3	13	20	6	3		1	5	20		71
PA					2								2
DE				1		2					2		5
MD		1		13	8	2						2	26
VA	3		1		3							1	8
NC		3	1		1							2	7
Total	3	4	5	32	68	73	60	27	17	19	35	5	348

Coast Programs (continued)

North Carolina - Winter Trawl Survey (recaptures in 2009 from fish tagged and released during 1992-2009)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA						4	8	9	2	3	1		27
RI						4	3	2					9
CT					1	1		2	1				5
NY					5	3	7	2	5	8	3		33
NJ				1	7	1				4	4		17
PA													0
DE				1							2	1	4
MD		2	1	14	8	3	2	1	2		6		39
VA	1	2	4		1						1	2	11
NC	4	2										2	8
Total	5	6	5	16	22	16	20	16	10	15	17	5	153

North Carolina - Winter Trawl Survey (recaptures in 2010 from fish tagged and released during 1992-2010)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME						1							1
NH								1					1
MA					1	8	6	6	3	1			25
RI					1	2	3	1	1	2			10
CT					1	2							3
NY				1	4	4	4		3	2	1		19
NJ				2	9	2	1		1	1	4		20
PA													0
DE				1	1					1	1		4
MD				7	5	2					1	1	16
VA			1	2	1			1		1		2	8
NC	2		2	4									8
Total	2	0	3	17	23	21	14	9	8	8	7	3	115

Producer Area Programs

Hudson River (recaptures in 2009 from fish tagged and released during 1992-2009)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME					1		1		1				3
NH							1						1
MA						6	5	7	1				19
RI							1	1	1				3
CT						3	1		1	1			6
NY				3	17	11	8	3	4	8	2	1	57
NJ				3	1	3	1			1	12		21
PA													0
DE											1		1
MD				2								2	4
VA		1		1									2
NC	1	2											3
Total	1	3	0	9	19	23	18	11	8	10	15	3	120

Hudson River (recaptures in 2010 from fish tagged and released during 1992-2010)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME							2						2
NH							1						1
MA						5	16	11	2				34
RI						1	3		1				5
CT					1	4	2		1				8
NY				8	22	10	4		1	4	4		53
NJ				2	3	2	2				16		25
PA													0
DE				1									1
MD											1		1
VA	1												1
NC	5												5
Total	6	0	0	11	26	22	30	11	5	4	21	0	136

Producer Area Programs (continued)

Delaware / Pennsylvania - Delaware River (recaptures in 2009 from fish tagged and released during 1992-2009)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA						1	2	2	1				6
RI									1				1
CT													0
NY					1		1	2					4
NJ				1	12	11	2	2	1	3	11		43
PA				1	6								7
DE					1	3	2	1		3	4		14
MD	1				2	2	2		1		1	1	10
VA	1												1
NC													0
Total	2	0	0	2	22	17	9	7	4	6	16	1	86

Delaware / Pennsylvania - Delaware River (recaptures in 2010 from fish tagged and released during 1992-2010)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH							1						1
MA						4	3	2	2				11
RI					1			1					2
CT						1							1
NY					1	2	1	1	1	1			7
NJ				1	14	6	1	1		3	5		31
PA					6		1						7
DE					4	2					2		8
MD	1			2	1		2		2	1			9
VA		1											1
NC	2		1										3
Total	3	1	1	3	27	15	9	5	5	5	7	0	81

Producer Area Programs (continued)

Maryland - Chesapeake Bay (recaptures in 2009 from fish tagged and released during 1992-2009)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH								1					1
MA							5	4					9
RI						1	2						3
CT													0
NY								1					1
NJ				1	3	1		1		1			7
PA													0
DE													0
MD			3	1	20	13	13	6	4	14	6	2	82
VA	1	1	1			1				2	3	1	10
NC													0
Total	1	1	4	2	23	16	20	13	4	17	9	3	113

Maryland - Chesapeake Bay (recaptures in 2010 from fish tagged and released during 1992-2010)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA						2	4	2	3				11
RI					1	5	1	1		1			9
CT													0
NY					2	2	4			2			10
NJ					1						1		2
PA													0
DE													0
MD		1	2	1	7	15	15	6	6	3	1	1	58
VA	2		1		5					3	1	1	13
NC	1												1
Total	3	1	3	1	16	24	24	9	9	9	3	2	104

Producer Area Programs (continued)

Virginia - Rappahannock River (recaptures in 2009 from fish tagged and released during 1990-2009)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA						1	3	5					9
RI						2		2					4
CT									2				2
NY					1	1		3		3	1		9
NJ						1					2		3
PA													0
DE					1	1							2
MD			1	1	8	2	4	3		2	3		24
VA	3	1	3	1	5	6			2	5	6	9	41
NC													0
Total	3	1	4	2	15	14	7	13	4	10	12	9	94

Virginia - Rappahannock River (recaptures in 2010 from fish tagged and released during 1990-2010)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA							3	6	2				11
RI								1	1				2
CT													0
NY						1	1			1			3
NJ					4	1					3		8
PA													0
DE					3								3
MD				2					1				3
VA					1						1		2
NC	1	2											3
Total	1	2	0	2	8	2	4	7	4	1	4	0	35

APPENDIX B

Akaike weights used to derive model averaged parameter estimates using program MARK for striped bass ≥28 inches. Models are described in Table 1.

	Coast Programs				**Producer Area Programs**			
Model	MADFW	NYTRL	NJDEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP
{S(.)r(.)}	0.000	**0.698**	0.000	0.000	0.000	0.000	0.000	0.000
{S(.)r(p)}	**0.209**	*	0.000	0.026	0.032	**0.052**	0.000	0.027
{S(.)r(t)}	0.103	0.124	0.006	0.000	0.000	0.000	0.000	0.057
{S(p)r(p)}	0.116	*	**0.423**	**0.521**	**0.477**	**0.063**	**0.564**	0.039
{S(p)r(t)}	**0.200**	*	0.070	0.001	0.000	0.014	0.000	0.004
{S(d)r(p)}	0.119	*	**0.155**	**0.228**	**0.179**	**0.051**	**0.227**	**0.648**
{S(v)r(p)}	0.054	*	**0.193**	**0.221**	**0.307**	**0.819**	**0.207**	**0.224**
{S(t)r(p)}	**0.199**	0.132	0.152	0.000	0.005	0.001	0.001	0.001
{S(t)r(t)}	0.000	0.046	0.001	0.003	0.000	0.000	0.000	0.001

*models not used due to short time series (1998-2010)

Akaike weights used to derive model averaged parameter estimates using program MARK for striped bass ≥18 inches. Models are described in Table 1.

	Coast Programs				**Producer Area Programs**			
Model	MADFW	NYTRL	NJDEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP
{S(.)r(.)}	0.000	**0.319**	0.000	0.000	0.000	0.001	0	0.000
{S(.)r(p)}	0.036	*	0.000	0.000	0.000	0.033	0	0.000
{S(.)r(t)}	**0.369**	**0.322**	0.000	0.000	0.000	0.049	0	0.003
{S(p)r(p)}	0.023	*	0.000	0.000	**0.476**	**0.499**	0	0.000
{S(p)r(t)}	**0.294**	*	0.000	0.000	0.000	0.024	**0.996**	0.002
{S(d)r(p)}	0.020	*	0.000	0.000	**0.320**	0.190	0	**0.027**
{S(v)r(p)}	0.014	*	0.000	0.000	**0.183**	**0.204**	0	0.000
{S(t)r(p)}	**0.243**	0.235	0.000	0.000	0.021	0.001	0.004	0.000
{S(t)r(t)}	0.000	0.124	**0.999**	**1.000**	0.000	0.000	0.000	**0.967**

*models not used due to short time series (1998-2010)

APPENDIX C

Akaike weights used to derive model averaged parameter estimates using the Instantaneous Rates model for striped bass ≥28 inches.

		Coast Programs			Producer Area Programs			
Model	MADFW	NYTRL	NJDEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP
F(t), Ft(t), M(.)	0	**0.710**	**0.960**	**0.197**	0.001	0.000	0.002	0
F((5p), Ft(t), M(.)	0	**0.290**	0	**0.755**	**0.999**	0.036	0.015	0
F(.), Ft(t), M(.)	0	0	0	0	0	0.008	0	0
F(t), Ft(5p), M(.)	**1.000**	0	0.040	0.003	0	0.003	**0.101**	0.003
F(t), Ft(.), M(.)	0	0	0	0	0	0.003	0	0
F(5p), Ft(5p), M(.)	0	0	0	0.012	0	**0.513**	**0.543**	0.001
F(.). Ft(.), M(.)	0	0	0	0	0	**0.263**	0	0
F(d), Ft(d), M(.)	0	0	0	0.018	0	**0.070**	**0.124**	0.045
F(v), Ft(v), M(.)	0	0	0	0.014	0	**0.103**	**0.215**	**0.951**

Akaike weights used to derive model averaged parameter estimates using the Instantaneous Rates model for striped bass ≥18 inches.

		Coast Programs			Producer Area Programs			
Model	MADFW	NYTRL	NJDEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP
F(t), Ft(t), M(.)	0	0.004	**0.144**	0.008	0.007	0.000	**1.000**	0
F((5p), Ft(t), M(.)	0	**0.996**	0.070	**0.988**	**0.993**	0.000	0	0
F(.), Ft(t), M(.)	0	0	0	0	0	0.001	0	0
F(t), Ft(5p), M(.)	**1.000**	0	**0.230**	0	0	0.000	0	0.030
F(t), Ft(.), M(.)	0	0	0	0	0	0.000	0	0
F(5p), Ft(5p), M(.)	0	0	**0.256**	0.002	0	**0.253**	0	0
F(.). Ft(.), M(.)	0	0	0	0	0	**0.626**	0	0
F(d), Ft(d), M(.)	0	0	**0.143**	0.001	0	**0.062**	0	**0.949**
F(v), Ft(v), M(.)	0	0	**0.156**	0.001	0	**0.057**	0	0.021

APPENDIX D

Unadjusted (unadj.) and bias-corrected (adj.) estimates of survival (S) and fishing mortality (F) for striped bass ≥ 28 inches, from Program MARK and assuming a constant natural mortality, for each tagging program.

Coast Programs

Massachusetts
C-hat adjustment = 1.00; bootstrap GOF probability = 0.23 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1992	0.77	0.11	0.05	0.75	-0.08	**0.84**	**0.03**	-0.07	0.17
1993	0.77	0.11	0.05	0.56	-0.07	**0.82**	**0.04**	-0.05	0.17
1994	0.76	0.12	0.06	0.68	-0.09	**0.84**	**0.02**	-0.07	0.15
1995	0.72	0.17	0.06	0.79	-0.10	**0.81**	**0.07**	-0.01	0.16
1996	0.71	0.20	0.09	0.60	-0.13	**0.81**	**0.06**	0.00	0.14
1997	0.71	0.20	0.10	0.47	-0.12	**0.80**	**0.07**	0.00	0.16
1998	0.71	0.20	0.09	0.57	-0.13	**0.81**	**0.06**	-0.01	0.15
1999	0.70	0.20	0.08	0.50	-0.09	**0.77**	**0.11**	0.01	0.22
2000	0.73	0.17	0.08	0.10	-0.02	**0.74**	**0.15**	0.06	0.27
2001	0.75	0.13	0.05	0.33	-0.04	**0.78**	**0.09**	-0.01	0.24
2002	0.74	0.15	0.07	0.58	-0.10	**0.82**	**0.05**	-0.03	0.16
2003	0.71	0.20	0.06	0.11	-0.02	**0.72**	**0.18**	0.12	0.26
2004	0.71	0.19	0.05	0.20	-0.02	**0.73**	**0.17**	0.11	0.24
2005	0.71	0.20	0.05	0.35	-0.04	**0.74**	**0.16**	0.09	0.23
2006	0.70	0.20	0.06	0.37	-0.06	**0.74**	**0.15**	0.07	0.23
2007	0.72	0.17	0.04	0.30	-0.03	**0.74**	**0.15**	0.06	0.26
2008	0.71	0.20	0.06	0.29	-0.04	**0.74**	**0.16**	0.09	0.24
2009	0.70	0.21	0.06	0.19	-0.03	**0.72**	**0.18**	0.09	0.31
2010	0.72	0.18	0.05	0.33	-0.04	**0.75**	**0.14**	0.05	0.26

Coast Programs (continued)

New York - Ocean Haul Seine/Trawl

C-hat adjustment = NA/0.405*; bootstrap GOF probability = 0.034/0.75*for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1988	0.81	0.06	0.12	0.81	-0.22	**1.03**	**-0.18**	-0.28	-0.03
1989	0.81	0.06	0.10	0.79	-0.18	**0.99**	**-0.14**	-0.23	0.01
1990	0.62	0.32	0.09	0.64	-0.13	**0.72**	**0.18**	0.13	0.24
1991	0.62	0.32	0.12	0.49	-0.14	**0.73**	**0.17**	0.11	0.23
1992	0.62	0.32	0.14	0 .61	-0.22	**0.80**	**0.08**	0.00	0.17
1993	0.62	0.33	0.11	0.49	-0.13	**0.71**	**0.19**	0.12	0.26
1994	0.62	0.32	0.11	0.59	-0.16	**0.74**	**0.15**	0.10	0.21
1995	0.65	0.28	0.15	0.38	-0.15	**0.77**	**0.11**	0.05	0.18
1996	0.65	0.28	0.14	0.55	-0.19	**0.81**	**0.06**	-0.01	0.14
1997	0.65	0.27	0.15	0.21	-0.10	**0.72**	**0.17**	0.10	0.26
1998	0.65	0.28	0.10	0.00	0.00	**0.65**	**0.28**	0.19	0.39
1999	0.65	0.28	0.13	0.14	-0.05	**0.69**	**0.22**	0.16	0.30
2000	0.75	0.14	0.12	0.46	-0.14	**0.87**	**-0.01**	-0.11	0.14
2001	0.75	0.14	0.10	0.46	-0.11	**0.84**	**0.02**	-0.08	0.17
2002	0.75	0.14	0.12	0.41	-0.13	**0.86**	**-**	-0.10	0.15
2003	0.56	0.42	0.09	0.28	-0.06	**0.60**	**0.36**	0.25	0.49
2004	0.56	0.43	0.10	0.43	-0.11	**0.63**	**0.32**	0.19	0.47
2005	0.56	0.42	0.12	0.20	-0.06	**0.60**	**0.36**	0.24	0.50
2006	0.57	0.42	0.09	0.37	-0.08	**0.62**	**0.33**	0.20	0.50
2007	0.56	0.42	0.05	0.92	-0.09	**0.62**	**0.32**	0.20	0.47
2008*	0.93	-0.08	0.06	0.46	-0.06	**0.99**	**-0.14**	-0.17	-0.10
2009*	0.93	-0.07	0.08	0.92	-0.16	**1.10**	**-0.24**	-0.27	-0.20
2010*	0.93	-0.07	0.07	0.00	0.00	**0.93**	**-0.07**	-0.10	-0.03

* = NY TRAWL

Coast Programs (continued)

New Jersey - Delaware Bay

C-hat adjustment = 0.66; bootstrap GOF probability = 0.88 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1989	0.89	-0.04	0.11	1.00	0.00	**0.89**	**-0.04**	-0.11	0.16
1990	0.66	0.27	0.12	1.00	-0.26	**0.89**	**-0.03**	-0.18	0.19
1991	0.61	0.34	0.22	0.67	-0.39	**1.01**	**-0.16**	-0.39	0.20
1992	0.65	0.28	0.08	1.00	-0.18	**0.79**	**0.09**	-0.04	0.26
1993	0.64	0.30	0.10	0.63	-0.14	**0.74**	**0.15**	0.02	0.32
1994	0.65	0.28	0.10	0.81	-0.18	**0.79**	**0.08**	-0.03	0.23
1995	0.68	0.24	0.11	0.60	-0.15	**0.80**	**0.07**	0.00	0.15
1996	0.67	0.25	0.13	0.43	-0.14	**0.78**	**0.10**	0.05	0.16
1997	0.67	0.25	0.10	0.42	-0.10	**0.75**	**0.14**	0.09	0.20
1998	0.66	0.27	0.16	0.10	-0.05	**0.69**	**0.21**	0.12	0.33
1999	0.68	0.24	0.10	0.67	-0.16	**0.81**	**0.06**	-0.02	0.15
2000	0.74	0.16	0.09	0.41	-0.09	**0.81**	**0.06**	-0.01	0.14
2001	0.73	0.16	0.09	0.37	-0.08	**0.80**	**0.08**	0.01	0.16
2002	0.73	0.16	0.08	0.41	-0.08	**0.79**	**0.08**	0.01	0.17
2003	0.62	0.33	0.10	0.41	-0.11	**0.69**	**0.22**	0.16	0.28
2004	0.62	0.33	0.10	0.45	-0.12	**0.70**	**0.21**	0.15	0.27
2005	0.62	0.33	0.14	0.48	-0.17	**0.75**	**0.14**	0.08	0.21
2006	0.63	0.31	0.08	0.48	-0.09	**0.70**	**0.21**	0.11	0.32
2007	0.63	0.31	0.09	0.39	-0.08	**0.69**	**0.23**	0.15	0.31
2008	0.63	0.32	0.10	0.36	-0.09	**0.68**	**0.23**	0.16	0.30
2009	0.62	0.33	0.10	0.20	-0.06	**0.65**	**0.27**	0.19	0.37
2010	0.62	0.33	0.08	0.31	-0.06	**0.66**	**0.27**	-0.21	7.44

Coast Programs (continued)

North Carolina - Cooperative Winter Trawl Survey

C-hat adjustment = 1.855; bootstrap GOF probability = 0.08 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1988	0.70	0.20	0.09	0.72	-0.16	**0.84**	**0.03**	-0.12	0.27
1989	0.70	0.20	0.06	0.78	-0.10	**0.78**	**0.10**	-0.06	0.33
1990	0.70	0.21	0.07	0.64	-0.11	**0.78**	**0.09**	0.03	0.16
1991	0.70	0.21	0.09	0.56	-0.12	**0.79**	**0.09**	0.03	0.15
1992	0.70	0.21	0.10	0.50	-0.12	**0.80**	**0.08**	0.01	0.16
1993	0.70	0.21	0.09	0.47	-0.10	**0.78**	**0.10**	0.04	0.17
1994	0.70	0.21	0.08	0.50	-0.09	**0.77**	**0.11**	0.05	0.18
1995	0.65	0.29	0.10	0.34	-0.09	**0.71**	**0.19**	0.12	0.27
1996	0.65	0.29	0.05	0.28	-0.03	**0.67**	**0.25**	0.19	0.32
1997	0.65	0.29	0.09	0.27	-0.06	**0.69**	**0.22**	0.16	0.30
1998	0.65	0.29	0.11	0.22	-0.07	**0.69**	**0.22**	0.15	0.29
1999	0.65	0.29	0.10	0.23	-0.06	**0.69**	**0.22**	0.15	0.30
2000	0.67	0.25	0.05	0.31	-0.03	**0.69**	**0.21**	0.12	0.33
2001	0.67	0.25	0.09	0.24	-0.05	**0.71**	**0.20**	0.10	0.31
2002	0.67	0.25	0.06	0.31	-0.05	**0.70**	**0.20**	0.11	0.32
2003	0.61	0.34	0.06	0.3	-0.04	**0.64**	**0.30**	0.24	0.36
2004	0.61	0.34	0.07	0.27	-0.05	**0.64**	**0.29**	0.22	0.37
2005	0.61	0.34	0.05	0.27	-0.03	**0.63**	**0.31**	0.25	0.38
2006	0.61	0.34	0.08	0.28	-0.05	**0.64**	**0.29**	0.23	0.36
2007	0.61	0.34	0.10	0.23	-0.06	**0.65**	**0.28**	0.22	0.34
2008	0.61	0.34	0.10	0.23	-0.06	**0.65**	**0.28**	0.21	0.35
2009	0.62	0.33	0.06	0.20	-0.03	**0.63**	**0.31**	0.21	0.42
2010	0.62	0.32	0.04	0.21	-0.02	**0.64**	**0.30**	0.19	0.45

Producer Area Programs

Hudson River

C-hat adjustment = 1.0128; bootstrap GOF probability = 0.194 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1988	0.73	0.16	0.09	0.56	-0.12	**0.83**	**0.03**	-0.07	0.17
1989	0.73	0.16	0.11	0.79	-0.20	**0.91**	**-0.06**	-0.16	0.08
1990	0.63	0.31	0.13	0.73	-0.23	**0.82**	**0.05**	0.01	0.09
1991	0.63	0.31	0.11	0.61	-0.15	**0.75**	**0.14**	0.10	0.18
1992	0.63	0.31	0.13	0.60	-0.20	**0.79**	**0.09**	0.05	0.13
1993	0.63	0.31	0.13	0.55	-0.18	**0.77**	**0.11**	0.07	0.15
1994	0.63	0.31	0.12	0.59	-0.18	**0.77**	**0.11**	0.07	0.15
1995	0.65	0.28	0.11	0.44	-0.13	**0.74**	**0.15**	0.11	0.19
1996	0.65	0.28	0.13	0.29	-0.10	**0.72**	**0.18**	0.14	0.22
1997	0.65	0.28	0.16	0.24	-0.11	**0.73**	**0.16**	0.12	0.21
1998	0.65	0.28	0.13	0.28	-0.10	**0.72**	**0.18**	0.14	0.22
1999	0.65	0.28	0.13	0.31	-0.11	**0.73**	**0.16**	0.12	0.20
2000	0.67	0.25	0.08	0.39	-0.08	**0.73**	**0.16**	0.11	0.22
2001	0.67	0.25	0.07	0.33	-0.06	**0.72**	**0.18**	0.13	0.25
2002	0.67	0.25	0.12	0.20	-0.07	**0.72**	**0.18**	0.12	0.24
2003	0.62	0.33	0.09	0.39	-0.09	**0.68**	**0.23**	0.19	0.28
2004	0.62	0.33	0.11	0.25	-0.07	**0.67**	**0.26**	0.21	0.30
2005	0.62	0.33	0.10	0.32	-0.08	**0.68**	**0.24**	0.20	0.29
2006	0.62	0.33	0.10	0.27	-0.07	**0.67**	**0.25**	0.21	0.30
2007	0.62	0.33	0.09	0.26	-0.06	**0.66**	**0.26**	0.22	0.31
2008	0.62	0.33	0.11	0.32	-0.09	**0.68**	**0.24**	0.19	0.28
2009	0.62	0.33	0.12	0.30	-0.09	**0.68**	**0.23**	0.17	0.29
2010	0.61	0.35	0.11	0.24	-0.07	**0.65**	**0.27**	0.17	0.40

Producer Area Programs (continued)

Delaware / Pennsylvania - Delaware River

C-hat adjustment = 0.66; bootstrap GOF probability = 0.88 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1993	0.83	0.03	0.10	0.40	-0.11	**0.93**	**-0.08**	-0.22	0.36
1994	0.83	0.03	0.11	0.43	-0.13	**0.96**	**-0.11**	-0.25	0.33
1995	0.61	0.35	0.11	0.42	-0.13	**0.70**	**0.21**	0.13	0.30
1996	0.61	0.35	0.16	0.22	-0.12	**0.69**	**0.22**	0.14	0.31
1997	0.61	0.35	0.11	0.13	-0.04	**0.63**	**0.31**	0.23	0.40
1998	0.61	0.35	0.15	0.19	-0.09	**0.67**	**0.26**	0.18	0.35
1999	0.61	0.35	0.09	0.20	-0.05	**0.64**	**0.29**	0.22	0.38
2000	0.64	0.30	0.15	0.17	-0.08	**0.69**	**0.22**	0.12	0.33
2001	0.64	0.30	0.14	0.10	-0.04	**0.66**	**0.26**	0.16	0.37
2002	0.64	0.30	0.09	0.00	0.00	**0.64**	**0.30**	0.21	0.42
2003	0.63	0.31	0.12	0.39	-0.13	**0.73**	**0.17**	0.09	0.25
2004	0.63	0.30	0.09	0.16	-0.04	**0.66**	**0.26**	0.19	0.35
2005	0.63	0.31	0.11	0.42	-0.12	**0.72**	**0.18**	0.10	0.26
2006	0.63	0.31	0.09	0.20	-0.05	**0.67**	**0.25**	0.18	0.33
2007	0.63	0.30	0.08	0.27	-0.06	**0.68**	**0.24**	0.17	0.33
2008	0.64	0.29	0.05	0.14	-0.02	**0.65**	**0.28**	0.19	0.38
2009	0.45	0.64	0.11	0.20	-0.06	**0.48**	**0.58**	0.16	1.23
2010	0.45	0.65	0.14	0.33	-0.14	**0.53**	**0.49**	0.08	1.14

Producer Area Programs (continued)

Maryland - Chesapeake Bay Spring Spawning Stock

C-hat adjustment = 1.0; bootstrap GOF probability = 0.84 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1987	0.90	-0.05	0.03		0.00	**0.90**	**-0.05**	-0.12	0.16
1988	0.90	-0.05	0.04	0.67	-0.06	**0.96**	**-0.11**	-0.18	0.10
1989	0.90	-0.05	0.05	0.79	-0.09	**1.00**	**-0.15**	-0.22	0.07
1990	0.66	0.26	0.07	0.57	-0.09	**0.73**	**0.17**	0.12	0.21
1991	0.66	0.26	0.12	0.60	-0.18	**0.80**	**0.07**	0.02	0.11
1992	0.66	0.26	0.11	0.51	-0.14	**0.77**	**0.11**	0.07	0.16
1993	0.66	0.26	0.10	0.46	-0.12	**0.75**	**0.14**	0.10	0.19
1994	0.66	0.26	0.09	0.47	-0.11	**0.74**	**0.15**	0.11	0.20
1995	0.63	0.30	0.12	0.27	-0.09	**0.70**	**0.21**	0.17	0.26
1996	0.63	0.30	0.10	0.29	-0.07	**0.68**	**0.23**	0.18	0.28
1997	0.63	0.30	0.11	0.23	-0.07	**0.68**	**0.23**	0.19	0.28
1998	0.63	0.30	0.11	0.20	-0.06	**0.68**	**0.24**	0.20	0.29
1999	0.63	0.30	0.12	0.19	-0.07	**0.68**	**0.24**	0.19	0.28
2000	0.64	0.30	0.08	0.19	-0.04	**0.66**	**0.26**	0.17	0.36
2001	0.64	0.30	0.07	0.24	-0.04	**0.67**	**0.26**	0.17	0.36
2002	0.64	0.30	0.06	0.36	-0.05	**0.67**	**0.25**	0.16	0.35
2003	0.62	0.32	0.07	0.20	-0.04	**0.65**	**0.29**	0.22	0.36
2004	0.62	0.32	0.04	0.17	-0.02	**0.63**	**0.31**	0.24	0.38
2005	0.62	0.32	0.06	0.22	-0.03	**0.64**	**0.29**	0.23	0.37
2006	0.62	0.32	0.07	0.22	-0.04	**0.65**	**0.28**	0.22	0.36
2007	0.62	0.32	0.05	0.23	-0.03	**0.64**	**0.30**	0.23	0.37
2008	0.62	0.32	0.06	0.15	-0.02	**0.64**	**0.30**	0.24	0.38
2009	0.62	0.33	0.07	0.11	-0.02	**0.63**	**0.30**	0.21	0.42
2010	0.61	0.34	0.06	0.24	-0.03	**0.64**	**0.30**	0.16	0.49

Producer Area Programs (continued)

Virginia - Rappahannock River

C-hat adjustment = 1.113; bootstrap GOF probability = 0.1627 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1990	0.63	0.31	0.09	0.58	-0.13	**0.72**	**0.18**	0.10	0.26
1991	0.63	0.31	0.09	0.56	-0.13	**0.72**	**0.17**	0.10	0.26
1992	0.63	0.31	0.12	0.53	-0.17	**0.76**	**0.12**	0.05	0.21
1993	0.63	0.31	0.10	0.35	-0.09	**0.69**	**0.22**	0.14	0.30
1994	0.63	0.31	0.08	0.32	-0.07	**0.68**	**0.24**	0.17	0.33
1995	0.59	0.38	0.13	0.20	-0.08	**0.64**	**0.30**	0.21	0.41
1996	0.59	0.38	0.05	0.13	-0.02	**0.60**	**0.37**	0.28	0.47
1997	0.59	0.38	0.08	0.17	-0.04	**0.61**	**0.35**	0.26	0.45
1998	0.59	0.38	0.13	0.22	-0.08	**0.64**	**0.29**	0.05	0.25
1999	0.59	0.38	0.10	0.20	-0.06	**0.62**	**0.32**	0.08	0.28
2000	0.67	0.25	0.08	0.35	-0.07	**0.72**	**0.17**	-0.08	0.16
2001	0.67	0.25	0.07	0.30	-0.05	**0.71**	**0.20**	-0.06	0.18
2002	0.67	0.25	0.10	0.30	-0.08	**0.73**	**0.17**	-0.09	0.15
2003	0.59	0.39	0.09	0.25	-0.06	**0.62**	**0.32**	0.09	0.27
2004	0.58	0.24	0.06	0.32	-0.05	**0.62**	**0.19**	0.11	0.28
2005	0.59	0.24	0.05	0.24	-0.03	**0.61**	**0.20**	0.12	0.29
2006	0.59	0.24	0.06	0.28	-0.04	**0.61**	**0.19**	0.11	0.28
2007	0.59	0.24	0.06	0.23	-0.04	**0.61**	**0.20**	0.12	0.29
2008	0.59	0.24	0.08	0.16	-0.02	**0.60**	**0.21**	0.13	0.31
2009	0.61	0.19	0.03	0.11	-0.01	**0.62**	**0.18**	0.01	0.41
2010	0.72	0.03	0.04	0.24	-0.02	**0.73**	**0.01**	-0.13	0.24

Unadjusted (unadj.) and bias-corrected (adj.) estimates of survival (S) and fishing mortality (F) for striped bass ≥ 18 inches, from Program MARK and assuming a constant natural mortality, for each tagging program.

Coast Programs

Massachusetts

C-hat adjustment= 1.07, bootstrap GOF probability = 0.24 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1992	0.76	0.12	0.05	0.75	-0.09	**0.84**	**0.03**	-0.06	0.16
1993	0.76	0.12	0.05	0.60	-0.07	**0.82**	**0.05**	-0.03	0.17
1994	0.76	0.13	0.06	0.73	-0.09	**0.83**	**0.03**	-0.05	0.14
1995	0.74	0.15	0.05	0.81	-0.10	**0.82**	**0.05**	-0.03	0.16
1996	0.71	0.19	0.09	0.73	-0.15	**0.84**	**0.03**	-0.03	0.09
1997	0.71	0.19	0.08	0.59	-0.11	**0.81**	**0.07**	0.00	0.14
1998	0.72	0.18	0.08	0.52	-0.10	**0.80**	**0.07**	0.02	0.14
1999	0.72	0.18	0.06	0.50	-0.06	**0.77**	**0.11**	0.05	0.18
2000	0.73	0.17	0.06	0.18	-0.03	**0.74**	**0.15**	0.07	0.24
2001	0.75	0.14	0.05	0.45	-0.05	**0.79**	**0.09**	0.00	0.22
2002	0.73	0.16	0.07	0.50	-0.08	**0.80**	**0.08**	0.00	0.17
2003	0.71	0.19	0.05	0.27	-0.03	**0.74**	**0.16**	0.09	0.23
2004	0.71	0.19	0.05	0.20	-0.02	**0.73**	**0.16**	0.11	0.23
2005	0.71	0.20	0.05	0.41	-0.05	**0.74**	**0.15**	0.08	0.23
2006	0.71	0.20	0.06	0.39	-0.05	**0.75**	**0.14**	0.07	0.24
2007	0.73	0.16	0.04	0.36	-0.04	**0.76**	**0.13**	0.05	0.23
2008	0.71	0.19	0.05	0.32	-0.04	**0.74**	**0.15**	0.08	0.22
2009	0.70	0.21	0.05	0.26	-0.03	**0.72**	**0.17**	0.07	0.31
2010	0.72	0.18	0.05	0.39	-0.04	**0.75**	**0.13**	0.05	0.23

Coast Programs (continued)

New York Ocean Haul Seine/Trawl

C-hat adjustment = 0/1.133*; bootstrap GOF probability = 0/0.302* for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery	% Released	bias	**S(adj.)**	**F(adj.)**	95%LCL (F)	95%UCL F(adj)
1988	0.53	0.48	0.07	0.83	-0.14	**0.62**	**0.33**	0.21	0.47
1989	0.91	-0.05	0.09	0.85	-0.18	**1.11**	**-0.25**	-0.26	-0.24
1990	0.57	0.42	0.07	0.73	-0.12	**0.64**	**0.29**	0.16	0.45
1991	0.76	0.12	0.08	0.63	-0.12	**0.87**	**-0.01**	-0.13	0.18
1992	0.93	-0.08	0.07	0.73	-0.11	**1.05**	**-0.20**	-0.21	-0.19
1993	0.49	0.57	0.06	0.69	-0.09	**0.54**	**0.48**	0.34	0.63
1994	0.68	0.24	0.06	0.78	-0.11	**0.76**	**0.12**	0.00	0.28
1995	0.84	0.03	0.06	0.62	-0.09	**0.92**	**-0.07**	-0.19	0.24
1996	0.83	0.03	0.06	0.74	-0.10	**0.93**	**-0.08**	-0.21	0.29
1997	0.68	0.24	0.06	0.72	-0.10	**0.75**	**0.14**	-0.03	0.40
1998	0.46	0.63	0.06	0.77	-0.10	**0.51**	**0.53**	0.33	0.76
1999	0.70	0.21	0.07	0.61	-0.10	**0.78**	**0.10**	-0.06	0.37
2000	0.60	0.36	0.05	0.75	-0.08	**0.65**	**0.28**	0.10	0.52
2001	0.69	0.22	0.06	0.66	-0.09	**0.76**	**0.13**	-0.04	0.39
2002	0.63	0.31	0.06	0.65	-0.09	**0.70**	**0.21**	0.02	0.50
2003	0.68	0.23	0.06	0.63	-0.08	**0.74**	**0.15**	-0.06	0.52
2004	0.55	0.44	0.05	0.66	-0.08	**0.60**	**0.36**	0.13	0.68
2005	0.43	0.69	0.06	0.74	-0.09	**0.48**	**0.59**	0.36	0.86
2006	0.88	-0.02	0.07	0.80	-0.13	**1.01**	**-0.16**	-0.28	0.58
2007	0.10	2.12	0.05	0.83	-0.09	**0.11**	**-**	-0.24	-
2008*	0.60	0.36	0.05	0.73	-0.08	**0.66**	**0.27**	0.03	0.65
2009*	0.58	0.39	0.08	0.73	-0.13	**0.67**	**0.25**	-0.09	0.88
2010*	0.55	0.45	0.08	0.61	-0.11	**0.61**	**0.34**	-0.12	1.81

* = NY TRAWL

Coast Programs (continued)

New Jersey - Delaware Bay

C-hat adjustment = 1.45; bootstrap GOF probability = 0.59 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Released	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1989	0.88	-0.02	0.11	0.92	-0.22	**1.12**	**-0.27**	-0.39	1.24
1990	0.88	-0.02	0.11	0.89	-0.22	**1.13**	**-0.27**	-0.40	1.72
1991	0.57	0.41	0.07	0.91	-0.14	**0.66**	**0.26**	-0.01	0.70
1992	0.63	0.32	0.07	0.87	-0.13	**0.72**	**0.17**	0.00	0.43
1993	0.55	0.45	0.08	0.91	-0.15	**0.65**	**0.28**	0.15	0.44
1994	0.66	0.27	0.08	0.88	-0.15	**0.77**	**0.11**	0.00	0.24
1995	0.83	0.04	0.09	0.76	-0.15	**0.98**	**-0.13**	-0.22	0.03
1996	0.75	0.14	0.11	0.68	-0.18	**0.91**	**-0.06**	-0.22	0.25
1997	0.52	0.50	0.09	0.76	-0.16	**0.62**	**0.33**	0.11	0.61
1998	0.69	0.22	0.12	0.62	-0.18	**0.84**	**0.02**	-0.11	0.21
1999	0.73	0.16	0.08	0.74	-0.13	**0.84**	**0.02**	-0.07	0.14
2000	0.78	0.10	0.09	0.69	-0.13	**0.90**	**-0.05**	-0.17	0.18
2001	0.70	0.21	0.09	0.63	-0.13	**0.80**	**0.07**	-0.03	0.22
2002	0.57	0.41	0.06	0.62	-0.09	**0.62**	**0.32**	0.19	0.49
2003	0.54	0.46	0.09	0.68	-0.14	**0.63**	**0.31**	0.17	0.47
2004	0.67	0.25	0.10	0.58	-0.14	**0.78**	**0.10**	-0.05	0.31
2005	0.58	0.40	0.09	0.67	-0.15	**0.68**	**0.24**	0.06	0.46
2006	0.58	0.40	0.08	0.71	-0.12	**0.66**	**0.27**	0.09	0.50
2007	0.64	0.30	0.09	0.55	-0.12	**0.72**	**0.17**	0.00	0.42
2008	0.67	0.26	0.09	0.58	-0.12	**0.76**	**0.13**	-0.04	0.38
2009	0.86	0.00	0.08	0.70	-0.13	**0.99**	**-0.14**	-0.28	0.61
2010	0.62	0.32	0.07	0.58	-0.09	**0.68**	**0.23**	0.15	0.33

Coast Programs (continued)

North Carolina - Cooperative Winter Trawl Survey

C-hat adjustment = 2.813; bootstrap GOF probability < 0.05 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1988	0.91	-0.06	0.09	0.85	-0.17	**1.10**	**-0.24**	-0.27	-0.21
1989	0.62	0.32	0.04	0.89	-0.08	**0.68**	**0.24**	0.05	0.51
1990	0.54	0.47	0.07	0.69	-0.11	**0.60**	**0.36**	0.17	0.60
1991	0.63	0.31	0.09	0.60	-0.13	**0.72**	**0.18**	-0.01	0.45
1992	0.78	0.10	0.10	0.51	-0.12	**0.88**	**-0.03**	-0.21	0.51
1993	0.78	0.10	0.09	0.50	-0.10	**0.87**	**-0.01**	-0.19	0.47
1994	0.48	0.57	0.07	0.55	-0.09	**0.53**	**0.48**	0.28	0.72
1995	0.91	-0.05	0.09	0.47	-0.11	**1.02**	**-0.17**	-0.19	-0.14
1996	0.57	0.42	0.05	0.42	-0.05	**0.60**	**0.37**	0.13	0.70
1997	0.50	0.53	0.08	0.37	-0.07	**0.55**	**0.46**	0.16	0.87
1998	0.67	0.25	0.10	0.36	-0.09	**0.74**	**0.15**	-0.09	0.65
1999	0.92	-0.06	0.09	0.34	-0.07	**0.99**	**-0.14**	-0.17	-0.11
2000	0.31	1.02	0.06	0.47	-0.06	**0.33**	**0.96**	0.73	1.21
2001	0.59	0.37	0.08	0.41	-0.07	**0.64**	**0.30**	0.11	0.56
2002	0.53	0.48	0.07	0.41	-0.07	**0.57**	**0.41**	0.21	0.68
2003	0.66	0.27	0.07	0.36	-0.06	**0.70**	**0.21**	0.02	0.51
2004	0.94	-0.08	0.06	0.37	-0.06	**0.99**	**-0.14**	-0.16	-0.13
2005	0.26	1.21	0.03	0.40	-0.03	**0.26**	**1.18**	0.97	1.41
2006	0.39	0.78	0.07	0.39	-0.07	**0.42**	**0.71**	0.38	1.13
2007	0.55	0.44	0.10	0.36	-0.09	**0.61**	**0.35**	0.03	0.88
2008	0.90	-0.05	0.10	0.33	-0.08	**0.98**	**-0.13**	-0.16	-0.10
2009	0.94	-0.09	0.06	0.35	-0.04	**0.98**	**-0.13**	-0.17	-0.05
2010	0.54	0.47	0.04	0.31	-0.03	**0.56**	**0.44**	0.36	0.53

Producer Area Programs

Hudson River

C-hat adjustment = 1.09; bootstrap GOF probability =0.0136 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1988	0.74	0.16	0.07	0.75	-0.11	**0.83**	**0.04**	-0.05	0.16
1989	0.73	0.17	0.09	0.83	-0.16	**0.87**	**-0.01**	-0.10	0.10
1990	0.64	0.30	0.11	0.79	-0.20	**0.80**	**0.07**	0.03	0.12
1991	0.64	0.30	0.10	0.72	-0.17	**0.77**	**0.11**	0.06	0.15
1992	0.64	0.30	0.10	0.65	-0.16	**0.76**	**0.12**	0.09	0.16
1993	0.64	0.30	0.10	0.64	-0.16	**0.76**	**0.13**	0.09	0.17
1994	0.64	0.30	0.10	0.65	-0.16	**0.76**	**0.12**	0.06	0.19
1995	0.66	0.26	0.10	0.48	-0.11	**0.75**	**0.14**	0.10	0.18
1996	0.66	0.26	0.11	0.43	-0.12	**0.76**	**0.13**	0.09	0.17
1997	0.66	0.26	0.13	0.31	-0.11	**0.74**	**0.15**	0.10	0.20
1998	0.66	0.26	0.11	0.33	-0.10	**0.74**	**0.16**	0.12	0.20
1999	0.66	0.26	0.10	0.38	-0.10	**0.74**	**0.16**	0.11	0.21
2000	0.69	0.22	0.08	0.56	-0.11	**0.77**	**0.11**	0.03	0.21
2001	0.69	0.23	0.07	0.51	-0.08	**0.74**	**0.15**	0.10	0.20
2002	0.68	0.23	0.08	0.58	-0.10	**0.76**	**0.12**	0.05	0.20
2003	0.61	0.34	0.08	0.55	-0.11	**0.69**	**0.22**	0.17	0.27
2004	0.61	0.34	0.09	0.44	-0.10	**0.68**	**0.24**	0.18	0.30
2005	0.61	0.34	0.08	0.55	-0.10	**0.68**	**0.24**	0.19	0.29
2006	0.61	0.34	0.09	0.43	-0.09	**0.67**	**0.24**	0.20	0.29
2007	0.61	0.34	0.08	0.43	-0.08	**0.67**	**0.25**	0.21	0.30
2008	0.61	0.34	0.08	0.52	-0.10	**0.68**	**0.24**	0.16	0.32
2009	0.62	0.33	0.10	0.39	-0.10	**0.69**	**0.22**	0.11	0.36
2010	0.60	0.36	0.08	0.39	-0.08	**0.65**	**0.28**	0.19	0.38

Producer Area Programs (continued)

Delaware / Pennsylvania - Delaware River

C-hat adjustment = 1.73; bootstrap GOF probability = 0.02 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1993	0.69	0.22	0.06	0.48	-0.07	**0.74**	**0.15**	-0.01	0.39
1994	0.69	0.22	0.05	0.55	-0.06	**0.74**	**0.16**	0.00	0.40
1995	0.60	0.37	0.04	0.58	-0.05	**0.63**	**0.31**	0.24	0.38
1996	0.60	0.37	0.04	0.51	-0.06	**0.63**	**0.31**	0.24	0.38
1997	0.60	0.37	0.04	0.48	-0.04	**0.62**	**0.32**	0.26	0.40
1998	0.60	0.37	0.03	0.48	-0.04	**0.62**	**0.33**	0.26	0.40
1999	0.60	0.37	0.04	0.49	-0.04	**0.62**	**0.32**	0.25	0.40
2000	0.61	0.34	0.03	0.45	-0.04	**0.63**	**0.30**	0.22	0.40
2001	0.61	0.34	0.03	0.41	-0.03	**0.63**	**0.31**	0.23	0.40
2002	0.61	0.34	0.03	0.31	-0.02	**0.63**	**0.32**	0.24	0.41
2003	0.54	0.47	0.03	0.45	-0.04	**0.56**	**0.43**	0.35	0.53
2004	0.54	0.47	0.04	0.33	-0.03	**0.56**	**0.44**	0.35	0.53
2005	0.54	0.47	0.04	0.68	-0.07	**0.58**	**0.39**	0.31	0.49
2006	0.54	0.47	0.04	0.55	-0.05	**0.57**	**0.42**	0.34	0.51
2007	0.54	0.47	0.04	0.63	-0.07	**0.58**	**0.40**	0.31	0.49
2008	0.54	0.47	0.04	0.66	-0.06	**0.58**	**0.40**	0.32	0.50
2009	0.53	0.48	0.05	0.58	-0.06	**0.57**	**0.41**	0.28	0.57
2010	0.54	0.47	0.05	0.59	-0.07	**0.58**	**0.40**	0.24	0.61

Producer Area Programs (continued)

Maryland - Chesapeake Bay Spring Spawning Stock

C-hat adjustment = 1.959 bootstrap GOF probability =0.002 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1987	0.84	0.02	0.07	0.95	-0.15	**0.99**	**-0.14**	-0.19	-0.07
1988	0.84	0.02	0.04	0.84	-0.08	**0.92**	**-0.06**	-0.11	0.00
1989	0.84	0.02	0.03	0.93	-0.07	**0.91**	**-0.05**	-0.10	0.02
1990	0.63	0.31	0.06	0.59	-0.07	**0.68**	**0.23**	0.19	0.27
1991	0.63	0.31	0.09	0.47	-0.10	**0.70**	**0.20**	0.17	0.24
1992	0.63	0.31	0.11	0.43	-0.12	**0.72**	**0.18**	0.14	0.22
1993	0.63	0.31	0.09	0.38	-0.08	**0.69**	**0.22**	0.18	0.25
1994	0.63	0.31	0.10	0.43	-0.11	**0.71**	**0.19**	0.16	0.23
1995	0.57	0.41	0.12	0.33	-0.11	**0.64**	**0.30**	0.25	0.35
1996	0.57	0.41	0.11	0.35	-0.10	**0.64**	**0.30**	0.25	0.35
1997	0.57	0.41	0.12	0.27	-0.08	**0.62**	**0.32**	0.27	0.38
1998	0.57	0.41	0.13	0.26	-0.09	**0.63**	**0.32**	0.26	0.37
1999	0.57	0.41	0.11	0.21	-0.06	**0.61**	**0.35**	0.30	0.40
2000	0.51	0.51	0.11	0.33	-0.09	**0.57**	**0.42**	0.31	0.54
2001	0.51	0.51	0.08	0.32	-0.06	**0.55**	**0.45**	0.34	0.57
2002	0.51	0.51	0.07	0.32	-0.05	**0.54**	**0.46**	0.35	0.58
2003	0.53	0.48	0.08	0.24	-0.05	**0.56**	**0.43**	0.35	0.53
2004	0.53	0.48	0.06	0.25	-0.04	**0.55**	**0.44**	0.36	0.54
2005	0.53	0.48	0.06	0.27	-0.04	**0.55**	**0.45**	0.36	0.54
2006	0.53	0.49	0.08	0.27	-0.05	**0.56**	**0.43**	0.35	0.53
2007	0.53	0.48	0.05	0.29	-0.04	**0.55**	**0.45**	0.36	0.54
2008	0.53	0.48	0.06	0.23	-0.03	**0.55**	**0.45**	0.37	0.55
2009	0.53	0.49	0.08	0.13	-0.03	**0.54**	**0.46**	0.37	0.55
2010	0.53	0.48	0.08	0.26	-0.05	**0.56**	**0.43**	0.35	0.53

Producer Area Programs (continued)

Virginia - Rappahannock River

C-hat adjustment = 1.888; bootstrap GOF probability = 0.004 for the full parameterized model.

Year	S(unadj.)	F(unadj.)	Recovery Rate	% Live Release	Bias Live Release	**S(adj.)**	**F(adj.)**	95%LCL F(adj)	95%UCL F(adj)
1990	0.81	0.06	0.11	0.48	-0.14	**0.94**	**-0.09**	-0.24	0.35
1991	0.29	1.10	0.06	0.52	-0.08	**0.31**	**1.02**	0.55	1.59
1992	0.80	0.08	0.12	0.41	-0.14	**0.93**	**-0.08**	-0.28	0.94
1993	0.60	0.36	0.09	0.46	-0.11	**0.67**	**0.25**	-0.08	0.89
1994	0.57	0.42	0.09	0.38	-0.09	**0.62**	**0.32**	-0.02	0.97
1995	0.68	0.24	0.08	0.26	-0.05	**0.72**	**0.18**	-0.09	0.85
1996	0.64	0.30	0.06	0.27	-0.04	**0.66**	**0.26**	-0.04	0.92
1997	0.57	0.42	0.07	0.33	-0.06	**0.60**	**0.36**	0.05	0.89
1998	0.41	0.73	0.06	0.36	-0.06	**0.44**	**0.67**	0.31	1.15
1999	0.38	0.82	0.08	0.29	-0.06	**0.40**	**0.76**	0.41	1.20
2000	0.43	0.69	0.07	0.44	-0.07	**0.47**	**0.61**	0.32	0.99
2001	0.47	0.62	0.07	0.37	-0.07	**0.50**	**0.54**	0.18	1.08
2002	0.60	0.35	0.07	0.37	-0.06	**0.64**	**0.29**	-0.03	0.91
2003	0.83	0.04	0.07	0.27	-0.05	**0.87**	**-0.01**	-0.18	0.92
2004	0.35	0.90	0.05	0.28	-0.04	**0.36**	**0.86**	0.48	1.33
2005	0.48	0.58	0.04	0.27	-0.03	**0.50**	**0.55**	0.20	1.06
2006	0.52	0.51	0.06	0.35	-0.06	**0.55**	**0.45**	0.13	0.94
2007	0.55	0.44	0.06	0.30	-0.04	**0.58**	**0.40**	0.05	1.01
2008	0.52	0.50	0.06	0.21	-0.02	**0.54**	**0.48**	0.06	1.24
2009	0.62	0.32	0.05	0.23	-0.03	**0.64**	**0.29**	1.36	1.38
2010	0.73	0.16	0.02	0.27	-0.01	**0.74**	**0.15**	-0.03	0.50

APPENDIX E

Estimates of fishing mortality for ≥28 inch striped bass obtained without assuming constant natural mortality, based on exploitation rate and Baranov's catch equation, using bias-adjusted estimates of survival from Appendix A. Column headings are S: bias-corrected survival rate, Z: total instantaneous mortality, A: annual percentage mortality expressed as a proportion, U: annual exploitation rate, F: instantaneous fishing mortality rate and M: instantaneous natural mortality rate.

Coast Programs

Massachusetts Fall Tagging

Year	Z	A	U	F	M
1988					
1989					
1990					
1991					
1992	0.18	0.16	0.04	0.04	0.14
1993	0.19	0.18	0.05	0.05	0.14
1994	0.17	0.16	0.04	0.04	0.14
1995	0.22	0.19	0.04	0.05	0.17
1996	0.21	0.19	0.08	0.09	0.13
1997	0.22	0.20	0.17	0.19	0.04
1998	0.21	0.19	0.07	0.08	0.14
1999	0.26	0.23	0.09	0.10	0.16
2000	0.30	0.26	0.13	0.15	0.15
2001	0.24	0.22	0.07	0.08	0.17
2002	0.20	0.18	0.07	0.08	0.12
2003	0.33	0.28	0.11	0.13	0.21
2004	0.32	0.27	0.09	0.11	0.21
2005	0.31	0.26	0.07	0.08	0.23
2006	0.30	0.26	0.09	0.10	0.19
2007	0.30	0.26	0.05	0.06	0.24
2008	0.31	0.26	0.08	0.09	0.22
2009	0.33	0.28	0.10	0.12	0.21
2010	0.29	0.25	0.07	0.09	0.21
Average	0.26	0.23	0.08	0.09	0.17

New York Ocean Haul Seine/Trawl Fall Tagging

Year	Z	A	U	F	M
1988	-0.03	-0.03	0.05	0.05	-0.08
1989	0.01	0.01	0.04	0.04	-0.04
1990	0.33	0.28	0.07	0.08	0.25
1991	0.32	0.27	0.13	0.15	0.17
1992	0.23	0.20	0.11	0.13	0.10
1993	0.34	0.29	0.14	0.16	0.17
1994	0.30	0.26	0.09	0.11	0.19
1995	0.26	0.23	0.21	0.24	0.02
1996	0.21	0.19	0.14	0.16	0.05
1997	0.32	0.28	0.34	0.40	-0.08
1998	0.43	0.35	0.17	0.21	0.22
1999	0.37	0.31	0.31	0.37	0.01
2000	0.14	0.13	0.18	0.19	-0.05
2001	0.17	0.16	0.11	0.12	0.05
2002	0.15	0.14	0.23	0.24	-0.09
2003	0.51	0.40	0.15	0.19	0.32
2004	0.47	0.37	0.15	0.18	0.28
2005	0.51	0.40	0.26	0.33	0.18
2006	0.48	0.38	0.13	0.16	0.32
2007	0.47	0.38	0.02	0.03	0.45
2008*	0.01	0.01	0.07	0.07	-0.06
2009*	-0.09	-0.10	0.01	0.01	-0.11
2010*	0.08	0.07	0.12	0.13	-0.05
Average	0.26	0.22	0.14	0.16	0.10

* = NY TRAWL

Coast Programs (continued)

New Jersey Delaware Bay March-April

Year	Z	A	U	F	M
1988					
1989	0.11	0.11	0.02	0.02	0.09
1990	0.12	0.11	0.04	0.04	0.08
1991	-0.01	-0.01	0.18	0.18	-0.19
1992	0.24	0.21	0.02	0.02	0.22
1993	0.30	0.26	0.09	0.10	0.20
1994	0.23	0.21	0.05	0.06	0.18
1995	0.22	0.20	0.10	0.12	0.11
1996	0.25	0.22	0.20	0.22	0.03
1997	0.29	0.25	0.25	0.29	0.00
1998	0.36	0.31	0.35	0.42	-0.06
1999	0.21	0.19	0.08	0.09	0.12
2000	0.21	0.19	0.14	0.15	0.06
2001	0.23	0.20	0.15	0.17	0.06
2002	0.23	0.21	0.11	0.12	0.11
2003	0.37	0.31	0.15	0.18	0.19
2004	0.36	0.30	0.15	0.18	0.18
2005	0.29	0.25	0.17	0.19	0.10
2006	0.36	0.30	0.14	0.17	0.19
2007	0.38	0.31	0.13	0.16	0.22
2008	0.38	0.32	0.14	0.17	0.21
2009	0.42	0.35	0.23	0.28	0.14
2010	0.42	0.34	0.13	0.16	0.26
Average	0.28	0.24	0.14	0.16	0.14

North Carolina Winter Trawl Survey

Year	Z	A	U	F	M
1988	0.18	0.16	0.03	0.04	0.14
1989	0.25	0.22	0.03	0.03	0.21
1990	0.24	0.22	0.06	0.07	0.17
1991	0.24	0.21	0.08	0.09	0.14
1992	0.23	0.20	0.14	0.15	0.07
1993	0.25	0.22	0.11	0.12	0.13
1994	0.26	0.23	0.08	0.09	0.17
1995	0.34	0.29	0.14	0.16	0.18
1996	0.40	0.33	0.11	0.13	0.27
1997	0.37	0.31	0.15	0.18	0.19
1998	0.37	0.31	0.14	0.17	0.20
1999	0.37	0.31	0.22	0.26	0.11
2000	0.36	0.31	0.08	0.10	0.27
2001	0.35	0.29	0.11	0.13	0.21
2002	0.35	0.30	0.12	0.14	0.21
2003	0.45	0.36	0.11	0.13	0.32
2004	0.44	0.36	0.12	0.14	0.30
2005	0.46	0.37	0.06	0.07	0.39
2006	0.44	0.36	0.10	0.13	0.31
2007	0.43	0.35	0.16	0.19	0.24
2008	0.43	0.35	0.18	0.22	0.21
2009	0.46	0.37	0.04	0.05	0.40
2010	0.45	0.36	0.07	0.09	0.37
Average	0.35	0.29	0.11	0.13	0.23

Producer Area Programs

Hudson River Spring Spawning Stock

Year	Z	A	U	F	M
1988	0.18	0.17	0.10	0.11	0.07
1989	0.09	0.09	0.07	0.07	0.02
1990	0.20	0.18	0.11	0.12	0.08
1991	0.29	0.25	0.10	0.12	0.17
1992	0.24	0.21	0.13	0.14	0.09
1993	0.26	0.23	0.16	0.18	0.08
1994	0.26	0.23	0.12	0.14	0.12
1995	0.30	0.26	0.15	0.17	0.13
1996	0.33	0.28	0.22	0.26	0.07
1997	0.31	0.27	0.29	0.33	-0.02
1998	0.33	0.28	0.21	0.25	0.08
1999	0.31	0.27	0.21	0.24	0.07
2000	0.31	0.27	0.14	0.16	0.15
2001	0.33	0.28	0.13	0.16	0.18
2002	0.33	0.28	0.19	0.23	0.10
2003	0.38	0.32	0.14	0.17	0.21
2004	0.41	0.33	0.21	0.25	0.16
2005	0.39	0.32	0.17	0.20	0.19
2006	0.40	0.33	0.15	0.18	0.22
2007	0.41	0.34	0.16	0.19	0.22
2008	0.39	0.32	0.15	0.18	0.21
2009	0.38	0.32	0.19	0.23	0.15
2010	0.42	0.35	0.19	0.24	0.19
Average	0.32	0.27	0.16	0.19	0.13

Delaware River - Delaware/Pennsylvania
Spring Spawning Stock

Year	Z	A	U	F	M
1988					
1989					
1990					
1991					
1992					
1993	0.07	0.07	0.14	0.15	-0.08
1994	0.04	0.04	0.12	0.12	-0.08
1995	0.36	0.30	0.16	0.19	0.17
1996	0.37	0.31	0.30	0.36	0.01
1997	0.46	0.37	0.31	0.38	0.07
1998	0.41	0.33	0.30	0.37	0.04
1999	0.44	0.36	0.18	0.22	0.22
2000	0.37	0.31	0.32	0.38	-0.01
2001	0.41	0.34	0.30	0.36	0.05
2002	0.45	0.36	0.23	0.29	0.16
2003	0.32	0.27	0.17	0.20	0.12
2004	0.41	0.34	0.23	0.28	0.14
2005	0.33	0.28	0.16	0.18	0.14
2006	0.40	0.33	0.21	0.26	0.15
2007	0.39	0.32	0.20	0.24	0.16
2008	0.43	0.35	0.12	0.14	0.28
2009	0.73	0.52	0.22	0.32	0.41
2010	0.64	0.47	0.23	0.31	0.33
Average	0.39	0.31	0.22	0.26	0.13

Producer Area Programs (continued)

Maryland - Chesapeake Bay Spring Spawning Stock

Year	Z	A	U	F	M
1987	0.10	0.10			0.10
1988	0.04	0.04	0.07	0.08	-0.04
1989	0.00	0.00	0.04	0.04	-0.03
1990	0.32	0.27	0.09	0.10	0.22
1991	0.22	0.20	0.12	0.13	0.08
1992	0.26	0.23	0.12	0.14	0.12
1993	0.29	0.25	0.12	0.14	0.15
1994	0.30	0.26	0.12	0.13	0.17
1995	0.36	0.30	0.21	0.25	0.12
1996	0.38	0.32	0.17	0.21	0.17
1997	0.38	0.32	0.23	0.28	0.10
1998	0.39	0.32	0.23	0.27	0.12
1999	0.39	0.32	0.21	0.26	0.13
2000	0.41	0.34	0.17	0.21	0.20
2001	0.41	0.33	0.11	0.13	0.27
2002	0.40	0.33	0.10	0.12	0.28
2003	0.44	0.35	0.11	0.13	0.31
2004	0.46	0.37	0.08	0.11	0.35
2005	0.44	0.36	0.11	0.14	0.30
2006	0.43	0.35	0.14	0.17	0.26
2007	0.45	0.36	0.09	0.12	0.33
2008	0.45	0.36	0.11	0.14	0.32
2009	0.45	0.37	0.17	0.21	0.25
2010	0.45	0.36	0.10	0.12	0.33
Average	0.34	0.28	0.13	0.16	0.21

Virginia - Rappahannock River Spring Spawning Stock

Year	Z	A	U	F	M
1987					
1988					
1989					
1990	0.06	0.06	0.17	0.18	-0.12
1991	1.17	0.69	0.14	0.23	0.93
1992	0.07	0.07	0.32	0.34	-0.26
1993	0.40	0.33	0.23	0.28	0.11
1994	0.47	0.38	0.26	0.33	0.15
1995	0.33	0.28	0.19	0.22	0.11
1996	0.41	0.34	0.15	0.18	0.23
1997	0.51	0.40	0.20	0.25	0.26
1998	0.82	0.56	0.15	0.22	0.60
1999	0.91	0.60	0.13	0.20	0.71
2000	0.76	0.53	0.14	0.19	0.57
2001	0.69	0.50	0.18	0.25	0.44
2002	0.44	0.36	0.19	0.23	0.21
2003	0.14	0.13	0.19	0.21	-0.07
2004	1.01	0.64	0.12	0.20	0.81
2005	0.70	0.50	0.15	0.20	0.49
2006	0.60	0.45	0.16	0.21	0.39
2007	0.55	0.42	0.14	0.19	0.36
2008	0.63	0.46	0.10	0.13	0.49
2009	0.44	0.36	0.09	0.11	0.33
2010	0.30	0.26	0.04	0.04	0.26
Average	0.54	0.40	0.16	0.21	0.41

Estimates of fishing mortality for ≥18 inch striped bass obtained without assuming constant natural mortality, based on exploitation rate and Baranov's catch equation, using bias-adjusted estimates of survival from Table 11. The tables also present annual estimates of instantaneous natural mortality, M. Column headings are S: bias-corrected survival rate, Z: total instantaneous mortality, A: annual percentage mortality expressed as a proportion, U: annual exploitation rate, F: instantaneous fishing mortality rate and M: instantaneous natural mortality rate.

Coast Programs

Massachusetts Fall Tagging

Year	Z	A	U	F	M
1988					
1989					
1990					
1991					
1992	0.18	0.16	0.04	0.04	0.14
1993	0.20	0.18	0.04	0.04	0.16
1994	0.18	0.17	0.04	0.04	0.14
1995	0.20	0.18	0.03	0.04	0.17
1996	0.18	0.16	0.06	0.06	0.11
1997	0.22	0.19	0.12	0.13	0.09
1998	0.22	0.20	0.08	0.09	0.13
1999	0.26	0.23	0.06	0.07	0.20
2000	0.30	0.26	0.08	0.10	0.20
2001	0.24	0.21	0.05	0.06	0.18
2002	0.23	0.20	0.08	0.09	0.13
2003	0.31	0.26	0.08	0.09	0.21
2004	0.31	0.27	0.09	0.10	0.21
2005	0.30	0.26	0.06	0.07	0.22
2006	0.29	0.25	0.08	0.09	0.20
2007	0.28	0.24	0.04	0.05	0.23
2008	0.30	0.26	0.07	0.08	0.22
2009	0.32	0.28	0.09	0.10	0.22
2010	0.28	0.25	0.07	0.08	0.20
Average	0.25	0.22	0.07	0.08	0.18

New York Ocean Haul Seine/Trawl Fall Tagging

Year	Z	A	U	F	M
1988	0.48	0.38	0.03	0.03	0.45
1989	-0.10	-0.11	0.03	0.03	-0.13
1990	0.44	0.36	0.04	0.05	0.39
1991	0.14	0.13	0.06	0.07	0.07
1992	-0.05	-0.05	0.05	0.05	-0.10
1993	0.63	0.46	0.04	0.06	0.57
1994	0.27	0.24	0.04	0.04	0.23
1995	0.08	0.08	0.06	0.06	0.02
1996	0.07	0.07	0.04	0.04	0.03
1997	0.29	0.25	0.05	0.06	0.23
1998	0.68	0.49	0.03	0.05	0.63
1999	0.25	0.22	0.06	0.07	0.19
2000	0.43	0.35	0.03	0.04	0.39
2001	0.28	0.24	0.05	0.06	0.22
2002	0.36	0.30	0.07	0.08	0.28
2003	0.30	0.26	0.05	0.06	0.23
2004	0.51	0.40	0.04	0.05	0.45
2005	0.74	0.52	0.04	0.06	0.68
2006	-0.01	-0.01	0.04	0.04	-0.04
2007	2.18	0.89	0.02	0.06	2.12
2008*	0.42	0.34	0.03	0.04	0.38
2009*	0.40	0.33	0.06	0.07	0.33
2010*	0.49	0.39	0.07	0.09	0.40
Average	0.40	0.28	0.04	0.05	0.35

* = NY TRAWL

Coast Programs (continued)

New Jersey Delaware Bay March-April

Year	Z	A	U	F	M
1988					
1989	-0.12	-0.12	0.03	0.03	-0.15
1990	-0.12	-0.13	0.07	0.07	-0.18
1991	0.41	0.34	0.03	0.03	0.38
1992	0.32	0.28	0.04	0.04	0.28
1993	0.43	0.35	0.03	0.03	0.40
1994	0.26	0.23	0.03	0.04	0.22
1995	0.02	0.02	0.06	0.06	-0.04
1996	0.09	0.09	0.09	0.09	0.00
1997	0.48	0.38	0.08	0.10	0.38
1998	0.17	0.16	0.12	0.13	0.04
1999	0.17	0.16	0.05	0.06	0.11
2000	0.10	0.10	0.07	0.08	0.03
2001	0.22	0.20	0.09	0.10	0.12
2002	0.47	0.38	0.06	0.07	0.40
2003	0.46	0.37	0.08	0.09	0.36
2004	0.25	0.22	0.12	0.13	0.12
2005	0.39	0.32	0.09	0.11	0.28
2006	0.42	0.34	0.06	0.08	0.34
2007	0.32	0.28	0.11	0.13	0.19
2008	0.28	0.24	0.09	0.10	0.18
2009	0.01	0.01	0.07	0.07	-0.06
2010	0.38	0.32	0.07	0.09	0.30
Average	0.28	0.24	0.07	0.08	0.23

North Carolina Winter Trawl Survey

Year	Z	A	U	F	M
1988	-0.09	-0.10	0.06	0.06	-0.15
1989	0.39	0.32	0.04	0.05	0.34
1990	0.51	0.40	0.09	0.11	0.40
1991	0.33	0.28	0.07	0.09	0.24
1992	0.12	0.12	0.13	0.14	-0.01
1993	0.14	0.13	0.11	0.12	0.02
1994	0.63	0.47	0.08	0.11	0.52
1995	-0.02	-0.02	0.14	0.14	-0.16
1996	0.52	0.40	0.11	0.14	0.37
1997	0.61	0.45	0.18	0.25	0.36
1998	0.30	0.26	0.20	0.23	0.07
1999	0.01	0.01	0.24	0.24	-0.23
2000	1.11	0.67	0.06	0.10	1.00
2001	0.45	0.36	0.15	0.19	0.26
2002	0.56	0.43	0.12	0.15	0.41
2003	0.36	0.30	0.11	0.14	0.22
2004	0.01	0.01	0.12	0.12	-0.12
2005	1.33	0.74	0.07	0.13	1.20
2006	0.86	0.58	0.12	0.18	0.68
2007	0.50	0.39	0.19	0.24	0.26
2008	0.02	0.02	0.19	0.19	-0.17
2009	0.02	0.02	0.05	0.05	-0.03
2010	0.59	0.44	0.07	0.09	0.50
Average	0.44	0.32	0.12	0.14	0.43

Producer Area Programs

Hudson River Spring Spawning Stock Survey

Year	Z	A	U	F	M
1987					
1988	0.19	0.17	0.05	0.05	0.14
1989	0.14	0.13	0.05	0.05	0.09
1990	0.22	0.20	0.07	0.08	0.14
1991	0.26	0.23	0.07	0.08	0.17
1992	0.27	0.24	0.09	0.10	0.18
1993	0.28	0.24	0.10	0.11	0.17
1994	0.27	0.24	0.09	0.10	0.17
1995	0.29	0.25	0.12	0.14	0.15
1996	0.28	0.24	0.15	0.18	0.10
1997	0.30	0.26	0.22	0.25	0.04
1998	0.31	0.26	0.17	0.20	0.11
1999	0.31	0.26	0.14	0.16	0.15
2000	0.26	0.23	0.10	0.11	0.15
2001	0.30	0.26	0.09	0.10	0.19
2002	0.27	0.24	0.08	0.09	0.18
2003	0.37	0.31	0.10	0.12	0.25
2004	0.39	0.32	0.13	0.15	0.23
2005	0.39	0.32	0.09	0.11	0.28
2006	0.39	0.33	0.10	0.12	0.27
2007	0.40	0.33	0.09	0.12	0.29
2008	0.39	0.32	0.09	0.10	0.28
2009	0.37	0.31	0.15	0.18	0.19
2010	0.43	0.35	0.12	0.14	0.28
Average	0.30	0.26	0.11	0.12	0.18

Delaware River - DE/PA Spring Spawning Stock

Year	Z	A	U	F	M
1987					
1988					
1989					
1990					
1991					
1992					
1993	0.30	0.26	0.14	0.16	0.13
1994	0.31	0.26	0.12	0.14	0.16
1995	0.46	0.37	0.14	0.17	0.29
1996	0.46	0.37	0.15	0.18	0.28
1997	0.47	0.38	0.14	0.18	0.30
1998	0.48	0.38	0.15	0.19	0.29
1999	0.47	0.38	0.11	0.14	0.33
2000	0.45	0.37	0.15	0.19	0.26
2001	0.46	0.37	0.15	0.19	0.27
2002	0.47	0.37	0.14	0.18	0.29
2003	0.58	0.44	0.15	0.20	0.38
2004	0.59	0.44	0.15	0.20	0.39
2005	0.54	0.42	0.11	0.14	0.40
2006	0.57	0.43	0.12	0.16	0.41
2007	0.55	0.42	0.08	0.10	0.45
2008	0.55	0.42	0.08	0.11	0.44
2009	0.56	0.43	0.12	0.15	0.41
2010	0.55	0.42	0.10	0.13	0.42
Average	0.49	0.39	0.13	0.16	0.33

Producer Area Programs (continued)

Maryland Chesapeake Bay Spring Spawning Stock

Year	Z	A	U	F	M
1987	0.01	0.01	0.01	0.01	0.00
1988	0.09	0.08	0.01	0.01	0.07
1989	0.10	0.09	0.01	0.01	0.09
1990	0.38	0.32	0.07	0.08	0.30
1991	0.35	0.30	0.10	0.12	0.24
1992	0.33	0.28	0.13	0.15	0.17
1993	0.37	0.31	0.11	0.13	0.23
1994	0.34	0.29	0.12	0.15	0.19
1995	0.45	0.36	0.19	0.23	0.21
1996	0.45	0.36	0.17	0.21	0.24
1997	0.47	0.38	0.21	0.26	0.21
1998	0.47	0.37	0.22	0.28	0.19
1999	0.50	0.39	0.17	0.22	0.28
2000	0.57	0.43	0.17	0.22	0.35
2001	0.60	0.45	0.12	0.16	0.44
2002	0.61	0.46	0.12	0.16	0.45
2003	0.58	0.44	0.13	0.17	0.41
2004	0.59	0.45	0.10	0.14	0.46
2005	0.60	0.45	0.11	0.15	0.45
2006	0.58	0.44	0.14	0.18	0.40
2007	0.60	0.45	0.09	0.12	0.48
2008	0.60	0.45	0.11	0.15	0.45
2009	0.61	0.46	0.17	0.23	0.38
2010	0.58	0.44	0.13	0.18	0.41
Average	0.45	0.35	0.12	0.15	0.30

Virginia Rappahanock River Spring Spawning Stock Survey

Year	Z	A	U	F	M
1987					
1988					
1989					
1990	0.06	0.06	0.17	0.18	-0.12
1991	1.17	0.69	0.14	0.23	0.93
1992	0.07	0.07	0.32	0.34	-0.26
1993	0.40	0.33	0.23	0.28	0.11
1994	0.47	0.38	0.26	0.33	0.15
1995	0.33	0.28	0.19	0.22	0.11
1996	0.41	0.34	0.15	0.18	0.23
1997	0.51	0.40	0.20	0.25	0.26
1998	0.82	0.56	0.15	0.22	0.60
1999	0.91	0.60	0.13	0.20	0.71
2000	0.76	0.53	0.14	0.19	0.57
2001	0.69	0.50	0.18	0.25	0.44
2002	0.44	0.36	0.19	0.23	0.21
2003	0.14	0.13	0.19	0.21	-0.07
2004	1.01	0.64	0.12	0.20	0.81
2005	0.70	0.50	0.15	0.20	0.49
2006	0.60	0.45	0.16	0.21	0.39
2007	0.55	0.42	0.14	0.19	0.36
2008	0.63	0.46	0.10	0.13	0.49
2009	0.44	0.36	0.09	0.11	0.33
2010	0.30	0.26	0.04	0.04	0.26
Average	0.54	0.40	0.16	0.21	0.41

APPENDIX F

Evidence of an increase in natural mortality and its potential impact on the models currently used to estimate population parameters

Introduction

There is increasing evidence that rather than being invariant, natural mortality has increased within striped bass stocks, most evidently in the Chesapeake Bay resident population. Jiang et al. (2007) analyzed striped bass tagging data from Maryland and found a significant increase in natural mortality rate at about the time when mycobacteriosis was first being detected in Chesapeake Bay striped bass. A similar analysis of Rappahannock River, Virginia, striped bass tagging data from this project also reveals an increase in natural mortality rate in recent years: natural mortality rate for fish age 2 and above was estimated to increase from M = .231 during the period 1990 – 1996 to M=.407 during the period 1997-2004 (Sadler *et al.* 2008).

At a recent symposium entitled "*Management Issues of the Restored Stock of Striped Bass in the Chesapeake Bay: Diseases, Nutrition, Forage Base and Survival*", Kahn (2004) reported that both Maryland and Virginia striped bass tag-recaptures have declined in recent years. This suggests that survival has declined significantly, from 60-70% in the early-mid 1990's to 40-50% during the late 1990's and early 2000's. Kahn (2004) and Crecco (2003) both concluded that the 20% decline in striped bass survival was not caused by fishing mortality, but by an increase in natural mortality. These analyses, however, are predicated on the assumption that tag reporting rate has not changed over time

Mycobacteriosis was first reported from Chesapeake Bay striped bass in 1997 (Vogelbein et al. 1999; Rhodes et al. 2002, 2003, 2004). Since then, the disease has spread throughout the Bay and the prevalence has risen to as high as 70 – 80% (Cardinal 2001; Vogelbein et al. 1999). Several species of *Mycobacterium* have been isolated from Chesapeake Bay striped bass, including several new species, but it is not yet clear which species are involved in disease processes. Indeed, there may be more than one pathogenic species.

Since 2005, the Virginia Institute of Marine Science (VIMS) and the Maryland Department of Natural Resources (MDNR) have conducted a tagging program on resident Chesapeake Bay (≥18 inches total length) fish. Striped bass are assessed for external evidence and severity of mycobacterial infection and the recapture results are used to estimate disease progression and differential survival rates. This program is described in detail in Hoenig et al. 2009 and Sadler et al. 2008. In addition, R. Latour and D. Gauthier used force-of-infection models to examine the epizootiology of mycobacteriosis in Chesapeake Bay striped bass from 2003-2005. The results of this analysis indicated that the probability a disease-negative fish becomes disease positive depends on age; the inclusion of sex and season as covariates significantly improved model fit; and that there is evidence of mortality associated with the disease (Gauthier et al. 2008).

Methods

In 2009, the Tagging Subcommittee developed an approach for adapting the Instantaneous Rates model to determine what time scenario with two natural mortality rates best fitted each tagging program's data. Each program used an iterative approach that tested all possible 2-M combinations (eg. M(1)=1987, M(2)=1988-2008, M(1)=1987-1988, M(2)=1989-2008…M(1)=1987-2007, M(2)=2008) and used the minimum QAIC (value after bootstrap and c-hat adjustment) as the determinant. These results were applied to this year's analysis.

Thus the 18 models are:

model number	model
1	F(t), Ft(t), M(.)
2	F((5p), Ft(t), M(.)
3	F(.), Ft(t), M(.)
4	F(t), Ft(5p), M(.)
5	F(t), Ft(.), M(.)
6	F(5p), Ft(5p), M(.)
7	F(.). Ft(.), M(,)
8	F(des), Ft(des), M(.)
9	F(vic), Ft(vic), M(.)
10	F(t), Ft(t), M(2p)
11	F(5p), Ft(t), M(2p)
12	F(.), Ft(t), M(2p)
13	F(t), Ft(5p), M(2p)
14	F(t), Ft(.), M(2p)
15	F(5p), Ft(5p), M(2p)
16	F(.), t'(.), M(2p)
17	F(d), Ft(d), M(2p)
18	F(v), t'(v), M(2p)

where F is fishing mortality, Ft is the "mortality" of recaptured tags, M is natural mortality, (t) is time saturated, (.) is constant, (5p) are 1987-1989, 1990-1994, 1995-1999, 2000-2002 and 2003-2010, des is (5P) but with a separate terminal year, vic is (5p) but a separate two-year terminal period and M(2p) is the program-specific two natural mortality periods. The reporting rate was assumed to be constant at 0.43 and tag loss over time was assumed to be zero. A c-hat adjustment was applied to the models and the models were ranked by their respective QAICs and weighted for overall model averaging of parameters.

Results

Instantaneous rates analyses:

The instantaneous rates model results indicate that natural mortality of 18 inch fish increased first in the two Chesapeake Bay programs (1997 in Virginia and 1998 in Maryland) and later among the coastal programs (Table 1). For fish greater than 28 inches, the temporal and spatial patterns are less clear, perhaps because the sample sizes are smaller than for the 18 inch fish.

When the instantaneous rates model was run with both the one and two M suites, the models with two natural mortality periods had lower QAICs than their respective constant natural mortality counterparts for every tagging program except for North Carolina for both the greater than 18” (Table 2) and the greater than 28” analyses (Table 3), although the 1 M models did receive up to 10% of the total weighting for the NYTRWAL (≥ 28”) and Massachusetts (≥ 28”).

The coastal programs all showed a decrease in survival and an increase in natural mortality with time for striped bass greater than 28” (Table 4). The estimates of M from the initial period ranged from 0.07 (NJ/DE) to 0.16 (NCCOOP) while the estimates for the second M period increased to from 0.18 (MASS) to 0.28 (NCCOOP).

The producer area programs had the same pattern of decreasing survival and increasing natural mortality, but had lower survival estimates and higher natural mortality estimates than the coastal programs, especially the Virginia Rappahannock River program. The coastal program estimates of M for the first period ranged from 0.09 (HUDSON) to 0.25 (VARAP) and then increased to 0.19 (HUDSON and DE/PA) to 0.46 (VARAP).

When the analyses are expanded to striped bass greater than 18”, the pattern of decreasing survival and increasing natural mortality remains consistent among the coastal and the producer programs (Table 5) but with lower estimates of survival and higher estimates of natural mortality.

The Massachusetts coastal program consistently had lower annual estimate of fishing mortality than the other coastal programs (Table 6) for striped bass greater than 18”. The averaged annual estimates of fishing mortality among the coastal programs varied from only 0.11-0.16 from 1995-2010. The Virginia program consistently had the lowest annual estimate of fishing mortality among the producer programs (Table 6). The weighted average annual fishing mortality estimate among the producer programs peaked at 0.22 in 1998 but decreased and has been 0.12-0.16 since 2000.

The Massachusetts program consistently had the lowest annual estimate of fishing mortality among the coastal programs (Table 7) for striped bass greater than 28”. The average estimate of fishing mortality from the coastal programs peaked at 0.23 in 1998 but has varied from 0.15-0.20 since 2000. Prior to 2000, there was little difference in the annual estimates of fishing mortality among the producer programs for striped bass greater than 28” (Table 7). From 2001-2010 the two Chesapeake Bay programs had similar, lower fishing mortality estimates than the Hudson River or the Delaware River program. The weighted average of fishing mortality from the producer programs peaked at 0.24 from 1995-1999, but has remained constant at 0.15 since 2000.

When the two natural mortality period analyses are compared to the constant natural mortality analyses, the weighted (producer areas) and unweighted (coastal areas) estimates of fishing mortality tended to higher in the most recent years for both the greater than 18" (Table 8) and the greater than 28" (Table 9) striped bass.

Discussion

There is evidence from multiple programs and analytical methods that natural mortality has increased for striped bass throughout the mid Atlantic and Northeastern jurisdictions. This elevation in the natural mortality of striped bass became evident in Chesapeake Bay as early as 1997 and seems to have progressed to all areas. While myco-infected striped bass have become prevalent in Chesapeake Bay, it is not the case for the Delaware and Hudson rivers and has not been tested for in the mixed coastal stocks. This could mean that there are multiple causes for the change in the natural mortality rate. It must be noted that all the analyses have assumed a constant reporting rate throughout their times series. If the reporting rate is changing, then the parameter estimates will be affected. Generally, a negative change in reporting rate will result in increased estimates of survival and fishing mortality and a decreased estimate of natural mortality when compared to a constant reporting rate. Conversely, a positive change in reporting rate will produce the opposite effect on parameter estimates.

The results of our investigations indicate that multiple mortality models should replace the constant M models currently used and that efforts must continue to evaluate the value of natural mortality, whether it is increasing, and evaluate its impact on the stocks of striped bass.

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Table 1. Definition of the two natural mortality periods used by each program in their Instantaneous Rates analysis.

striped bass ≥ 18"

Coast programs	M1	M2
Massachusetts	1992-1998	1999-2010
New York OHS/Trawl	1988-1998	1999-2010
New Jersey/ Delaware	1989-2001	2002-2010
North Carolina	1988-1999	2000-2010
Producer programs		
Hudson River	1988-2001	2002-2010
Delaware River	1993	
Maryland Chesapeake Bay	1987-1998	1999-2010
Virginia Rappahannock River	1990-1997	1998-2010

striped bass ≥ 28"

Coast programs	M1	M2
Massachusetts	1992-1998	1999-2010
New York Trawl	1988-2004	2005-2010
New Jersey/ Delaware	1989-2002	2003-2010
North Carolina	1988-1999	2000-2010
Producer programs		
Hudson River	1988-2000	2001-2010
Delaware River	1993-2002	2003-2010
Maryland Chesapeake Bay	1987-2000	2001-2010
Virginia Rappahannock River	1990-2003	2004-2010

Table 2. Resultant model weighting of the Instantaneous rates model analyses by program for striped bass greater than 18 inches total length.

		Coastal Programs				Producer Area Programs			
Model number	Model	MADFW	NYTRL	NJDEL	NCCOP	HUDSON	DE/PA	MDCB	VARAP
1	F(t), Ft(t), M(.)	0	0	0	0.248	0	0	0	0
2	F((5p), Ft(t), M(.)	0	0	0	0.714	0	0	0	0
3	F(.), Ft(t), M(.)	0	0	0	0	0	0	0	0
4	F(t), Ft(5p), M(.)	0.016	0	0	0.004	0	0	0	0
5	F(t), Ft(.), M(.)	0	0	0	0	0	0	0	0
6	F(5p), Ft(5p), M(.)	0	0	0	0.004	0	0	0	0
7	F(.). Ft(.), M(,)	0	0	0	0	0	0	0	0
8	F(des), Ft(des), M(,)	0	0	0	0.026	0	0	0	0
9	F(vic), Ft(vic), M(.)	0	0	0	0.003	0	0	0	0
10	F(t), Ft(t), M(2p)	0	0.001	0.002	0	0.001	0	1.000	0
11	F(5p), Ft(t), M(2p)	0	0.999	0.014	0	0.999	0	0	0
12	F(.), Ft(t), M(2p)	0	0	0	0	0	0	0	0
13	F(t), Ft(5p), M(2p)	0.981	0	0.077	0	0	0	0	0.007
14	F(t), Ft(.), M(2p)	0	0	0	0	0	0	0	0
15	F(5p), Ft(5p), M(2p)	0.001	0.000	0.665	0	0	0.333	0	0
16	F(.), Ft(.), M(2p)	0	0	0	0	0	0.566	0	0
17	F(d), Ft(d), M(2p)	0.001	0	0.150	0	0	0.048	0	0.984
18	F(v), Ft(v), M(2p)	0	0	0.092	0	0	0.049	0	0.009

Table 3. Resultant model weighting of the Instantaneous rates model analyses by program for striped bass greater than 28 inches total length.

		Coastal Programs				Producer Area Programs			
Model number	Model	MADFW	NYTRL	NJDEL	NCCOP	HUDSON	DE/PA	MDCB	VARAP
1	F(t), Ft(t), M(.)	0	0.072	0	0.653	0	0	0	0
2	F((5p), Ft(t), M(.)	0	0.029	0	0.292	0	0.003	0	0
3	F(.), Ft(t), M(.)	0	0	0	0	0	0.001	0	0
4	F(t), Ft(5p), M(.)	0.022	0	0	0.036	0	0	0	0
5	F(t), Ft(.), M(.)	0	0	0	0	0	0	0	0
6	F(5p), Ft(5p), M(.)	0	0	0	0.011	0	0.043	0	0
7	F(.). Ft(.), M(,)	0	0	0	0	0	0.022	0	0
8	F(des), Ft(des), M(,)	0	0	0	0.004	0	0.006	0	0
9	F(vic), Ft(vic), M(.)	0	0	0	0.004	0	0.009	0	0.001
10	F(t), Ft(t), M(2p)	0	0.061	0.007	0	0	0	0	0
11	F(5p), Ft(t), M(2p)	0	0.838	0	0	1.000	0.012	0.060	0
12	F(.), Ft(t), M(2p)	0	0	0	0	0	0.007	0	0
13	F(t), Ft(5p), M(2p)	0.974	0	0.993	0	0	0.004	0	0.001
14	F(t), Ft(.), M(2p)	0	0	0	0	0	0.002	0	0
15	F(5p), Ft(5p), M(2p)	0.001	0	0	0	0	0.414	0.720	0.080
16	F(.), Ft(.), M(2p)	0	0	0	0	0	0.270	0	0
17	F(d), Ft(d), M(2p)	0.001	0	0	0	0	0.078	0.108	0.346
18	F(v), Ft(v), M(2p)	0.001	0	0	0	0	0.131	0.111	0.571

Table 4. Parameter estimates of survival (S), instantaneous fishing mortality (F) and instantaneous natural mortality (M), by program, for striped bass greater than 28 inches total length.

Coast Programs

Massachusetts

Year	S	F	M
1987			
1988			
1989			
1990			
1991			
1992	0.87	0.03	0.10
1993	0.84	0.06	0.10
1994	0.83	0.08	0.10
1995	0.81	0.10	0.10
1996	0.75	0.18	0.10
1997	0.74	0.20	0.10
1998	0.76	0.17	0.10
1999	0.69	0.19	0.18
2000	0.70	0.18	0.18
2001	0.76	0.09	0.18
2002	0.73	0.14	0.18
2003	0.72	0.14	0.18
2004	0.74	0.12	0.18
2005	0.75	0.11	0.18
2006	0.75	0.11	0.18
2007	0.77	0.07	0.18
2008	0.74	0.12	0.18
2009	0.73	0.14	0.18
2010	0.76	0.09	0.18

NYOHS/TRL

Year	S	F	M
1987			
1988	0.88	0.03	0.10
1989	0.87	0.03	0.10
1990	0.78	0.13	0.10
1991	0.77	0.14	0.10
1992	0.77	0.14	0.10
1993	0.77	0.15	0.10
1994	0.78	0.14	0.10
1995	0.68	0.27	0.10
1996	0.68	0.27	0.10
1997	0.68	0.28	0.10
1998	0.67	0.29	0.10
1999	0.68	0.28	0.10
2000	0.73	0.21	0.10
2001	0.73	0.21	0.10
2002	0.72	0.21	0.10
2003	0.72	0.21	0.10
2004	0.72	0.21	0.10
2005	0.63	0.20	0.25
2006	0.64	0.20	0.25
2007	0.64	0.19	0.25
2008	0.62	0.22	0.25
2009	0.61	0.25	0.25
2010	0.64	0.21	0.25

Table 4 continued.

New Jersey/Delaware				North Carolina			
Year	S	F	M	Year	S	F	M
1987				1987			
1988				1988	0.81	0.05	0.16
1989	0.92	0.00	0.07	1989	0.81	0.04	0.16
1990	0.82	0.11	0.07	1990	0.77	0.09	0.16
1991	0.63	0.38	0.07	1991	0.78	0.08	0.16
1992	0.92	0.00	0.07	1992	0.75	0.13	0.16
1993	0.83	0.10	0.07	1993	0.75	0.13	0.16
1994	0.87	0.05	0.07	1994	0.75	0.12	0.16
1995	0.83	0.11	0.07	1995	0.72	0.17	0.16
1996	0.75	0.21	0.07	1996	0.74	0.15	0.16
1997	0.76	0.19	0.07	1997	0.70	0.20	0.16
1998	0.67	0.32	0.07	1998	0.71	0.18	0.16
1999	0.76	0.19	0.07	1999	0.72	0.17	0.16
2000	0.80	0.16	0.07	2000	0.68	0.10	0.28
2001	0.78	0.18	0.07	2001	0.64	0.16	0.28
2002	0.80	0.16	0.07	2002	0.66	0.14	0.28
2003	0.66	0.19	0.21	2003	0.65	0.15	0.28
2004	0.67	0.19	0.21	2004	0.64	0.16	0.28
2005	0.65	0.21	0.21	2005	0.65	0.15	0.28
2006	0.69	0.15	0.21	2006	0.65	0.15	0.28
2007	0.67	0.19	0.21	2007	0.63	0.18	0.28
2008	0.64	0.23	0.21	2008	0.62	0.19	0.28
2009	0.61	0.27	0.21	2009	0.64	0.17	0.28
2010	0.63	0.24	0.21	2010	0.64	0.16	0.28

Table 4 continued.

Producer Area Programs

Hudson River					Delaware River			
Year	S	F	M		Year	S	F	M
1987					1987			
1988	0.83	0.09	0.09		1988			
1989	0.82	0.09	0.09		1989			
1990	0.76	0.16	0.09		1990			
1991	0.77	0.16	0.09		1991			
1992	0.77	0.16	0.09		1992			
1993	0.77	0.16	0.09		1993	0.73	0.20	0.10
1994	0.77	0.16	0.09		1994	0.73	0.20	0.10
1995	0.70	0.25	0.09		1995	0.68	0.27	0.10
1996	0.70	0.25	0.09		1996	0.68	0.27	0.10
1997	0.70	0.25	0.09		1997	0.68	0.27	0.10
1998	0.70	0.25	0.09		1998	0.68	0.27	0.10
1999	0.70	0.25	0.09		1999	0.68	0.27	0.10
2000	0.77	0.17	0.09		2000	0.68	0.28	0.10
2001	0.69	0.17	0.19		2001	0.68	0.28	0.10
2002	0.69	0.17	0.19		2002	0.68	0.28	0.10
2003	0.66	0.22	0.19		2003	0.65	0.23	0.19
2004	0.66	0.22	0.19		2004	0.65	0.23	0.19
2005	0.66	0.22	0.19		2005	0.65	0.23	0.19
2006	0.66	0.22	0.19		2006	0.65	0.23	0.19
2007	0.66	0.22	0.19		2007	0.65	0.23	0.19
2008	0.66	0.22	0.19		2008	0.65	0.23	0.19
2009	0.66	0.22	0.19		2009	0.65	0.24	0.19
2010	0.66	0.22	0.19		2010	0.65	0.24	0.19

Table 4 continued.

Maryland Chesapeake Bay				Virginia Rappahannock River			
Year	S	F	M	Year	S	F	M
1987	0.84	0.03	0.14	1987			
1988	0.84	0.03	0.14	1988			
1989	0.84	0.03	0.14	1989			
1990	0.75	0.13	0.14	1990	0.67	0.14	0.25
1991	0.75	0.13	0.14	1991	0.67	0.14	0.25
1992	0.75	0.13	0.14	1992	0.67	0.14	0.25
1993	0.75	0.13	0.14	1993	0.67	0.14	0.25
1994	0.75	0.13	0.14	1994	0.67	0.14	0.25
1995	0.67	0.25	0.14	1995	0.62	0.22	0.25
1996	0.67	0.25	0.14	1996	0.62	0.22	0.25
1997	0.67	0.25	0.14	1997	0.62	0.22	0.25
1998	0.67	0.25	0.14	1998	0.62	0.22	0.25
1999	0.67	0.25	0.14	1999	0.62	0.22	0.25
2000	0.75	0.14	0.14	2000	0.69	0.11	0.25
2001	0.64	0.14	0.29	2001	0.69	0.11	0.25
2002	0.64	0.14	0.29	2002	0.69	0.11	0.25
2003	0.64	0.14	0.29	2003	0.69	0.12	0.25
2004	0.64	0.14	0.29	2004	0.57	0.12	0.43
2005	0.64	0.14	0.29	2005	0.57	0.12	0.43
2006	0.64	0.14	0.29	2006	0.57	0.12	0.43
2007	0.64	0.14	0.29	2007	0.57	0.12	0.43
2008	0.64	0.14	0.29	2008	0.57	0.12	0.43
2009	0.64	0.14	0.29	2009	0.59	0.10	0.43
2010	0.64	0.14	0.29	2010	0.60	0.09	0.43

Table 5. Parameter estimates of survival (S), instantaneous fishing mortality (F) and instantaneous natural mortality (M), by program, for striped bass greater than 18 inches total length.

Coast Programs

Massachusetts				NYOHS/TRL			
Year	S	F	M	Year	S	F	M
1987				1987			
1988				1988	0.82	0.01	0.19
1989				1989	0.81	0.01	0.19
1990				1990	0.78	0.05	0.19
1991				1991	0.78	0.05	0.19
1992	0.86	0.03	0.11	1992	0.78	0.05	0.19
1993	0.84	0.05	0.11	1993	0.78	0.05	0.19
1994	0.83	0.07	0.11	1994	0.78	0.05	0.19
1995	0.83	0.07	0.11	1995	0.76	0.08	0.19
1996	0.78	0.13	0.11	1996	0.76	0.08	0.19
1997	0.75	0.16	0.11	1997	0.76	0.08	0.19
1998	0.77	0.14	0.11	1998	0.76	0.08	0.19
1999	0.72	0.14	0.19	1999	0.66	0.08	0.33
2000	0.72	0.14	0.19	2000	0.67	0.08	0.33
2001	0.77	0.08	0.19	2001	0.67	0.08	0.33
2002	0.73	0.13	0.19	2002	0.67	0.08	0.33
2003	0.73	0.12	0.19	2003	0.66	0.08	0.33
2004	0.74	0.11	0.19	2004	0.66	0.08	0.33
2005	0.74	0.11	0.19	2005	0.66	0.08	0.33
2006	0.75	0.11	0.19	2006	0.66	0.08	0.33
2007	0.77	0.07	0.19	2007	0.66	0.08	0.33
2008	0.74	0.11	0.19	2008*	0.66	0.08	0.33
2009	0.73	0.13	0.19	2009*	0.66	0.08	0.33
2010	0.76	0.09	0.19	2010*	0.66	0.08	0.33

*NY TRAWL

Table 5 continued.

New Jersey				North Carolina			
Year	S	F	M	Year	S	F	M
1987				1987			
1988				1988	0.79	0.02	0.22
1989	0.85	0.02	0.13	1989	0.78	0.02	0.22
1990	0.83	0.03	0.13	1990	0.73	0.09	0.22
1991	0.83	0.04	0.13	1991	0.72	0.10	0.22
1992	0.84	0.03	0.13	1992	0.72	0.11	0.22
1993	0.84	0.03	0.13	1993	0.72	0.11	0.22
1994	0.84	0.03	0.13	1994	0.72	0.10	0.22
1995	0.77	0.12	0.13	1995	0.69	0.14	0.22
1996	0.77	0.12	0.13	1996	0.70	0.14	0.22
1997	0.77	0.12	0.13	1997	0.69	0.15	0.22
1998	0.76	0.12	0.13	1998	0.69	0.15	0.22
1999	0.77	0.12	0.13	1999	0.69	0.14	0.22
2000	0.77	0.12	0.13	2000	0.58	0.12	0.43
2001	0.77	0.12	0.13	2001	0.58	0.12	0.43
2002	0.68	0.12	0.25	2002	0.57	0.12	0.43
2003	0.66	0.15	0.25	2003	0.56	0.14	0.43
2004	0.66	0.15	0.25	2004	0.56	0.14	0.43
2005	0.66	0.15	0.25	2005	0.57	0.13	0.43
2006	0.66	0.15	0.25	2006	0.57	0.13	0.43
2007	0.66	0.15	0.25	2007	0.57	0.14	0.43
2008	0.66	0.15	0.25	2008	0.56	0.15	0.43
2009	0.66	0.15	0.25	2009	0.56	0.16	0.43
2010	0.66	0.15	0.25	2010	0.56	0.15	0.43

Table 5 continued.

Producer Area Programs

Hudson River				Delaware River			
Year	S	F	M	Year	S	F	M
1987				1987			
1988	0.83	0.04	0.14	1988			
1989	0.82	0.04	0.14	1989			
1990	0.77	0.10	0.14	1990			
1991	0.77	0.10	0.14	1991			
1992	0.77	0.10	0.14	1992			
1993	0.77	0.10	0.14	1993	0.70	0.15	0.19
1994	0.77	0.10	0.14	1994	0.70	0.15	0.19
1995	0.71	0.19	0.14	1995	0.70	0.16	0.19
1996	0.71	0.19	0.14	1996	0.70	0.16	0.19
1997	0.71	0.19	0.14	1997	0.70	0.16	0.19
1998	0.71	0.19	0.14	1998	0.70	0.16	0.19
1999	0.71	0.19	0.14	1999	0.70	0.16	0.19
2000	0.76	0.12	0.14	2000	0.70	0.16	0.19
2001	0.77	0.12	0.14	2001	0.70	0.16	0.19
2002	0.69	0.12	0.25	2002	0.61	0.16	0.32
2003	0.67	0.15	0.25	2003	0.61	0.16	0.32
2004	0.67	0.15	0.25	2004	0.61	0.16	0.32
2005	0.67	0.15	0.25	2005	0.61	0.16	0.32
2006	0.67	0.15	0.25	2006	0.61	0.16	0.32
2007	0.67	0.15	0.25	2007	0.61	0.16	0.32
2008	0.67	0.15	0.25	2008	0.61	0.16	0.32
2009	0.67	0.15	0.25	2009	0.61	0.16	0.32
2010	0.67	0.15	0.25	2010	0.61	0.16	0.32

Table 5 continued.

Maryland Chesapeake Bay				Virginia Rappahannock River			
Year	S	F	M	Year	S	F	M
1987	0.82	0.00	0.20	1987			
1988	0.81	0.01	0.20	1988			
1989	0.82	0.00	0.20	1989			
1990	0.76	0.07	0.20	1990	0.62	0.08	0.39
1991	0.72	0.12	0.20	1991	0.62	0.08	0.39
1992	0.68	0.18	0.20	1992	0.62	0.08	0.39
1993	0.69	0.16	0.20	1993	0.62	0.08	0.39
1994	0.70	0.16	0.20	1994	0.62	0.08	0.39
1995	0.65	0.23	0.20	1995	0.60	0.12	0.39
1996	0.66	0.21	0.20	1996	0.60	0.12	0.39
1997	0.63	0.26	0.20	1997	0.60	0.12	0.39
1998	0.61	0.29	0.20	1998	0.51	0.12	0.56
1999	0.52	0.25	0.41	1999	0.51	0.12	0.56
2000	0.53	0.21	0.41	2000	0.52	0.09	0.56
2001	0.55	0.18	0.41	2001	0.52	0.09	0.56
2002	0.57	0.14	0.41	2002	0.52	0.09	0.56
2003	0.54	0.20	0.41	2003	0.51	0.11	0.56
2004	0.56	0.16	0.41	2004	0.51	0.11	0.56
2005	0.58	0.14	0.41	2005	0.51	0.11	0.56
2006	0.56	0.17	0.41	2006	0.51	0.11	0.56
2007	0.59	0.12	0.41	2007	0.51	0.11	0.56
2008	0.57	0.14	0.41	2008	0.51	0.11	0.56
2009	0.55	0.19	0.41	2009	0.51	0.11	0.56
2010	0.57	0.15	0.41	2010	0.54	0.05	0.56

Table 6. Summaries of tag-based estimates of annual instantaneous fishing mortality of striped bass ≥ 18 inches based on the 2M instantaneous rates model, along with the unweighted average for coastal programs, the weighted average for producer areas, and 95% confidence intervals.

Coast Programs

Year	MADFW	NYOH/TRL	NJDEL	NCCOOP	**Unweighted average**	lower 95% CI	upper 95% CI
1987							
1988		0.04		0.02	**0.03**	0.03	0.04
1989		0.04	0.02	0.02	**0.03**	0.02	0.04
1990		0.10	0.03	0.09	**0.07**	0.06	0.09
1991		0.10	0.04	0.10	**0.08**	0.07	0.09
1992	0.03	0.10	0.03	0.11	**0.07**	0.06	0.08
1993	0.05	0.10	0.03	0.11	**0.07**	0.06	0.09
1994	0.07	0.10	0.03	0.10	**0.08**	0.07	0.08
1995	0.07	0.19	0.12	0.14	**0.13**	0.12	0.14
1996	0.13	0.19	0.12	0.14	**0.15**	0.13	0.16
1997	0.16	0.19	0.12	0.15	**0.16**	0.14	0.17
1998	0.14	0.19	0.13	0.15	**0.15**	0.14	0.17
1999	0.14	0.19	0.12	0.14	**0.15**	0.13	0.16
2000	0.14	0.12	0.12	0.12	**0.12**	0.11	0.14
2001	0.08	0.12	0.12	0.12	**0.11**	0.10	0.12
2002	0.13	0.12	0.12	0.12	**0.12**	0.11	0.13
2003	0.12	0.15	0.15	0.14	**0.14**	0.13	0.15
2004	0.11	0.15	0.15	0.14	**0.14**	0.13	0.15
2005	0.11	0.15	0.15	0.13	**0.13**	0.12	0.15
2006	0.11	0.15	0.15	0.13	**0.13**	0.12	0.14
2007	0.07	0.15	0.15	0.14	**0.13**	0.12	0.14
2008	0.11	0.15*	0.15	0.15	**0.14**	0.12	0.15
2009	0.13	0.15*	0.15	0.16	**0.14**	0.12	0.17
2010	0.09	0.15*	0.15	0.14	**0.13**	0.12	0.15

*NY TRAWL

Table 6 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	**Weighted average***	lower 95% CI	upper 95% CI
1987			0.00		**0.00**	0.00	0.00
1988	0.04		0.01		**0.02**	0.01	0.02
1989	0.04		0.00		**0.01**	0.00	0.01
1990	0.10		0.07	0.08	**0.08**	0.06	0.08
1991	0.10		0.12	0.08	**0.11**	0.09	0.11
1992	0.10		0.18	0.08	**0.14**	0.12	0.14
1993	0.10	0.15	0.16	0.08	**0.13**	0.12	0.15
1994	0.10	0.15	0.16	0.08	**0.13**	0.12	0.14
1995	0.19	0.16	0.23	0.12	**0.19**	0.18	0.21
1996	0.19	0.16	0.21	0.12	**0.19**	0.16	0.20
1997	0.19	0.16	0.26	0.12	**0.21**	0.19	0.22
1998	0.19	0.16	0.29	0.12	**0.22**	0.20	0.24
1999	0.19	0.16	0.25	0.12	**0.20**	0.18	0.22
2000	0.12	0.16	0.21	0.09	**0.16**	0.14	0.19
2001	0.12	0.16	0.18	0.09	**0.15**	0.13	0.16
2002	0.12	0.16	0.14	0.09	**0.13**	0.11	0.14
2003	0.15	0.16	0.20	0.11	**0.17**	0.15	0.18
2004	0.15	0.16	0.16	0.11	**0.15**	0.13	0.16
2005	0.15	0.16	0.14	0.11	**0.14**	0.12	0.15
2006	0.15	0.16	0.17	0.11	**0.12**	0.13	0.17
2007	0.15	0.16	0.12	0.11	**0.12**	0.11	0.14
2008	0.15	0.16	0.14	0.11	**0.14**	0.12	0.16
2009	0.15	0.16	0.19	0.11	**0.16**	0.14	0.18
2010	0.15	0.16	0.15	0.05	**0.12**	0.10	0.14

* Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 7. Summaries of tag-based estimates of fishing mortality of striped bass ≥ 28 inches based on the 2M instantaneous rates model, along with the unweighted average for coastal programs, the weighted average for producer areas, and 95% confidence intervals.

Coast Programs

Year	MADFW	NYOHS/TRL	NJDEL	NCCOOP	**Unweighted average**	lower 95% CI	upper 95% CI
1987							
1988		0.09		0.05	**0.07**	0.06	0.09
1989		0.09	0.00	0.04	**0.05**	0.03	0.06
1990		0.16	0.11	0.09	**0.12**	0.08	0.16
1991		0.16	0.38	0.08	**0.21**	0.13	0.29
1992	0.03	0.16	0.00	0.13	**0.08**	0.07	0.09
1993	0.06	0.16	0.10	0.13	**0.11**	0.09	0.14
1994	0.08	0.16	0.05	0.12	**0.10**	0.09	0.11
1995	0.10	0.25	0.11	0.17	**0.16**	0.14	0.17
1996	0.18	0.25	0.21	0.15	**0.20**	0.18	0.22
1997	0.20	0.25	0.19	0.20	**0.21**	0.19	0.23
1998	0.17	0.25	0.32	0.18	**0.23**	0.21	0.26
1999	0.19	0.25	0.19	0.17	**0.20**	0.17	0.22
2000	0.18	0.17	0.16	0.10	**0.15**	0.13	0.18
2001	0.09	0.17	0.18	0.16	**0.15**	0.13	0.17
2002	0.14	0.17	0.16	0.14	**0.15**	0.13	0.17
2003	0.14	0.22	0.19	0.15	**0.18**	0.16	0.19
2004	0.12	0.22	0.19	0.16	**0.17**	0.16	0.19
2005	0.11	0.22	0.21	0.15	**0.17**	0.15	0.19
2006	0.11	0.22	0.15	0.15	**0.16**	0.14	0.17
2007	0.07	0.22	0.19	0.18	**0.16**	0.15	0.18
2008	0.12	0.22*	0.23	0.19	**0.19**	0.17	0.21
2009	0.14	0.22*	0.27	0.17	**0.20**	0.18	0.22
2010	0.09	0.22*	0.24	0.16	**0.18**	0.16	0.20

*NY TRAWL

Table 7 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	**Weighted average***	lower 95% CI	upper 95% CI
1987			0.03		**0.03**		
1988	0.09		0.03		**0.04**	0.01	0.05
1989	0.09		0.03		**0.04**	0.01	0.04
1990	0.16		0.13	0.14	**0.14**	0.11	0.15
1991	0.16		0.13	0.14	**0.14**	0.11	0.15
1992	0.16		0.13	0.14	**0.14**	0.11	0.15
1993	0.16	0.20	0.13	0.14	**0.14**	0.13	0.17
1994	0.16	0.20	0.13	0.14	**0.14**	0.13	0.17
1995	0.25	0.27	0.25	0.22	**0.24**	0.22	0.27
1996	0.25	0.27	0.25	0.22	**0.24**	0.22	0.27
1997	0.25	0.27	0.25	0.22	**0.24**	0.22	0.27
1998	0.25	0.27	0.25	0.22	**0.24**	0.22	0.28
1999	0.25	0.27	0.25	0.22	**0.24**	0.22	0.28
2000	0.17	0.28	0.14	0.11	**0.15**	0.13	0.18
2001	0.17	0.28	0.14	0.11	**0.15**	0.13	0.18
2002	0.17	0.28	0.14	0.11	**0.15**	0.13	0.18
2003	0.22	0.23	0.14	0.12	**0.15**	0.14	0.17
2004	0.22	0.23	0.14	0.12	**0.15**	0.14	0.18
2005	0.22	0.23	0.14	0.12	**0.15**	0.14	0.18
2006	0.22	0.23	0.14	0.12	**0.15**	0.14	0.18
2007	0.22	0.23	0.14	0.12	**0.15**	0.14	0.18
2008	0.22	0.23	0.14	0.12	**0.15**	0.14	0.18
2009	0.22	0.24	0.14	0.10	**0.15**	0.14	0.18
2010	0.22	0.24	0.14	0.09	**0.15**	0.14	0.18

* Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 8. Comparison in the estimates of instantaneous fishing mortality (F) between the one and two natural mortality instantaneous rates analyses for striped bass greater than 18 inches total length (unweighted average of the coastal programs and weighted average of the producer programs).

Coast Programs

	1M analyses			2M analyses		
Year	Unweighted F	lower 95% CI	upper 95% CI	Unweighted F	lower 95% CI	upper 95% CI
1987						
1988	0.02	0.01	0.02	0.03	0.03	0.04
1989	0.01	0.01	0.02	0.03	0.02	0.04
1990	0.06	0.05	0.08	0.07	0.06	0.09
1991	0.07	0.05	0.08	0.08	0.07	0.09
1992	0.06	0.05	0.07	0.07	0.06	0.08
1993	0.06	0.05	0.07	0.07	0.06	0.09
1994	0.06	0.06	0.07	0.08	0.07	0.08
1995	0.11	0.09	0.13	0.13	0.12	0.14
1996	0.13	0.12	0.14	0.15	0.13	0.16
1997	0.14	0.13	0.16	0.16	0.14	0.17
1998	0.14	0.12	0.16	0.15	0.14	0.17
1999	0.14	0.12	0.15	0.15	0.13	0.16
2000	0.12	0.10	0.13	0.12	0.11	0.14
2001	0.10	0.09	0.11	0.11	0.10	0.12
2002	0.11	0.10	0.12	0.12	0.11	0.13
2003	0.11	0.09	0.12	0.14	0.13	0.15
2004	0.10	0.09	0.12	0.14	0.13	0.15
2005	0.10	0.09	0.11	0.13	0.12	0.15
2006	0.10	0.09	0.11	0.13	0.12	0.14
2007	0.09	0.08	0.10	0.13	0.12	0.14
2008	0.10	0.09	0.11	0.14	0.12	0.15
2009	0.10	0.09	0.11	0.14	0.12	0.17
2010	0.09	0.08	0.10	0.13	0.12	0.15

Table 8 continued.

Producer programs

	1M analyses			2M analyses		
Year	Weighted F	lower 95% CI	upper 95% CI	Weighted F	lower 95% CI	upper 95% CI
1987	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.02	0.01	0.02	0.02	0.01	0.02
1989	0.01	0.00	0.01	0.01	0.00	0.01
1990	0.08	0.06	0.08	0.08	0.06	0.08
1991	0.11	0.09	0.11	0.11	0.09	0.11
1992	0.15	0.12	0.15	0.14	0.12	0.14
1993	0.14	0.12	0.15	0.13	0.12	0.15
1994	0.14	0.12	0.15	0.13	0.12	0.14
1995	0.20	0.18	0.22	0.19	0.18	0.21
1996	0.20	0.17	0.21	0.19	0.16	0.20
1997	0.23	0.21	0.25	0.21	0.19	0.22
1998	0.25	0.23	0.28	0.22	0.20	0.24
1999	0.21	0.20	0.25	0.20	0.18	0.22
2000	0.17	0.15	0.19	0.16	0.14	0.19
2001	0.14	0.12	0.16	0.15	0.13	0.16
2002	0.12	0.10	0.13	0.13	0.11	0.14
2003	0.14	0.12	0.15	0.17	0.15	0.18
2004	0.12	0.10	0.13	0.15	0.13	0.16
2005	0.11	0.09	0.12	0.14	0.12	0.15
2006	0.11	0.10	0.13	0.12	0.13	0.17
2007	0.09	0.08	0.11	0.12	0.11	0.14
2008	0.09	0.08	0.11	0.14	0.12	0.16
2009	0.11	0.10	0.13	0.16	0.14	0.18
2010	0.09	0.07	0.10	0.12	0.10	0.14

* Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

Table 9. Comparison in the estimates of instantaneous fishing mortality (F) between the one and two natural mortality instantaneous rates analyses for striped bass greater than 28 inches total length (unweighted average of the coastal programs and weighted average of the producer programs).

Coast Programs

	1M analyses			2M analyses		
	Unweighted	lower	upper	Unweighted	lower	upper
Year	F	95% CI	95% CI	F	95% CI	95% CI
1987						
1988	0.04	0.02	0.05	0.07	0.06	0.09
1989	0.02	0.01	0.03	0.05	0.03	0.06
1990	0.11	0.07	0.14	0.12	0.08	0.16
1991	0.21	0.13	0.29	0.21	0.13	0.29
1992	0.07	0.06	0.09	0.08	0.07	0.09
1993	0.11	0.09	0.14	0.11	0.09	0.14
1994	0.09	0.08	0.11	0.10	0.09	0.11
1995	0.16	0.14	0.17	0.16	0.14	0.17
1996	0.21	0.18	0.23	0.20	0.18	0.22
1997	0.23	0.20	0.25	0.21	0.19	0.23
1998	0.26	0.23	0.29	0.23	0.21	0.26
1999	0.23	0.19	0.26	0.20	0.17	0.22
2000	0.18	0.15	0.21	0.15	0.13	0.18
2001	0.16	0.14	0.19	0.15	0.13	0.17
2002	0.17	0.15	0.19	0.15	0.13	0.17
2003	0.19	0.16	0.21	0.18	0.16	0.19
2004	0.17	0.15	0.20	0.17	0.16	0.19
2005	0.16	0.13	0.18	0.17	0.15	0.19
2006	0.13	0.11	0.15	0.16	0.14	0.17
2007	0.12	0.11	0.13	0.16	0.15	0.18
2008	0.16	0.14	0.17	0.19	0.17	0.21
2009	0.16	0.14	0.17	0.20	0.18	0.22
2010	0.11	0.10	0.13	0.18	0.16	0.20

Table 10 continued.

Producer programs

	1M analyses			2M analyses		
Year	Weighted F	lower 95% CI	upper 95% CI	Weighted F	lower 95% CI	upper 95% CI
1987	0.02	0.00	0.02	0.03		
1988	0.04	0.01	0.05	0.04	0.01	0.05
1989	0.04	0.01	0.04	0.04	0.01	0.04
1990	0.14	0.10	0.15	0.14	0.11	0.15
1991	0.14	0.10	0.15	0.14	0.11	0.15
1992	0.14	0.10	0.15	0.14	0.11	0.15
1993	0.14	0.12	0.17	0.14	0.13	0.17
1994	0.14	0.12	0.16	0.14	0.13	0.17
1995	0.25	0.23	0.28	0.24	0.22	0.27
1996	0.25	0.22	0.27	0.24	0.22	0.27
1997	0.25	0.22	0.28	0.24	0.22	0.27
1998	0.25	0.22	0.29	0.24	0.22	0.28
1999	0.25	0.22	0.29	0.24	0.22	0.28
2000	0.16	0.13	0.19	0.15	0.13	0.18
2001	0.16	0.13	0.19	0.15	0.13	0.18
2002	0.16	0.13	0.18	0.15	0.13	0.18
2003	0.13	0.11	0.16	0.15	0.14	0.17
2004	0.13	0.11	0.15	0.15	0.14	0.18
2005	0.13	0.11	0.15	0.15	0.14	0.18
2006	0.13	0.11	0.15	0.15	0.14	0.18
2007	0.13	0.11	0.15	0.15	0.14	0.18
2008	0.13	0.11	0.15	0.15	0.14	0.18
2009	0.12	0.10	0.14	0.15	0.14	0.18
2010	0.12	0.09	0.14	0.15	0.14	0.18

* Weighting Scheme: Hudson (0.13); Delaware (0.09);
Chesapeake Bay (0.78), where MD (0.67) and VA (0.33).

APPENDIX G

Recommendations for striped bass tag reporting rate obtained from high reward study conducted in 2007 and 2008 -
Preliminary findings of the Striped Bass Tagging Subcommittee

Summary

In mathematical models for tagging data, tag reporting rate is largely confounded with fishing mortality and natural mortality rates. As tag reporting rate decreases more of the estimated total mortality is attributed to fishing mortality and, conversely, as tag reporting rate increases more total mortality is attributed to natural mortality. In the context of the striped bass stock assessment, where tag reporting rate has been obtained external to the analysis of the tagging data and held constant through time in the tagging models, a decline in the actual tag reporting rate that is not accounted for in the model will cause estimates of natural mortality to increase. Similarly, if the reporting rate in the model has been held constant while the actual tag reporting rate has been increasing, the model will estimate declines in natural mortality rate. Currently, model results obtained from striped bass tagging data estimate unreasonably low fishing mortality rates and high natural mortality rates. The low fishing mortality estimates obtained could reflect reality, or more likely given the relatively static management of the fishery, reflect an artifact created by the tag reporting rate (lambda) declining or natural mortality rate (M) increasing. In 2005, researchers at VIMS began a study to investigate the effects of the bacterial disease mycobacteriosis on the natural mortality rate of striped bass. Results from this work, as well as the work of several other researchers (Jiang et al. 2007 ; Gauthier et al. 2008), conclude that the natural mortality rate of striped bass in the Chesapeake Bay has increased coincident with the onset of mycobacteriosis. These findings, while significant by themselves, do not rule out the possibility that lambda has also changed in the decade since it was last estimated to be 0.43 (Kahn and Shirey 2000).

A high reward tagging study was conducted in order to determine if the tag reporting rate has changed. This study was conducted by the state agencies of Delaware, Maryland, New York, and Virginia during the 2007 and 2008 tagging seasons. For all regions combined, 6,576 standard tags were released and 1,250 high reward tags were released. Tags were recaptured for four years resulting in the return of 755 standard tags and 183 high reward tags across all regions. Two separate lines of analysis were conducted in order to explore regional differences in tag reporting rate as well as determine a range of potential tag reporting rates.

Commercial fishers appear to have a much lower reporting rate than sport fishers. Estimates for commercial tag reporting rate range from 13% to 91% depending on the method of analysis. The tagging subcommittee agreed to eliminate the original model from consideration because of concerns that the commercial fishery was not returning anywhere near 100% of the high reward tags they encountered, and thus violating a major assumption of the method. Removal of this method results in a range of commercial tag reporting rate estimates from 2% to 34%. Recreational anglers appear to have a high reporting rate, with estimates ranging from 66% to 100%.

Due to the large difference in fishing sector specific tag reporting rates and the regional differences in fishery composition, it was determined that an overall tag reporting

rate for all regions was not credible. Overall rates were generated for the regions that participated in the study and resulted in estimates of 0.7 for Delaware, 0.42 for Maryland, 0.61 for New York and 0.44 for Virginia. Using methods outlined in this appendix, state specific estimates of tag reporting rate can be estimated for all member states.

Introduction

The purpose of this project is to obtain estimates of the tag reporting rate for use in the tagging model based assessment of Atlantic striped bass. Tag reporting rate is defined to be the probability a fisher returns a tag to the U.S. Fish and Wildlife service given that the fisher has captured a tagged fish. This information is needed to apportion estimates of total mortality into its fishing and “natural” components where natural mortality is mortality do to all causes other than fishing.

Tag reporting rate can be estimated from high reward tagging studies (Henny and Burnham 1976). Two kinds of tags are released: those with standard reward, and those with a special marking and a high value reward. A comparison of rates of return provides an estimate of the tag reporting rate for standard tags, on the assumption that all high reward tags encountered by the fishers are returned. The method has been evaluated by Henny and Burnham (1976), Conroy and Blandin (1984) and Pollock et al. (2001, 2002).

Previously, tag reporting rate for striped bass has been estimated using the high reward tagging method to be 75% in the Chesapeake Bay (Rugolo et al. 1994), 64% in Chesapeake Bay (Hornick et al. 2000), and 43% in the coastal fishery (Kahn and Shirey 2000). The rate of 0.43 obtained in the study by Kahn and Shirey (2000) has been used in the recent stock assessments of striped bass.

Conroy and Williams (1981) studied what happens in cases where the assumption of 100% reporting rate of high reward tags is violated. They found that the percent error in the estimate of reporting rate for standard tags is a function of the true reporting rate, □, for high reward tags and that the estimates are positively biased if the 100% reporting rate assumption is violated. Therefore, as part of the current study, it is important to explore the sensitivity of the results to violations of the assumption of 100% reporting of high reward tags.

There is strong reason to believe that commercial fishers might behave differently than recreational fishers with respect to their willingness to participate in tagging studies. In particular, commercial fishers may have lower reporting rates of both standard and high reward tags because: 1) in the process of handling large numbers of fish tags can be overlooked, 2) commercial fishers may not want to take the time to handle tags, and 3) commercial fishers may not wish to cooperate with government agencies because of tension over management or enforcement action. Because the two fishing sectors behave differently, multi-component fishery tagging models (Pollock et al. 2002) were used to analyze the data.

Methods

Representatives from Delaware, Maryland, New York, and Virginia tagged and released fish in the spring of 2007 and 2008. These fish were tagged with either a standard Fish and

Wildlife Service tag or a high reward tag. Fishers who captured a tag were able to report the tag to the Fish and Wildlife Service and receive a hat or t-shirt for reporting a standard tag or $125 for reporting a high reward tag. Prior to the release of tagged striped bass, participating regions undertook extensive advertising campaigns at boat ramps, tackle shops, and angling clubs in order to increase awareness of the high reward tagging study in the general angling public. In addition, information about the study was circulated to all licensed commercial fisherman that would be pursuing striped bass.

Any fish released less than 457mm total length was removed from the data set. This is done to ensure that the tagged population is composed of legal sized striped bass and thus representative of the group for which a tag reporting rate estimate is desired. Any fish released by Virginia that was recapture within the first week at liberty was removed from the data set. Virginia released fish in close proximity to cooperative commercial fisherman who regularly recapture tagged fish and are believed to report tags at a rate exceeding that of the general commercial fisher population. These exclusions resulted in changes to the release and recapture matrices. The modified release and recapture data are used in all analyses. Chi-square tests of independence were conducted on the tag recovery rates between years and between tag types. The test results confirmed that there was no difference in tag reporting rate between years and thus the data was pooled to increase sample size.

Method 1: Original model

Originally we proposed to estimate tag reporting rate by comparing the rate of return of standard tags and high reward tags (equation 1) under the assumption that 100% of high reward tags encountered were returned (Henny and Burnham 1976; Pollock et al. 2002).

$$\lambda_{hat} = (R_{std} / N_{std}) / (R_{high} / N_{high}) \qquad \textit{Equation 1.}$$

λ_{hat} is the estimated tag reporting rate for standard tags, R_{std} is the number of standard-reward tags returned, N_{std} is the number of fish marked with standard reward tags, R_{high} is the number of high-reward tags returned and N_{high} is the number of fish tagged with high-reward tags. The preponderance of evidence suggests that the 100% high reward tag return rate for both the commercial and recreational fisheries assumed in the original method is significantly violated. This assumption can be relaxed in the framework of the original method; however, it cannot be separated into fishery specific rates making it difficult to readily determine an appropriate combined high reward tag return rate. Because of this, the original method results will be noted but not considered further.

Method 2: Multi-component model

Fishery specific estimates of tag reporting rate as well as anecdotal evidence suggested that the commercial fishery was largely responsible for the violation of 100% high reward tag reporting rate. As a result, the multi-component fishery tagging model proposed by Paulik (1961), Kimura (1976), and Hearn et al. (1999) and described in Pollock et al. 2002 was used. This approach allows one to estimate tag reporting rate with the more reasonable assumption that 100% of high reward tags encountered by recreational anglers were returned. This approach can be generalized to allow for recreational anglers to return less than 100% of high reward tags encountered. The multi-component method produces fishing sector specific tag reporting rates by default and can easily produce regional estimates through appropriate subsetting. The multi-component approach requires weighting by landings. The weights are the percentage of total landings attributed to the commercial and recreational fisheries obtained using 2007 and 2008 commercial landings data from striped bass compliance reports and MRFSS recreational landings estimates for the same time period (Tables 1-3). Information on recreational catch and release numbers was not used in calculating recreational landings as similar discard information is not readily available for the commercial fishery. The steps in calculating the multi-component lambda estimates are described below.

1). We calculated a recreational reporting rate for standard tags using equation 2

$$\lambda_{rechat} = (R_{recstd} / N_{std}) / (R_{rechigh} / N_{high}) \qquad \textit{Equation 2}$$

Where R_{recstd} is the number of standard-reward tags returned, N_{std} is the number of fish marked with standard reward tags, $R_{rechigh}$ is the number of high-reward tags returned and N_{high} is the number of fish tagged with high-reward tags.

2). By assuming a high reward tag reporting rate of 100% and a 50/50 split of the recreational to commercial landings, the expected number of standard tags that should have been recovered and reported by the commercial sector is represented in equation 3.

$$\text{Expected } \lambda_{comhat} = \lambda_{rechat} * R_{comstd} / R_{recstd} \qquad \textit{Equation 3}$$

2a). If the ratio of commercial to recreational landings is not 50:50, equation 3 can be modified to equation 3a.

$$\text{Expected } \lambda_{comhat} = \lambda_{rechat} * (R_{comstd} / R_{recstd}) * (\text{\% rec. landings/\% comm. Landings}) \qquad \textit{Equation 3a}$$

3). Equation 4 calculates the number of standard tags that should have been recovered in the recreational sector.

$$\text{Expected } R_{recstd} = R_{recstd} / \lambda_{rechat} \qquad \textit{Equation 4}$$

4). Equation 5 calculates the number of standard tags that should have been recovered in the commercial sector.

$$\text{Expected } R_{comstd} = R_{comstd} / \text{Expected } \lambda_{comhat} \qquad \textit{Equation 5}$$

5). The sum of equation 4 and 5 is the number of standard tags that should have been reported. The sum of R_{recstd} and R_{comstd} is the number of standard tags that were actually reported. Then the overall standard reporting rate is the number of standard tags that were actually reported divided by the number of standard tags that should have been reported. To explore sensitivity of the method to failure of the assumption of 100% recreational high reward tag return rate, rates of 100%, 90% and 80% were used in the analysis.

Regional overall rate calculation

Once estimates of recreational and commercial tag reporting rate are obtained a method is required to calculate an overall rate for each member state. The following protocol was presented and agreed upon by the tagging committee as a reasonable approach. Data for the examples were taken from the high reward tagging study conducted in 2007 and 2008 in order to determine the tag reporting rate for striped bass. The fisher types listed in the FWS tag return database are: C – commercial, H – Charter, S – Sport, R – Researcher, O – other, and U – unknown.

Assume recreational tag reporting rate (Sport and Charter) is 0.81, commercial tag reporting rate is 0.11, tags recaptured by researchers have a reporting rate of 1 and tags recaptured by other or unknown sources have a reporting rate of 0.52 (Table 9).

1. Tabulate your regions recaptures by capture year (not calendar year) and fisher type (e.g. recreational, commercial…). Data may need to be tabulated for each capture year, for three year overlapping blocks, or for regulatory periods.

2. Adjust fisher type specific tag returns by dividing the observed recaptures by the corresponding fisher type tag reporting rates.

3. Sum the total adjusted tag returns across all fisher types.

4. Divide the adjusted tag return values (step 2) by the total adjusted tag return number (Step 3) to generate weights by fisher type.

5. Multiply fisher type specific weights (result of step 4) by the corresponding fisher type reporting rate to generate fisher type specific components of a regions overall tag reporting rate.

6. Sum the component reporting rates (step 5) to give the overall tag reporting rate for each region.

Results

The total number of standard and high reward tags released by the participating agencies varied by state and year as did the number of recaptures (Table 4 and Table 5). Data used in the analysis differs from that presented in tables 4 and 5. For the analysis, fish released less than 15 inches total length, Virginia releases at large less than 8 days, releases at large less than 0 days, and recaptures occurring after 4/1/2011 were removed from both the recapture and release data sets. The final data sets used in the analysis are tabulated in tables 6 and 7.

Original method results

Estimates of lambda were calculated using the original method for four different scenarios, all data combined, fishery specific, region specific, and region and fishery specific. With all data combined, lambda was estimated to be 0.79. Fishery specific estimates obtained by pooling years and regions are 0.90 and 0.34 for the recreational and commercial fisheries respectively. Regional and fishery specific results are tabulated in Table 8.

Multi-component model results

The same four scenarios used to analyze the data with the original method were used to analyze the data using the multi-component method. The multi-component method allows for relaxation of the assumption of 100% high reward tag return rate by recreational fisherman. To explore sensitivity of lambda estimates to this assumption, values of 100%, 90%, and 80% recreational angler high reward tag return rate were used. Assuming 90% recreational high reward tag return rate, the multi-component method estimated overall standard tag reporting rate to be 0.52 and fishery specific rates of 0.81 and 0.11 for the recreational and commercial fisheries respectively (Table 9). Standard tag reporting rate by recreational anglers was fairly consistently estimated among Delaware (0.60), Maryland (0.71), and Virginia (0.77), with New York standing out with an estimate of 100% standard tag reporting rate by recreational anglers (Table 10). Standard tag reporting rate by the commercial fishery was consistently low with an estimated 2% reported in Delaware, 11% reported in Maryland, 28% reported in New York, and 23% reported in Virginia (Table 11). Overall standard tag reporting rate varied widely by region, with an estimated reporting rates of 19% in Delaware, 40% in Maryland, 87% in New York, and 57% in Virginia (Table 12).

Regional overall rate results

These rates can be calculated for any specific year or block of years and for each member state regardless of their participation in the high reward tagging study.
Delaware = 0.70
Maryland = 0.42
New York = 0.61
Virginia = 0.44

Discussion

Original method

The preponderance of evidence suggests that the 100% high reward tag return rate for both the commercial and recreational fisheries assumed in the original method is significantly violated. This assumption can be relaxed in the framework of the original method; however, it cannot be separated into fishery specific rates making it difficult to readily determine an appropriate combined high reward tag return rate. Because of this, the original method results will be noted but not considered further.

Multi-component model

For the purpose of interpreting and discussing the results of the multi-component model, we will assume a recreational high reward tag reporting rate of 90%. This is a subjective conclusion that is open to debate but one that seems reasonable. Table 9 shows that under this assumption the estimated overall standard tag reporting rate is 0.52 with estimates of 0.81 and 0.11 for the recreational and commercial fishing sectors respectively. The fishery specific estimates illustrate a dramatic difference between the two fishery sectors willingness to participate in tagging studies. Tables 10 and 11 show each region has a significant gap between their respective recreational and commercial tag reporting rates suggesting that the reporting rate disparity is systematic and not just a regional phenomenon.

The weighting factors presented in table 3 shows clearly that the different member states have dramatically different fisheries. Many of these fisheries include no commercial component and would be misguided to apply a tag reporting rate derived, in part, from commercial tag returns to tagging data obtained solely from recreational anglers. As a result an overall rate for all member states is not logical and some form of region specific tag reporting rate is required. Use of the regional overall rate calculation method resulted in reporting rates that reflect the fishers that each member states releases are exposed to. This is a significant improvement over using a single tag reporting rate that will tend to overinflate recaptures in regions that lack commercial fisheries.

The choice of weights is the most contentious aspect of the multi-component model method for the reason states above and the highly migratory nature of striped bass. Additional analysis should be done in order to determine the magnitude and direction of potential bias introduced by using the proposed weights. Further analysis and discussion is required to identify what years we can apply the new rates to and what rate to use for the rest of the years in the time series.

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Table 1. Striped bass recreational landings in number of fish obtained from MFRSS including wave 1 estimates

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	PRFC	VA	NC
2007	71443	7070	347102	102112	109856	370722	206275	10096	679024	0	366964	45502
2008	49172	6642	343347	56056	112972	448271	318115	16994	442280	0	396950	44890

Table 2. Striped bass commercial landings in numbers

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	PRFC	VA	NC
2007	0	0	54265	12205	0	78287	0	30717	598495	86695	140602	16621
2008	0	0	61075	16616	0	73263	0	31866	594655	81720	134603	12903

Table 3. Percent of landings in numbers attributed to commercial fishing by region. Used as weights for multi-component method

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	PRFC	VA	NC
2007	0	0	0.14	0.11	0	0.17	0	0.75	0.47	1	0.28	0.27
2008	0	0	0.15	0.23	0	0.14	0	0.65	0.57	1	0.25	0.22
overall	0	0	0.14	0.15	0	0.16	0	0.70	0.52	1	0.26	0.25

Table 4. Number of standard and high reward tags released by each region during the 2007 and 2008 tagging seasons

Year	Tag Type	Delaware/Pennsylvania	Maryland	New York	Virginia
2007	Standard	465	681	843	1961
	High Reward	83	91	186	393
2008	Standard	535	545	1236	524
	High Reward	65	83	263	104

Table 5. All Standard and high reward tag recaptures by region, year of release, and year of recapture.

		2007 recaptures		2008 recaptures		2009 recaptures		2010 recaptures		2011 recaptures	
Release year		Std	HRT	Std	HRT	Std	HRT	Std	HRT	Std	HRT
2007	DE	36	6	13	6	11	5	3	3	1	0
	MD	32	7	16	1	6	4	3	1	2	0
	NY	47	13	52	9	25	9	11	2	3	0
	VA	96	39	41	16	20	6	4	1	1	0
2008	DE	-	-	41	5	25	6	11	2	3	1
	MD	-	-	25	6	18	2	7	1	1	2
	NY	-	-	85	17	62	14	44	5	11	0
	VA	-	-	21	7	11	2	1	1	0	0

Table 6. Release data used in the 2011 analysis of tag reporting rate.

Year	Tag Type	Delaware/Pennsylvania	Maryland	New York	Virginia
2007	Standard	464	624	754	1951
	High Reward	81	90	186	380

2008	Standard	529	505	1226	523
	High Reward	64	83	263	103

Table 7. Standard and high reward tag recaptures by region, year of release, and year of recapture used in the 2011 analysis of tag reporting rate.

		2007 recaptures		2008 recaptures		2009 recaptures		2010 recaptures		2011 recaptures	
Release year		Std	HRT	Std	HRT	Std	HRT	Std	HRT	Std	HRT
2007	DE	36	4	13	6	11	5	3	3	0	0
	MD	29	7	16	1	6	4	3	1	2	0
	NY	47	13	51	9	25	9	11	2	0	0
	VA	87	26	41	16	20	6	4	1	0	0
2008	DE	-	-	41	5	25	6	11	2	1	1
	MD	-	-	24	6	17	2	7	1	0	2
	NY	-	-	84	17	62	14	44	5	2	0
	VA	-	-	20	6	11	2	1	1	0	0

Table 8. Estimates of region and fishery specific tag reporting rates obtained using the original method with pooled years of release and recapture.

Region of release	Commercial	Recreational	Combined
Delaware	0.58	0.66	0.66
Maryland	0.31	0.79	0.66
New York	0.91	1.11	1.07
Virginia	0.23	0.86	0.62

Table 9. Overall (fisheries combined) and fishery specific tag reporting rate estimates obtained by pooling data across years and region of release under assumptions of 100%, 90%, and 80% recreational high reward tag reporting rate

	Assumed recreational high reward tag reporting rate		
	100%	90%	80%
Overall	0.58	0.52	0.47
Commercial	0.13	0.11	0.10
Recreational	0.90	0.81	0.72

Table 10. Regional recreational standard tag reporting rates obtained by pooling data across years under assumptions of 100%, 90%, and 80% recreational high reward tag reporting rate

	Assumed recreational high reward tag reporting rate		
	100%	90%	80%
Delaware	0.66	0.60	0.53
Maryland	0.79	0.71	0.63
New York	1.11	1.00	0.89
Virginia	0.86	0.77	0.68

Table 11. Regional commercial standard tag reporting rates obtained by pooling data across years under assumptions of 100%, 90%, and 80% recreational high reward tag reporting rate

	Assumed recreational high reward tag reporting rate		
	100%	90%	80%
Delaware	0.02	0.02	0.01
Maryland	0.12	0.11	0.09
New York	0.32	0.28	0.25
Virginia	0.26	0.23	0.20

Table 12. Regional overall standard tag reporting rates obtained by pooling data across years and fisheries under assumptions of 100%, 90%, and 80% recreational high reward tag reporting rate

	Assumed recreational high reward tag reporting rate		
	100%	90%	80%
Delaware	0.21	0.19	0.17
Maryland	0.45	0.40	0.36
New York	0.98	0.87	0.79
Virginia	0.63	0.57	0.50