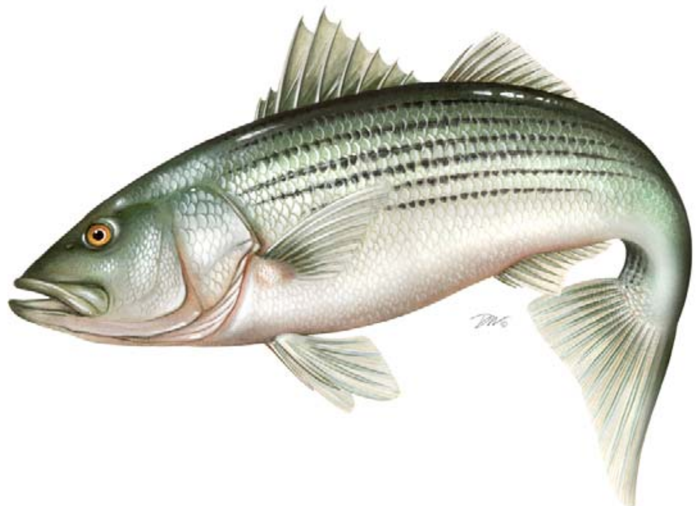
2009 Stock Assessment Report for Atlantic Striped Bass



A report prepared by the Atlantic Striped Bass Technical Committee

Accepted for management use
November 2009

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

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Atlantic Striped Bass Stock Assessment Summary

State of Stock: Relative to the biological reference points accepted by the Striped Bass Management Board in 2008 (SSB threshold = 30,000 metric tons (mt); F threshold = 0.34), the striped bass stock complex is not overfished and overfishing is not occurring. This conclusion is based on a 2008 female spawning stock biomass estimate of 55,500 mt and average age 8-11 *F*=0.21 from the statistical catch at age (SCA) model results. Using state and federal indices, the SCA model estimates a low fishing mortality rate (*F*), stable spawning and total biomass, and a slight increase in population numbers following a recent four year decline. Abundance estimates increased from a low of 8.8 million fish in 1982 to a peak of 70.8 million fish in 2004, and have since decreased to 52.8 million fish in 2008.

Forecast: Forecasts of age 8+ abundance from 2009 to 2015 and spawning stock biomass from 2009 to 2011 at status quo F (0.21) and selectivity show increases in abundance through 2011, but a subsequent decline in abundance through 2014. Spawning stock biomass would remain relatively stable through 2011. Projected landings of age 8+ fish at status quo F show a continuing decline in 2010 but an increase in landings in 2011.

Landings Table (weights in '000 mt): Striped Bass

Year	2002	2003	2004	2005	2006	2007	2008	Max	Min	Mean
USA Commercial landings[1]	2.7	3.2	3.3	3.2	3.1	3.2	3.3	5.9	0.1	2.4
USA Recreational landings[2]	8.4	10.4	12.6	11.6	13.8	11.2	12.3	13.8	0.3	5.3
Total Landings[2]	11.1	13.6	15.9	14.8	16.9	14.4	15.6	16.9	0.4	7.0

[1] Min, max and mean since 1947.
[2] Min, max and mean landings 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 2008, recreational anglers along the Atlantic Coast landed over 2.2 million striped bass weighing 12,310 metric tons (mt) (Figure 1 and 2, Table 1 and 2). Recreational landings have ranged from a low of 336 mt in 1989 to a high of 13,814 mt in 2006. Coastwide landings of 2.2 million fish in 2008 reflected a 17% decline from a high of 2.7 million fish in 2006 (Tables 2 and 3). Changes in landings have varied by state (Table 3), with MA, CT, and NY showing an increase in landings and the remaining states showing a 32% decrease on average. Recreational discard mortalities (assuming an 8% mortality of releases) in 2008 were 950,000 fish (Table 4), a 64% decrease from a high of 2.1 million fish in 2006. Since 2000, MA, ME, CT, and MD have had the highest number of released fish and have accounted for 72% of total discard losses. Changes in discard numbers since 2006 have varied by state with ME and NH showing an 88% decrease in discards while CT, NY, and DE experienced either little change or an increase in discards. Landings from the commercial striped bass fishery have been consistently lower than the recreational catch (Figure 1). Commercial landings (Tables 1 and 5) increased from 63 mt in 1987 to 2,679 mt in 1997 and have remained steady due to quota restrictions. Landings in 2008 were 3,281 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 6). 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. However, limited 2007 and 2008 recaptures by area required the use of tag recaptures aggregated across areas. State agencies between Massachusetts and North Carolina conduct annual marine finfish surveys and the indices, partitioned by age, 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 (Table 7); age 1 indices from MD and NY (Table 7); age specific indices from the NY ocean haul seine (through 2007), NJ trawl survey, MD spawning stock survey, and the DE spawning stock survey (Table 8); and age aggregated indices from MFRSS catch per angler, CT catch per angler, NEFSC trawl survey, and the CT trawl survey (Table 8). The ASMFC Tagging Subcommittee analyzed tag release and recovery data through 2008 gathered by state and federal agencies as part of the USFWS Atlantic coastwide cooperative striped bass tagging program. Estimates of fishing mortality from tag data are developed using the Program MARK which assumes constant natural mortality. In addition estimates 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 index in 2006 (3.82) was among the lowest in the time series but increased in 2007 (35.02) to the highest index in the time series. The 2008 index (13.86) was equal to the time series average. 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.

Delaware River stock:

The juvenile index of the Delaware River stock collected by NJ DEP shows an annually variable but relatively stable pattern since 1989. The 2007 and 2008 indices were near average. The Delaware spawning stock indices in 2007 (1.78) and 2008 (1.72) were below the time series average of 2.48.

Chesapeake Bay stock:

Maryland juvenile indices have a variable and declining trend since 2000. The 2008 index was the lowest since the early 1990s. A similar index of the Chesapeake Bay stock collected in VA shows a high annual variability with little trend since the early 1990s. 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). The MD spawning stock survey shows a low in 2007 for the index time series but was average in 2008.

Coastal mixed stock:

Among the age based indices, the NY ocean haul seine survey, terminated in 2007, showed above average abundance in 2006. Other coastal indices, such as the MA commercial CPUE and the NJ trawl survey index, declined below average in 2008. The age aggregated index based on MRFSS catch per angler trip shows an increase between 2003 and 2006 then a sharp decrease in 2007. The 2008 index was the lowest since the mid-1990s. The index from the Northeast Fisheries Science Center trawl survey was near average in 2007 and 2008 while the CT DEP trawl survey shows a variable but relatively stable index since the late 1990s, although the 2008 value was slightly below average. A fisheries dependent index of CPUE from CT volunteer anglers shows a sharp increasing series since 2003 with the 2008 value the highest in the time series.

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 declined since 2006 (Figure 4, Table 9). Fishing mortality for ages 8 to 11 decreased from 0.26 in 2006 to 0.21 in 2008 while F on ages 3 to 8 changed from 0.18 in 2006 to 0.15 in 2008. Fishing mortality for ages 7-11 weighted by N (Figure 5) follow the same pattern as ages 8 to 11. A retrospective bias caused the 2006 F estimates to decrease since the 2007 assessment from 0.3 to 0.26 for ages 8 to 11 (Figure 9).

Fishing Mortality – Tag models:

Coastal programs -The estimates of fishing mortality in 2008 for striped bass greater than 28 inches were 0.15 using the catch equation method and 0.13 using the instantaneous rates tag return model (IRCR). The average fishing mortality in 2008 averaged across the two models equaled 0.14. Aside from peak estimates in 1998 and 2004, the annual mean estimates have varied from include based on CEM and IRCR only since 1994 (Figure 10, Table 9).

Hudson River - Striped bass fishing mortality in 2008, for fish 28 inches and greater, equaled 0.18 when averaged across the two models. Average F over the time series has ranged from 0.31 in 1997 to 0.08 in 1989. Since 2000 F has remained relatively stable with an average of 0.19. F in 2008 on fish 18 inches and greater averaged 0.15 (Figure 10, Table 9).

Delaware River - Average striped bass fishing mortality in 2008, for fish 28 inches and greater, equaled 0.14 which was a decline from 0.30 in 2004. Fishing mortality for fish 18 inches and greater in 2008 was 0.11, and decreased from an F=0.20 in 2004 (Figure 10, Table 9).

Chesapeake Bay - The estimates of fishing mortality in 2008 for striped bass greater than 18 inches averaged 0.10 and has steadily decreased since 1998 when F=0.24 (0.26 in 2005). Fish 28” and greater from the Chesapeake stock averaged 0.13 in 2008 and has also remained steady since the late 1990’s (Figure 10, Table 9).

Abundance and Biomass: Striped bass abundance and biomass were estimated using the SCA model (Figure 6 and 7, Table 10 and 11). Abundance increased steadily from 8.9 million fish in 1982 to a peak of 70.8 million in 2004 then declined to 51.4 million fish in 2007. The 2008 estimate increased slightly to 52.8 million fish. Striped bass age 8 and greater, representing fish 28” and greater, reached a low in 1985 and also increased to a series high in 2004. Abundance of age 8+ fish decreased from 9.8 million fish in 2004 to 6.4 million in 2007 with a slight increase to 6.6 million at the start of 2008. Total biomass followed a similar pattern increasing from a low in 1984 to a peak of 112,100 mt in 2004. Biomass since 2004 declined to 101,900 mt in 2007 but increased in 2008 to 108,300 mt with the continued growth of strong cohorts.

Spawning Stock Biomass: SSB for striped bass is presented as female spawning biomass (Figure 7, Table 12). The 2008 estimate of SSB equaled 55,500 mt, a slight increase from the 2007 estimate of 54,574 mt. Both 2007 and 2008 are less than the time series maximum of 63,588 mt in 2004. The threshold SSB is equivalent to the 1995 estimate; the 2008 estimate was at 185% of the threshold and 148% of the target.

Recruitment: Recruitment estimated in the SCA model as age-1 abundance has averaged 12.5 million fish since 1995 when the stock complex was declared restored (Figure 8). The 2006 and 2007 estimates were the lowest in recent years at 7.4 million and 5.8 million fish, respectively. The 2003 cohort (2004, age 1) remains the largest since 1982 at 22.8 million fish. Recruitment in 2008 (2007 cohort) of 13.3 million fish was slightly above the recent average.

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 30,000 mt with a target SSB of 37,500 mt. The female SSB estimate for 2008 (55,500 mt) exceeds both the threshold and target and is not considered overfished. The current F of 0.21 is below the approved F target of 0.30 and therefore, it is concluded that striped bass is not experiencing overfishing.

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 although there was a small increase between 2007 and 2008. The decrease in abundance is reflected in a decline in coastwide landings in 2007 and 2008. 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 remains relatively stable 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 also exhibit an increasing retrospective bias where F is overestimated and abundance and biomass underestimated (Figure 9). Retrospective bias may be the result of error in catch estimates, natural mortality, unequal stock mixing and changes in catchability or selectivity. Analysis of tag data also suggests an increasing natural mortality in Chesapeake Bay, likely the result of the mycobacteriosis. Table 13 summarizes the likely direction of bias associated with various sources of uncertainty in the striped bass assessment results.

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, Maine to North Carolina

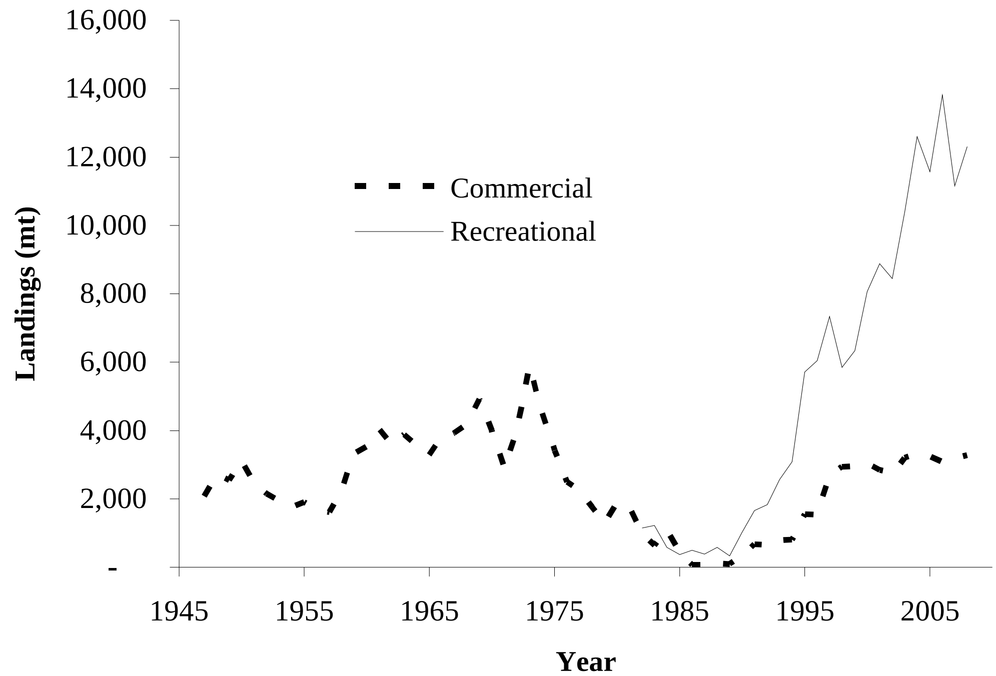


Figure 2. Total catch (landings plus discards) in number (000s) for recreational and commercial fisheries of striped bass, Maine to North Carolina, 1982-2008

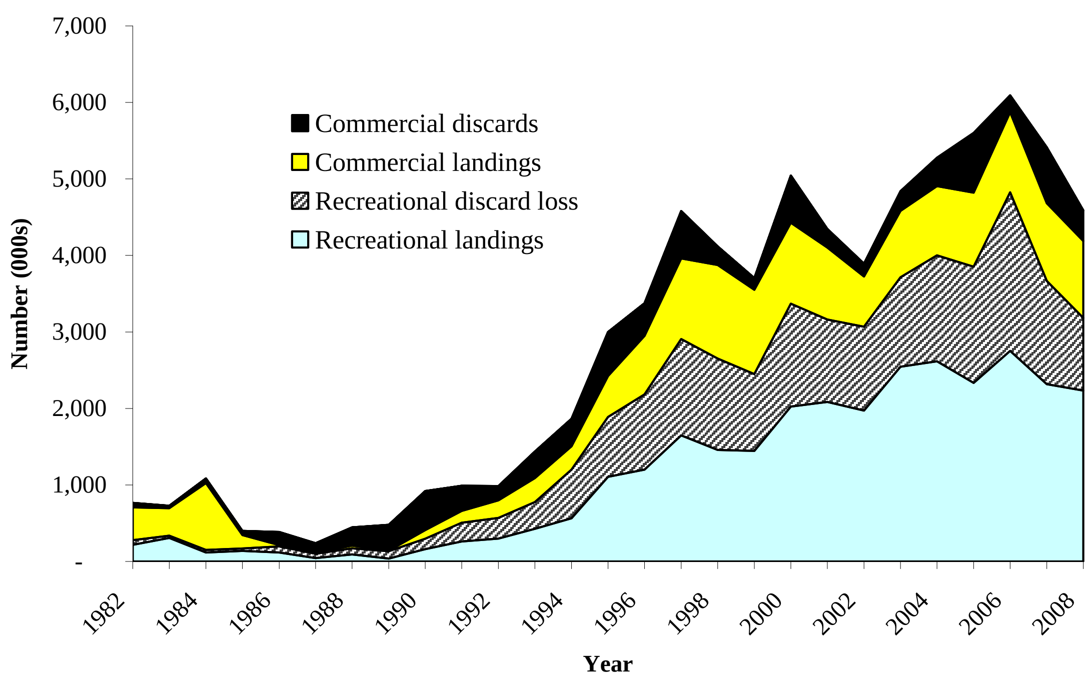


Figure 3. Total catch at age of striped bass along the Atlantic coast, 1997-2008; dominant year classes evident in juvenile indices are shown in solid colors

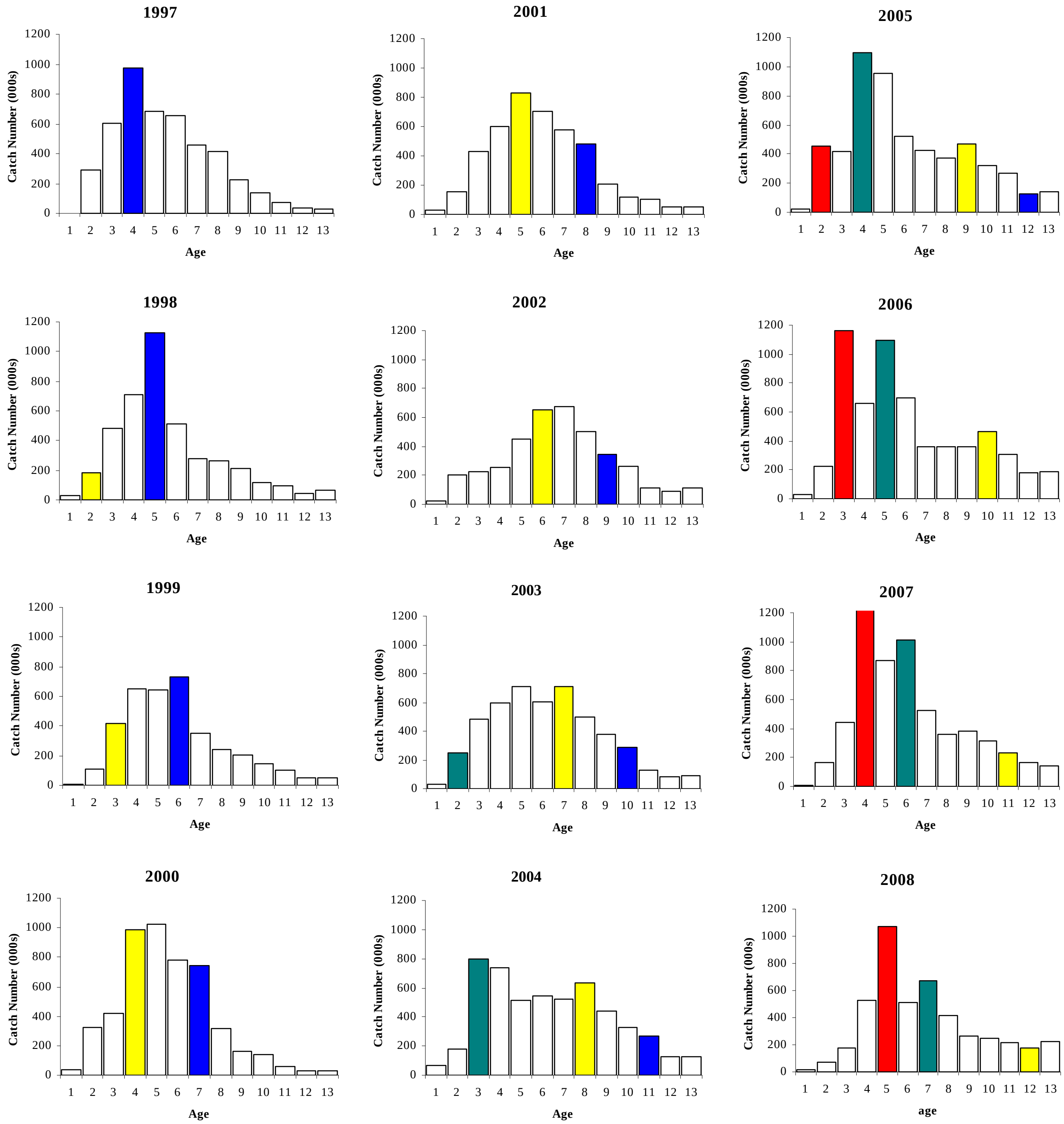


Figure 4. Fishing mortality estimates of striped bass from SCA model, 1982-2008

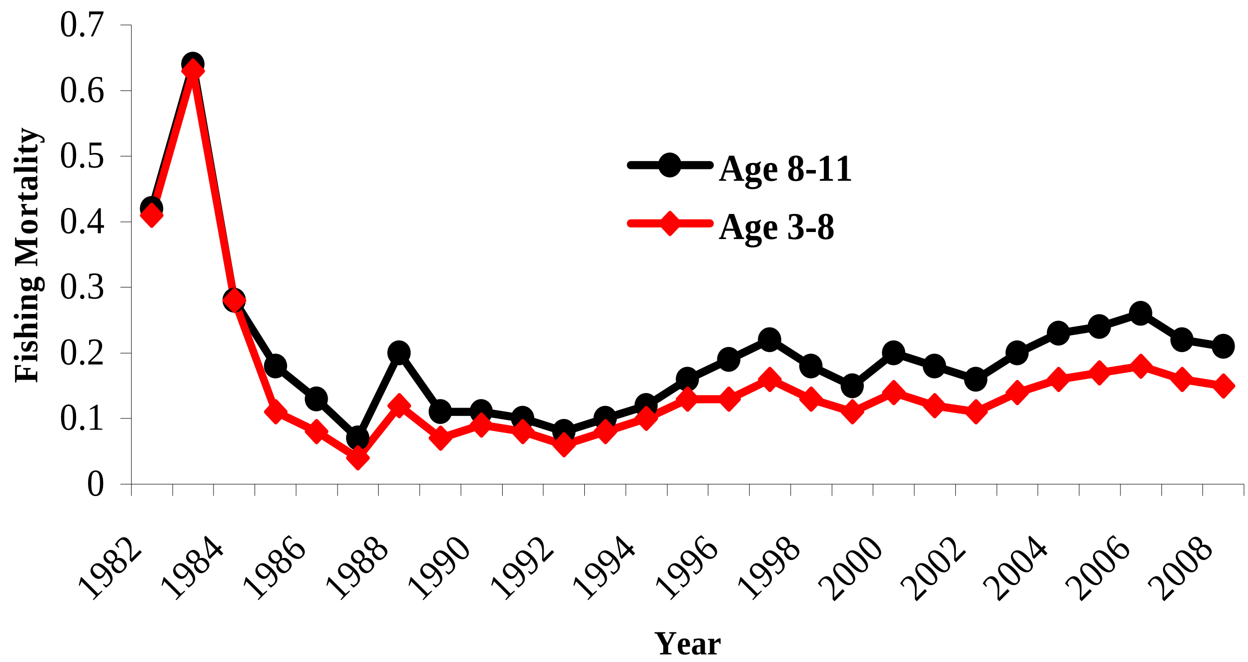


Figure 5. Fishing mortality estimates for ages 7-11 (weighted by N) from the SCA model, and tag based estimate of F for striped bass 28" and greater

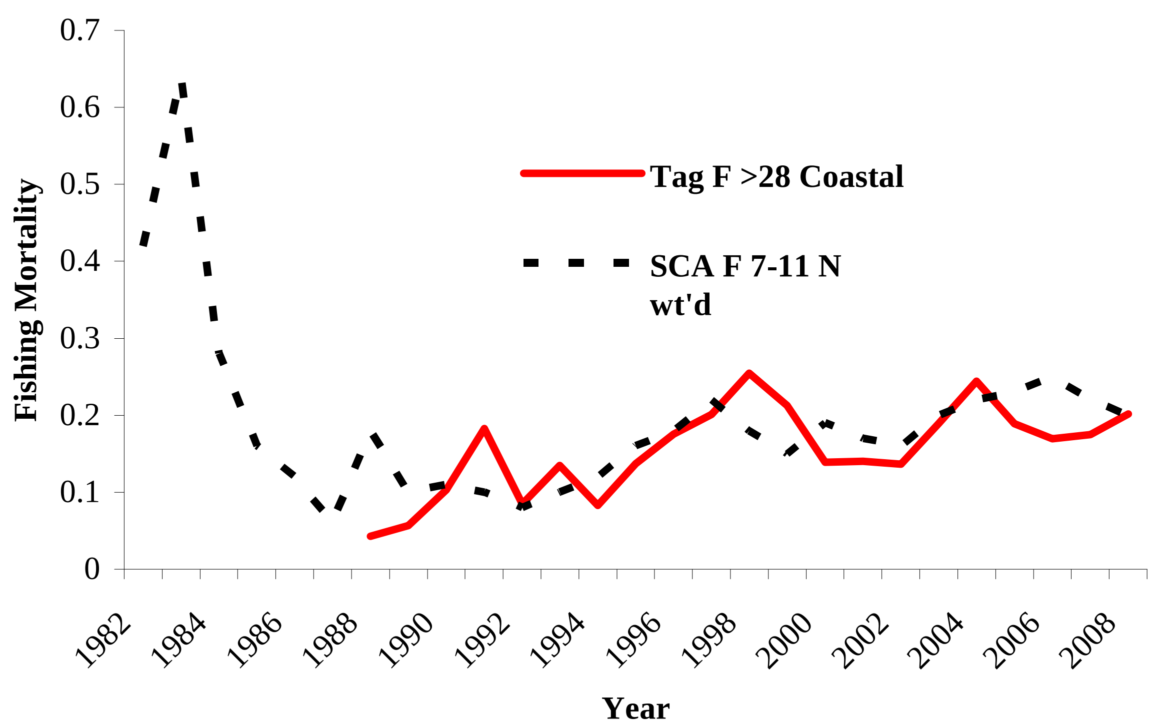


Figure 6. Total and age 8+ abundance (000s) of striped bass estimated in SCA model, 1982-2008

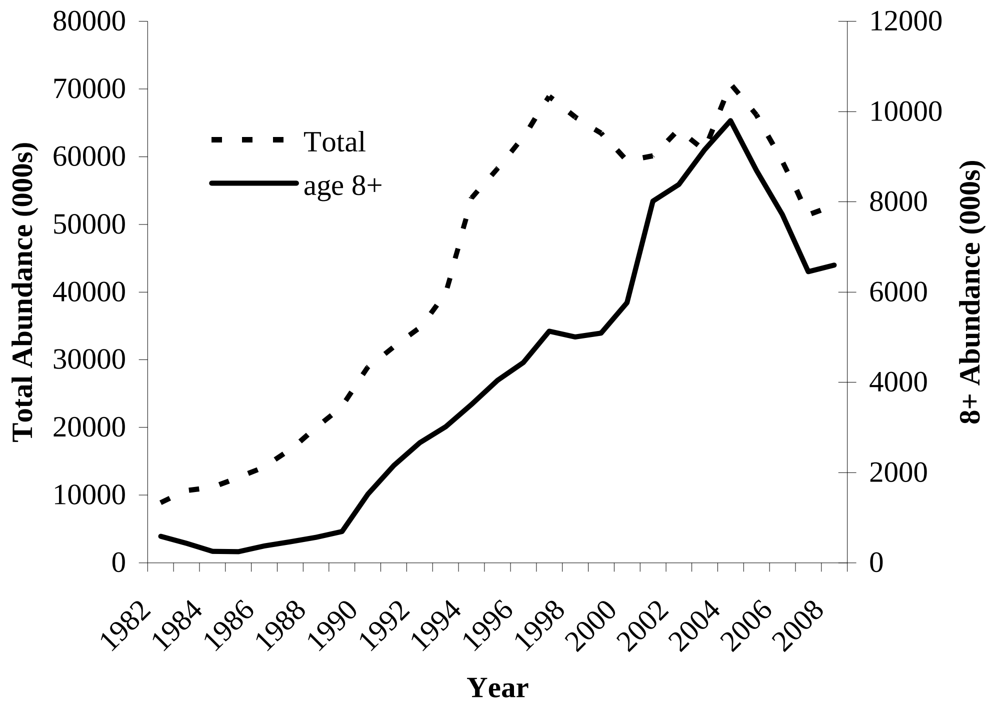


Figure 7. Total, spawning stock, and age 8+ biomass (000s MT) of striped bass estimated in SCA model, 1982-2008

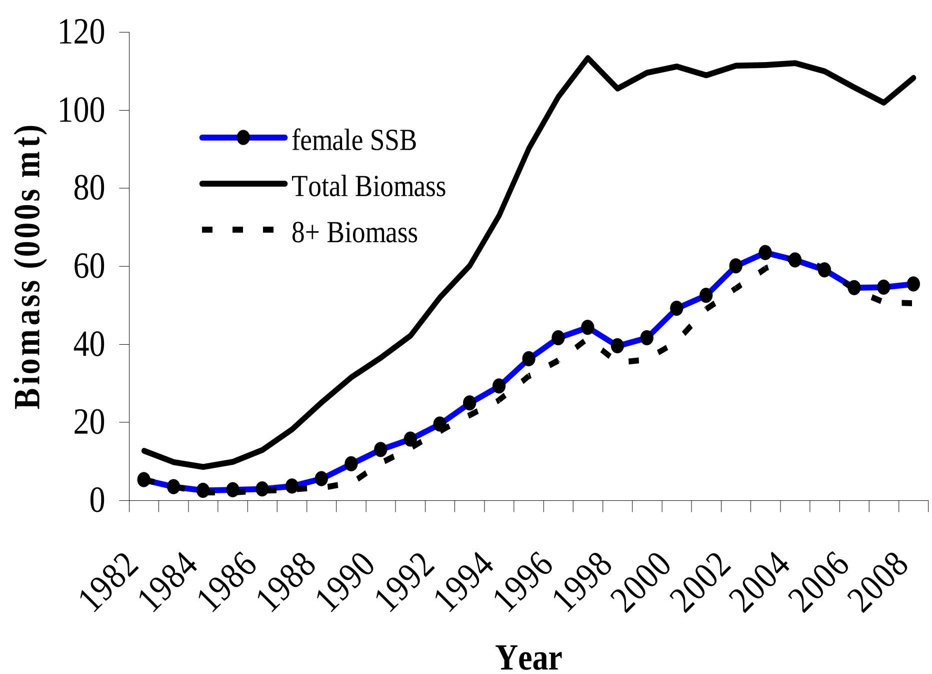


Figure 8. Recruitment (age 1) estimates for striped bass from SCA model; 1995-2008 average shown as dotted line

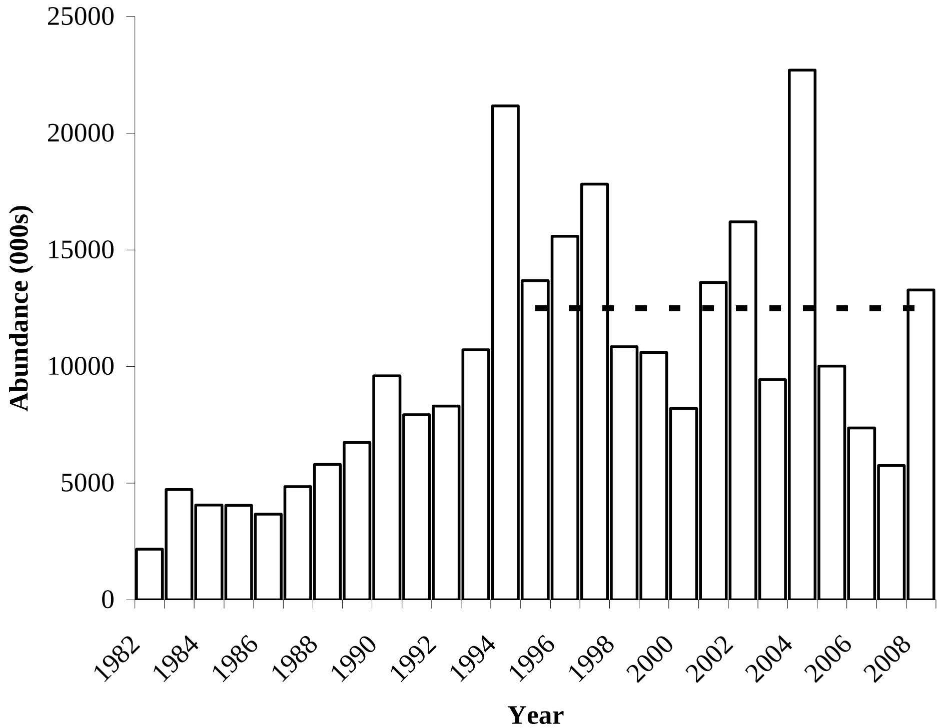


Figure 9. Retrospective pattern of fully-recruited fishing mortality, age 8+ abundance, and spawning stock biomass for striped bass in SCA model

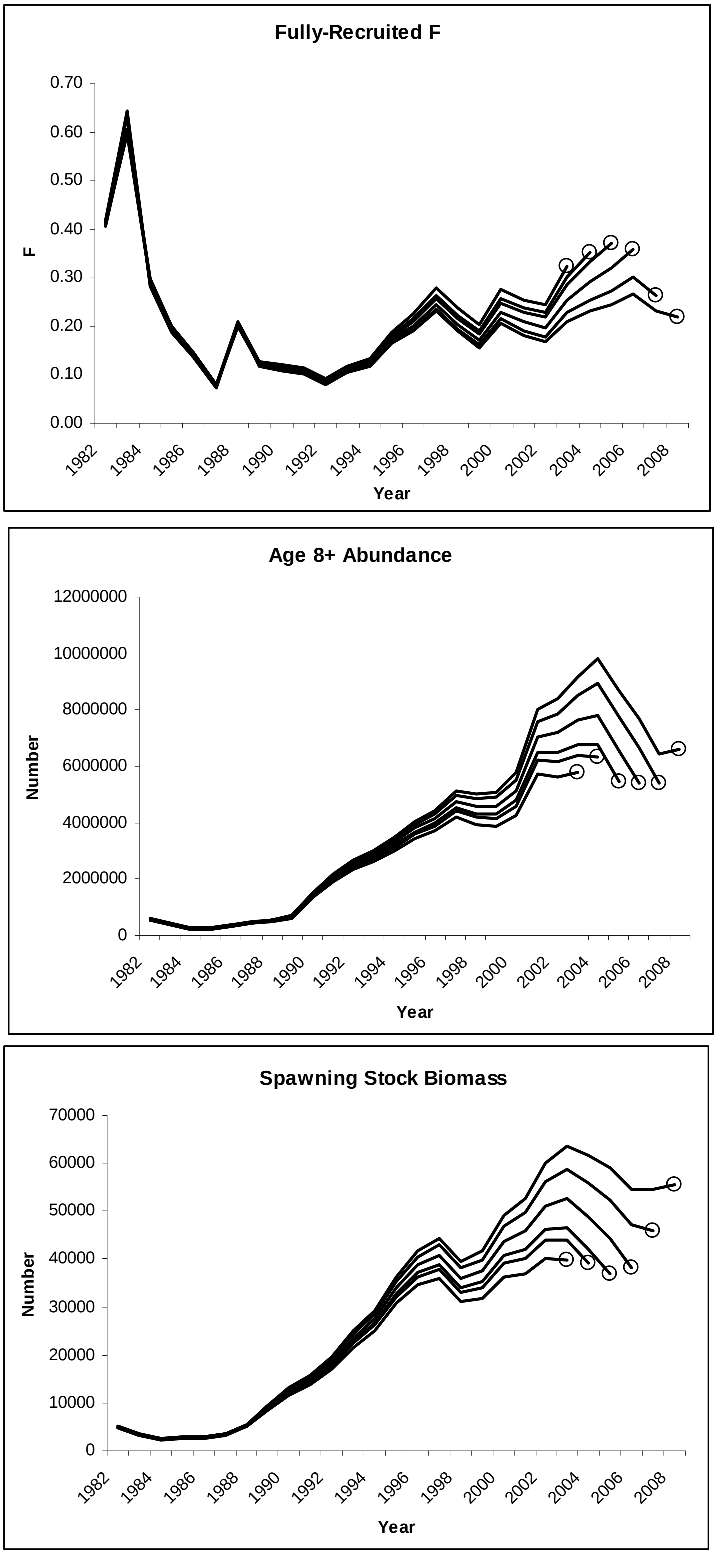


Figure 10. Tag based model averages of fishing mortality by producer area; dots indicate point estimates from CE and IRCR models (IRCR model not available for Delaware stock)

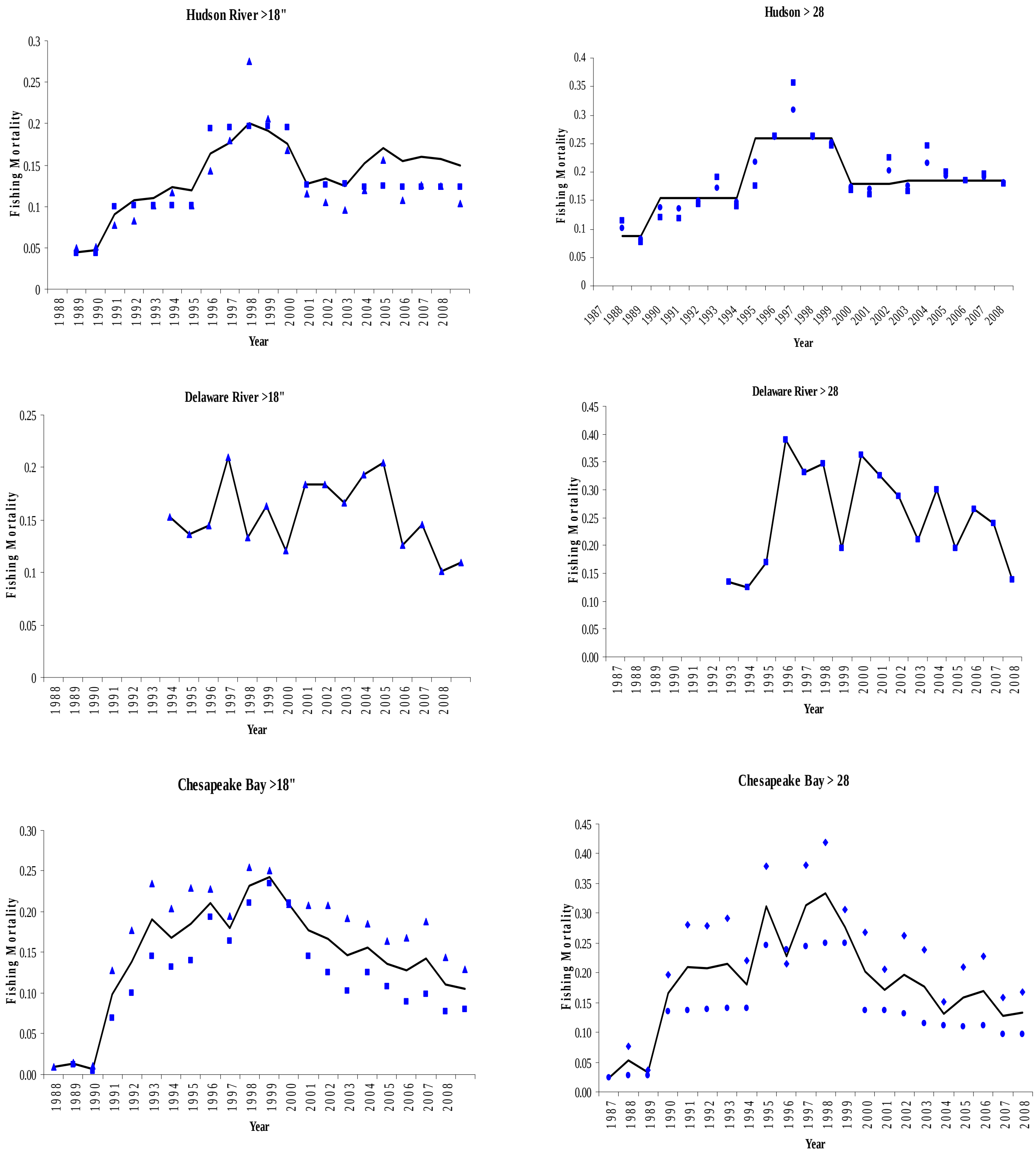


Table 1. Striped bass commercial and recreational landings in metric tons (mt)

	Commercial		Commercial	Recreational
1947	2,085	**1982**	992	1,144
1948	2,726	**1983**	639	1,224
1949	2,543	**1984**	1,104	582
1950	3,128	**1985**	431	376
1951	2,444	**1986**	63	502
1952	2,148	**1987**	63	388
1953	1,960	**1988**	117	578
1954	1,759	**1989**	91	336
1955	1,906	**1990**	313	1,010
1956	1,686	**1991**	668	1,653
1957	1,619	**1992**	650	1,830
1958	2,266	**1993**	794	2,563
1959	3,317	**1994**	806	3,083
1960	3,524	**1995**	1,555	5,709
1961	4,042	**1996**	1,541	6,040
1962	3,567	**1997**	2,679	7,336
1963	3,879	**1998**	2,936	5,850
1964	3,558	**1999**	2,963	6,335
1965	3,278	**2000**	3,038	8,060
1966	3,820	**2001**	2,843	8,880
1967	3,924	**2002**	2,740	8,449
1968	4,169	**2003**	3,199	10,405
1969	4,912	**2004**	3,332	12,596
1970	3,999	**2005**	3,240	11,567
1971	2,890	**2006**	3,073	13,814
1972	4,012	**2007**	3,192	11,156
1973	5,888	**2008**	3,281	12,310
1974	4,536			
1975	3,416			
1976	2,494			
1977	2,245			
1978	1,764			
1979	1,290			
1980	1,895			
1981	1,744			

Table 2. Atlantic striped bass landings and discards, 1982-2008, in numbers of fish (000s); AB1 are recreational landings and B2 are recreational discards

	Number (000s)						
year	**AB1**	**B2**	**B2 dead**	**Comm land**	**Comm disc**	**MA consumption**	**Total**
1982	217.3	783.2	62.7	428.6	57.7	-	766.2
1983	307.1	384.2	30.7	357.5	32.3	-	727.7
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	-	239.1
1988	92.5	1,001.9	80.1	33.3	238.9	-	444.9
1989	38.1	1,200.8	96.1	7.4	338.4	-	479.9
1990	163.2	1,653.6	132.3	115.6	510.1	-	921.3
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	-	1,437.0
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	-	3,704.3
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	654.1	166.8	4.0	3,893.5
2003	2,545.1	14,847.1	1,168.9	869.0	253.3	5.8	4,842.0
2004	2,615.6	17,290.0	1,383.2	907.5	366.3	5.9	5,278.6
2005	2,335.4	18,949.4	1,516.0	968.2	776.8	5.7	5,602.0
2006	2,750.9	25,904.2	2,072.3	1,049.6	216.8	5.1	6,094.6
2007	2,316.2	16,869.1	1,349.5	1,019.6	726.7	3.4	5,415.4
2008	2,235.7	11,854.6	948.4	1,006.7	395.4	4.3	4,590.4

Table 3. Striped bass recreational landings (number of fish) by state, 1982-2008, including Wave 1 estimates

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	Total
1982	929		83933	1757	50081	21278	58294		984			217,256
1983	7212	4576	39316	1990	42826	43731	127912	135	31746			299,444
1984			3481	1230	5678	57089	13625	16571	16789			114,463
1985	11862		66019	670	15350	23107	13145		2965	404		133,522
1986			29434	3291	1760	27477	36999		14077	1585		114,623
1987		90	10807	2399	522	14191	9279		4025	2442		43,755
1988		647	21050	5226	2672	20230	12141		133	24259	6141	92,499
1989	738		13044	4303	5777	12388	1312				512	38,074
1990	2912	617	20515	4677	6082	24799	44878	2009	736	56017		163,242
1991	3265	274	20799	17193	4907	54502	38300	2741	77873	42224	391	262,469
1992	6357	2213	57084	14945	9154	45162	41426	2400	99354	21118	1317	300,530
1993	612	1540	58511	17826	19253	78560	64935	4055	104682	78481	264	428,719
1994	3771	3023	74538	5915	16929	87225	34877	4140	199378	127945	7930	565,671
1995	2189	3902	73806	29997	38261	155821	254055	15361	355237	149103	30821	1,108,553
1996	1893	6461	68300	60074	62840	225428	127952	22867	337415	250731	35996	1,199,957
1997	35259	13546	199373	62162	64639	236902	67800	19706	334068	518483	96189	1,648,127
1998	38094	5929	207952	44890	64215	166868	88973	18758	391824	383786	45768	1,457,057
1999	21102	4641	126755	56320	55805	195261	237010	8772	263191	411873	65658	1,446,388
2000	62186	4262	181295	95496	53191	270798	402302	39543	506462	389126	20452	2,025,113
2001	59947	15291	288032	80125	54165	189714	560208	41195	382557	355020	58876	2,085,130
2002	71907	12857	308749	78190	51060	202075	416455	29149	282429	411248	109052	1,973,171
2003	57765	24878	407100	115471	95983	313761	391842	29522	525191	455812	127727	2,545,052
2004	36886	10359	400252	84814	75244	242623	448524	25178	380461	633018	278270	2,615,629
2005	68638	26026	368422	112918	114965	298387	327016	19955	490275	403792	104997	2,335,391
2006	72827	14748	339994	73650	83390	313464	489319	19076	648644	539543	90753	2,685,408
2007	71443	7070	347102	102112	109856	370722	206275	10096	679024	366964	45502	2,316,166
2008	49172	6642	343347	56056	112972	448271	318115	16994	442280	396950	44890	2,235,689

Table 4. Striped bass recreational discard losses (discard number x 8% release mortality rate) by state, 1982-2008

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	-	30,738
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	-	29,967
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	-	56,653
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	-	96,064
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	347,566
1994	29,096	3,480	168,201	11,119	39,197	90,617	45,444	8,319	222,831	15,762	400	634,467
1995	40,461	22,839	262,471	28,506	40,570	96,767	55,591	9,229	192,102	29,676	1,298	779,509
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	1,257,467
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	1,344,705
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	1,168,907
2004	59,871	15,744	471,333	53,598	86,344	119,416	105,883	12,094	299,082	141,408	18,428	1,383,202
2005	241,943	41,022	387,180	59,282	137,083	107,870	95,795	17,987	300,266	118,763	8,763	1,515,955
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	1,349,528
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

Table 5. Striped bass commercial landings (number of fish) by state, 1982-2008

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	PRFC	VA	NC	Total 000s
1982			26,183	52,896	207	74,935		12,794	189,089	54,421	14,905	3,200	428.6
1983			9,528	48,173	83	66,334		5,806	147,079	63,171	15,962	1,405	357.5
1984			5,838	8,878	192	70,472		12,832	392,696	372,924	6,507	532	870.9
1985	90		7,601	7,173	350	52,048		1,359		82,550	23,450		174.6
1986			3,797	2,668						10,965	251		17.7
1987			3,284	23						9,884	361		13.6
1988			3,388							19,334	10,588		33.3
1989			7,402										7.4
1990			5,927	784		11,784		698	534	38,884	56,222	803	115.6
1991			9,901	3,596		15,426		3,091	31,880	44,521	44,970	413	153.8
1992			11,532	9,095		20,150		2,703	119,286	23,291	42,912	1,745	230.7
1993			13,099	6,294		11,181		4,273	211,089	24,451	39,059	3,414	312.9
1994			11,066	4,512		15,212		4,886	208,914	25,196	32,382	5,275	307.4
1995			44,965	19,722		43,704		5,565	280,051	29,308	88,274	23,325	534.9
1996			38,354	18,570		39,707		20,660	415,272	46,309	184,495	3,151	766.5
1997			44,841	7,061		37,852		33,223	656,416	87,643	165,583	25,562	1,058.2
1998			43,315	8,835		45,149		31,386	780,893	93,299	204,911	16,040	1,223.8
1999			40,838	11,559		49,795		34,841	650,022	90,575	205,143	21,010	1,103.8
2000			40,256	9,418		54,894		25,188	627,777	91,471	202,227	6,480	1,057.7
2001			40,248	10,917		58,296		34,373	538,808	87,809	148,346	22,936	941.7
2002			44,897	11,653		47,142		30,440	296,635	80,300	127,211	15,784	654.1
2003			55,433	15,497		68,354		31,530	439,482	83,090	161,778	13,823	869.0
2004			60,632	16,040		70,367		28,406	461,064	91,980	147,998	31,014	907.5
2005			59,966	14,949		70,560		26,336	569,964	80,615	119,244	26,572	968.2
2006			69,986	15,429		73,528		30,212	655,951	92,288	109,395	2,798	1,049.6
2007			54,265	12,205		78,287		30,717	598,495	86,695	140,602	16,621	1,017.9
2008			61,075	16,616		73,263		31,866	594,655	81,720	134,603	12,903	1,006.7

Table 6. Striped bass catch at age (000s of fish)

total catch at age (000s)	Age													
	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
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	728
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	1,085
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	401
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	385
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
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	445
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	480
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
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
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	987
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
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	1,867
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	3,000
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
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
1998	26.4	183.4	485.4	706.7	1125.0	510.9	280.4	265.0	215.5	113.8	95.1	45.2	65.5	4,118
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
2000	37.9	321.5	417.7	984.5	1020.0	781.6	744.0	313.7	161.3	142.0	59.8	29.4	30.9	5,044
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
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	3,894
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
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	5,279
2005	18.9	456.7	419.4	1097.7	957.5	520.9	426.2	376.4	468.5	323.9	271.5	125.3	139.2	5,602
2006	33.7	225.8	1165.8	657.4	1092.7	700.8	359.9	359.4	362.9	461.3	307.5	177.1	190.1	6,095
2007	9.7	163.7	441.3	1222.2	873.5	1016.0	525.2	356.3	385.7	316.3	232.3	166.3	139.4	5,848
2008	15.9	69.4	172.7	530.9	1070.0	513.9	669.0	413.6	263.2	249.9	217.8	179.4	224.8	4,590

Table 7. Young of year and juvenile indices of striped bass abundance from state surveys

	Young of year					Age 1	
Year	NY	NJ	MD	VA	Year	NY	MD
1969			2.81		1969		0.25
1970			12.52		1970		0.13
1971			4.02		1971		1.36
1972			3.26		1972		0.46
1973			2.32		1973		0.46
1974			2.63		1974		0.26
1975			2.81		1975		0.22
1976			1.58		1976		0.13
1977			1.60		1977		0.06
1978			3.75		1978		0.18
1979	2.15		1.78		1979		0.29
1980	6.08	0.05	1.02		1980		0.18
1981	8.86	0.01	0.59		1981		0.02
1982	14.17	0.12	3.57	2.71	1982		0.02
1983	16.25	0.03	0.61	3.40	1983		0.32
1984	15.00	0.29	1.64	4.47	1984		0.00
1985	1.92	0.02	0.91	2.41	1985	0.61	0.16
1986	2.92	0.27	1.34	4.74	1986	0.30	0.03
1987	15.90	0.41	1.46	15.74	1987	0.21	0.06
1988	33.46	0.34	0.73	7.64	1988	0.81	0.07
1989	21.35	1.03	4.87	11.23	1989	1.78	0.19
1990	19.08	1.00	1.03	7.34	1990	0.37	0.33
1991	3.60	0.51	1.52	3.76	1991	1.26	0.20
1992	11.43	1.21	2.34	7.35	1992	1.34	0.15
1993	12.59	1.81	13.97	18.11	1993	0.75	0.20
1994	17.64	0.96	6.40	10.48	1994	1.43	0.78
1995	16.23	1.98	4.41	5.45	1995	1.29	0.12
1996	8.93	1.61	17.61	23.00	1996	1.54	0.08
1997	22.30	1.01	3.91	9.35	1997	1.00	0.26
1998	13.39	1.31	5.50	13.25	1998	2.10	0.17
1999	26.64	1.90	5.34	2.80	1999	2.05	0.37
2000	3.16	1.77	7.42	16.18	2000	1.56	0.27
2001	22.98	1.07	12.57	14.17	2001	2.16	0.32
2002	12.32	0.52	2.20	3.98	2002	2.53	0.79
2003	17.36	2.42	10.83	22.89	2003	1.19	0.08
2004	8.81	1.13	4.85	12.70	2004	2.41	0.74
2005	8.61	1.21	6.91	9.09	2005	0.64	0.28
2006	3.82	0.68	1.78	10.10	2006	2.02	0.28
2007	35.02	1.42	5.12	11.96	2007	0.58	0.07
2008	13.86	1.11	1.26	7.97	2008	1.24	0.31

Table 8. Age specific and multi-age indices of abundance used in SCA model

	age specific				Multi age				
Year	**NY OHS**	**NJ Trawl**	**MD SSN**	**DE SSN**	**CT Trawl**	**NEFSC**	**MA Comm**	**MRFSS**	**CT CPUE**
1981									
1982									0.91
1983									0.75
1984					0.02				0.92
1985			488.1		0.01				0.89
1986			1006.9		0.01				1.51
1987	3.80		715.0		0.05				1.15
1988	3.60		327.4		0.04			0.36	1.36
1989	2.60	0.23	395.9		0.06			0.22	1.83
1990	3.50	1.13	503.6		0.16			0.21	2.19
1991	3.30	1.41	460.8		0.15	0.23	0.63	0.38	2.15
1992	3.00	0.65	629.0		0.22	0.24	0.68	0.68	2.38
1993	3.30	0.67	625.3		0.27	0.48	0.67	0.55	2.84
1994	2.90	1.47	513.5		0.30	1.39	0.65	0.80	3.94
1995	2.80	4.21	461.8		0.60	0.95	0.77	1.07	5.40
1996	5.10	5.66	759.2	3.38	0.63	0.60	0.87	1.28	7.58
1997	4.80	5.82	387.1	4.10	0.85	1.18	0.81	1.29	5.98
1998	5.00	5.01	478.8	3.73	0.97	0.73	0.84	1.61	7.59
1999	3.50	3.51	396.6	2.59	1.10	0.45	0.74	1.57	5.55
2000	4.40	5.31	352.5	2.05	0.84	1.27	0.85	1.45	6.93
2001	3.50	1.58	282.6	1.88	0.61	0.62	0.88	1.17	8.12
2002	3.20	2.13	400.3	1.60	1.30	0.98	0.86	0.97	6.43
2003	4.20	6.83	455.0	2.47	0.87	0.77	0.83	0.83	6.41
2004	4.90	6.05	610.9	2.89	0.56	0.33	0.94	0.90	8.31
2005	3.90	6.41	500.3	1.77	1.17	0.29	0.83	1.09	13.48
2006	4.40	2.61	505.8	2.22	0.61	0.63	0.87	1.29	14.05
2007		3.50	216.0	1.78	1.02	0.74	0.83	0.67	13.95
2008		1.38	454.0	1.72	0.57	0.65	0.76	0.58	15.73

Table 9. Striped bass average F (ages 8-11, and ages 3-8) and N weighted F estimates (ages 7-11) from the SCA model, and tag based F averaged among models for striped bass 18" or greater from producer areas and fish 28" or greater.

	ages 8-11	ages 3-8	N wt'd ages 7-11	tag coastal ≥ 28"
1982	0.42	0.41	0.42	
1983	0.64	0.63	0.64	
1984	0.28	0.28	0.28	
1985	0.18	0.11	0.16	
1986	0.13	0.08	0.12	
1987	0.07	0.04	0.06	
1988	0.20	0.12	0.18	0.04
1989	0.11	0.07	0.10	0.06
1990	0.11	0.09	0.11	0.10
1991	0.10	0.08	0.10	0.18
1992	0.08	0.06	0.08	0.08
1993	0.10	0.08	0.10	0.13
1994	0.12	0.10	0.12	0.08
1995	0.16	0.13	0.16	0.14
1996	0.19	0.13	0.18	0.18
1997	0.22	0.16	0.22	0.20
1998	0.18	0.13	0.18	0.25
1999	0.15	0.11	0.15	0.21
2000	0.20	0.14	0.19	0.14
2001	0.18	0.12	0.17	0.14
2002	0.16	0.11	0.16	0.14
2003	0.20	0.14	0.20	0.19
2004	0.23	0.16	0.22	0.24
2005	0.24	0.17	0.23	0.19
2006	0.26	0.18	0.25	0.17
2007	0.22	0.16	0.22	0.17
2008	0.21	0.15	0.20	0.20

Tag estimates by producer area

	Fish 18" >			Fish ≥ 28"		
	Hudson	Delaware	Chesapeake	Hudson	Delaware	Chesapeake
1987			0.01			0.02
1988	0.04		0.01	0.64		0.05
1989	0.05		0.01	0.28		0.03
1990	0.09		0.14	0.14		0.17
1991	0.11		0.30	0.10		0.18
1992	0.11		0.19	0.05		0.18
1993	0.12	0.15	0.19	0.11	0.14	0.20
1994	0.12	0.11	0.21	0.08	0.13	0.19
1995	0.16	0.16	0.22	0.10	0.21	0.29
1996	0.18	0.19	0.21	0.12	0.33	0.25
1997	0.20	0.18	0.27	0.07	0.31	0.31
1998	0.19	0.19	0.33	0.10	0.32	0.31
1999	0.18	0.17	0.33	0.10	0.27	0.28
2000	0.13	0.21	0.30	0.14	0.30	0.21
2001	0.13	0.22	0.28	0.16	0.30	0.19
2002	0.12	0.21	0.22	0.19	0.28	0.20
2003	0.15	0.31	0.18	0.19	0.25	0.23
2004	0.17	0.34	0.30	0.16	0.31	0.20
2005	0.15	0.27	0.26	0.16	0.26	0.22
2006	0.16	0.29	0.27	0.14	0.30	0.23
2007	0.16	0.28	0.25	0.14	0.25	0.20
2008	0.15	0.27	0.23	0.18	0.15	0.20

Table 10. Striped bass population abundance 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	2,175	1,816	1,821	1,565	506	228	173	122	95	95	86	116	74	8,873	589
1983	4,730	1,869	1,262	1,066	891	287	129	98	69	54	54	49	108	10,667	432
1984	4,069	4,061	1,157	600	486	403	130	58	44	31	24	24	71	11,160	254
1985	4,047	3,498	3,023	767	390	315	262	84	38	29	20	16	62	12,552	249
1986	3,676	3,477	2,976	2,512	616	303	238	193	61	27	21	15	55	14,171	373
1987	4,850	3,160	2,968	2,497	2,056	492	237	183	147	46	21	16	53	16,724	465
1988	5,800	4,171	2,707	2,519	2,092	1,699	402	192	147	118	37	16	54	19,957	566
1989	6,740	4,982	3,545	2,242	2,010	1,607	1,266	293	138	105	83	26	50	23,086	694
1990	9,606	5,794	4,257	2,984	1,847	1,621	1,273	989	227	106	80	64	58	28,905	1,523
1991	7,934	8,264	4,929	3,509	2,384	1,449	1,260	985	764	175	82	62	94	31,890	2,162
1992	8,306	6,825	7,035	4,073	2,815	1,880	1,132	981	766	594	136	64	121	34,728	2,662
1993	10,724	7,147	5,824	5,865	3,319	2,263	1,501	902	780	609	472	108	147	39,659	3,017
1994	21,166	9,226	6,083	4,811	4,703	2,614	1,767	1,168	700	606	472	366	198	53,880	3,510
1995	13,684	18,208	7,841	4,996	3,820	3,660	2,015	1,356	894	536	463	361	431	58,265	4,042
1996	15,588	11,769	15,400	6,324	3,846	2,859	2,702	1,479	993	654	392	339	579	62,924	4,436
1997	17,823	13,387	9,958	12,583	4,951	2,903	2,105	1,959	1,063	710	466	279	653	68,842	5,131
1998	10,849	15,300	11,288	8,050	9,660	3,638	2,070	1,473	1,357	731	487	319	638	65,860	5,005
1999	10,598	9,318	12,948	9,227	6,307	7,301	2,682	1,503	1,060	972	522	347	682	63,468	5,087
2000	8,201	9,106	7,908	10,678	7,346	4,874	5,527	2,005	1,115	784	716	385	757	59,403	5,762
2001	13,603	7,042	7,695	6,436	8,298	5,490	3,546	3,955	1,421	786	551	503	801	60,126	8,016
2002	16,207	11,684	5,964	6,303	5,061	6,305	4,073	2,592	2,867	1,025	566	396	936	63,979	8,381
2003	9,435	13,923	9,908	4,905	4,993	3,884	4,734	3,017	1,905	2,098	748	412	970	60,934	9,151
2004	22,707	8,102	11,761	8,054	3,804	3,721	2,816	3,374	2,130	1,337	1,468	523	965	70,761	9,797
2005	10,020	19,493	6,830	9,502	6,177	2,791	2,649	1,967	2,332	1,463	916	1,003	1,016	66,158	8,696
2006	7,377	8,601	16,413	5,498	7,239	4,491	1,965	1,828	1,342	1,581	988	617	1,360	59,300	7,717
2007	5,769	6,330	7,228	13,136	4,145	5,187	3,108	1,331	1,223	891	1,046	652	1,304	51,350	6,447
2008	13,282	4,953	5,337	5,842	10,083	3,045	3,697	2,174	921	841	611	716	1,338	52,839	6,601

Table 11. Striped bass population 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	137	959	1,770	1,942	1,051	851	794	694	515	788	950	1,280	1,046	12,779
1983	546	500	979	1,303	1,702	811	485	500	409	382	493	518	1,202	9,828
1984	613	1,407	1,115	740	929	1,144	531	270	268	214	201	269	880	8,580
1985	79	1,339	2,423	1,285	735	976	1,068	444	234	205	170	150	862	9,968
1986	219	643	2,620	4,026	1,240	792	895	963	335	176	157	132	709	12,905
1987	455	1,037	2,660	4,087	5,036	1,310	795	791	777	276	142	135	691	18,193
1988	1,099	1,780	2,492	4,209	5,367	5,388	1,435	791	735	659	278	148	722	25,101
1989	457	2,527	3,735	3,511	4,949	6,043	5,880	1,528	733	705	591	239	664	31,563
1990	227	2,186	4,141	4,719	4,229	5,549	6,003	5,595	1,350	636	645	575	730	36,585
1991	919	2,242	5,282	5,519	5,525	3,954	5,407	5,185	4,742	1,043	614	487	1,337	42,255
1992	301	2,598	7,723	6,426	6,952	5,828	4,463	5,177	4,800	4,309	1,061	689	1,692	52,021
1993	194	1,970	5,537	9,470	7,673	7,177	6,299	4,933	4,977	4,546	4,159	1,107	2,134	60,176
1994	2,974	2,501	6,894	8,185	11,200	8,140	7,432	6,370	4,514	4,406	4,171	3,696	2,515	72,998
1995	1,979	7,463	9,335	9,590	9,451	11,803	8,742	7,480	6,004	4,160	3,498	3,517	7,184	90,206
1996	1,037	6,381	15,622	11,192	10,205	10,117	13,052	9,147	6,887	5,350	3,559	2,961	7,938	103,448
1997	952	3,944	11,085	23,929	12,641	9,956	9,506	11,153	7,351	6,008	4,461	2,724	9,653	113,363
1998	2,785	4,841	9,736	11,130	22,726	10,474	8,553	7,444	7,977	5,031	4,108	3,163	7,568	105,537
1999	6,977	5,520	11,971	12,130	11,094	17,351	8,445	7,301	6,462	7,109	4,083	3,022	8,169	109,632
2000	2,994	5,317	7,868	13,547	12,342	11,251	17,271	8,292	6,670	5,449	6,251	3,709	10,262	111,223
2001	1,564	2,641	6,039	8,929	14,855	13,857	12,021	17,476	8,084	5,851	4,397	4,507	8,702	108,923
2002	870	2,602	3,785	8,197	9,886	16,688	15,031	12,317	15,773	7,108	4,761	3,634	10,779	111,431
2003	519	3,736	5,516	5,975	9,101	10,259	17,066	14,084	11,016	13,824	5,999	3,813	10,670	111,578
2004	3,234	1,472	8,349	9,529	7,016	9,733	10,249	15,535	11,965	8,814	11,267	4,581	10,335	112,079
2005	448	7,241	3,923	11,016	10,840	7,783	9,342	9,472	13,202	9,329	6,910	8,560	11,884	109,951
2006	984	1,923	11,372	6,269	12,950	11,146	7,118	8,094	7,910	10,415	7,280	5,238	15,094	105,792
2007	366	1,899	5,034	13,853	6,815	12,875	10,348	6,050	6,985	6,215	8,470	5,927	17,080	101,916
2008	5,987	1,125	3,526	7,000	17,791	8,203	14,142	10,201	5,231	6,242	5,143	6,778	16,920	108,289

Table 12. 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	37	71	227	471	482	414	662	823	1,133	955	5,276
1983	0	0	0	24	113	212	281	340	321	314	418	448	1,072	3,542
1984	0	0	0	14	64	309	319	190	218	182	177	242	814	2,529
1985	0	0	0	25	51	268	650	316	193	176	151	136	805	2,772
1986	0	0	0	79	87	218	547	689	277	152	140	120	666	2,975
1987	0	0	0	81	354	363	488	570	647	240	127	124	653	3,646
1988	0	0	0	83	374	1,478	873	563	604	565	246	134	673	5,593
1989	0	0	0	69	347	1,668	3,601	1,096	607	611	528	218	624	9,369
1990	0	0	0	93	295	1,529	3,672	4,011	1,118	551	577	525	687	13,059
1991	0	0	0	108	386	1,090	3,310	3,719	3,931	904	550	445	1,259	15,703
1992	0	0	0	127	487	1,610	2,738	3,722	3,988	3,743	952	631	1,597	19,595
1993	0	0	0	186	536	1,979	3,856	3,538	4,125	3,939	3,721	1,011	2,010	24,902
1994	0	0	0	161	782	2,241	4,543	4,562	3,736	3,812	3,727	3,372	2,366	29,302
1995	0	0	0	188	657	3,236	5,320	5,333	4,947	3,584	3,111	3,194	6,726	36,297
1996	0	0	0	219	710	2,773	7,933	6,509	5,662	4,597	3,157	2,682	7,412	41,655
1997	0	0	0	468	877	2,720	5,757	7,908	6,021	5,143	3,942	2,458	8,978	44,272
1998	0	0	0	218	1,582	2,871	5,199	5,299	6,559	4,323	3,645	2,866	7,068	39,630
1999	0	0	0	238	774	4,768	5,148	5,212	5,330	6,129	3,634	2,747	7,654	41,634
2000	0	0	0	265	858	3,080	10,483	5,893	5,476	4,675	5,537	3,355	9,568	49,190
2001	0	0	0	175	1,035	3,801	7,313	12,448	6,652	5,032	3,904	4,086	8,133	52,579
2002	0	0	0	161	689	4,582	9,156	8,786	12,997	6,122	4,233	3,299	10,089	60,115
2003	0	0	0	117	633	2,807	10,355	10,006	9,040	11,856	5,312	3,447	9,944	63,516
2004	0	0	0	186	487	2,658	6,206	11,012	9,797	7,543	9,955	4,132	9,611	61,588
2005	0	0	0	215	752	2,124	5,650	6,706	10,796	7,973	6,097	7,711	11,036	59,059
2006	0	0	0	122	897	3,036	4,297	5,719	6,455	8,882	6,410	4,709	13,988	54,514
2007	0	0	0	271	473	3,517	6,267	4,289	5,720	5,320	7,485	5,347	15,886	54,574
2008	0	0	0	137	1,236	2,243	8,575	7,241	4,289	5,349	4,550	6,123	15,756	55,500

Table 13. 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).

Assessment Result	Source of Uncertainty: 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 2009

A forward-projecting age-structured statistical catch-at-age (SCA) model for the Atlantic coast migratory stocks of striped bass was constructed and is used to estimate fishing mortality, abundance, and spawning stock biomass during 1982-2008 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 1982-2008 since complete catch data are only available back to 1982. However, there are relative abundance data (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:

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

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:

$$P_{rdev} = \lambda_R \sum_y e_y^2 \qquad (4)$$

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 $F_{1982,a-1}$:

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

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

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

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:

$$\hat{F}_y = \hat{\bar{F}} \cdot exp^{d_y} \qquad (7)$$

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:

$$P_{fdev} = \lambda_F \sum_y d_y^2 \qquad (8)$$

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:

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

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

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

where α and β are estimates. Selectivity patterns are estimated for 4 periods: 1982-1984, 1985-1989, 1990-1995, and 1996-2008. 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

$$\hat{C}_y = \sum_a \hat{C}_{y,a} \quad (15)$$

Predicted Proportions of Catch-At-Age

$$\hat{P}_{y,a} = \frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \quad (16)$$

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

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

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

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

where n_y is the effective number of fish aged in year y and $P_{y,a}$ is the observed proportion of catch-at-age. 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 374 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 yearlings indices from New York (Hudson River YOY: 1980-2008; West Long Island Sound Age 1: 1986-2008), New Jersey (Delaware Bay YOY: 1981-2006), Maryland (Chesapeake Bay YOY and Age 1: 1970-2008), and Virginia (Chesapeake Bay YOY: 1983-2008) 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 qs 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: 1988-2006), Connecticut (Recreational CPUE: 1982-2006 ;bottom trawl survey: 1984-2006), and Northeast Fisheries Science Center (NEFSC spring bottom trawl survey: 1991-2006) 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 arithmetic means of the survey. 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: 1989-2008), Maryland (gillnet: 1985-2008), and Delaware (electrofishing: 1996-2008) 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

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

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

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

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

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

and predicted age composition is calculated as

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

The age composition negative log-likelihood for survey t is

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

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. Used as starting values, the average effective sample size for each survey was calculated by using methods in Pennington and Volstad (1994) and Pennington et al. (2002). In essence, effective sample size was estimated by first calculating the length sample variance using the simple random sampling equation and dividing into it the cluster sampling variance of mean length derived through bootstrapping, assuming each seine/trawl haul, gillnet set, or electrofishing run was the sampling unit. The average of the annual effective sample sizes was used as starting values in each survey multinomial error distribution.

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

$$r_{t,y} = \frac{\log I_{t,y} - \log \hat{I}_{t,y}}{\sqrt{\frac{\sum_{y=1}^{n_y} (\log I_{t,y} - \log \hat{I}_{t,y})^2}{n_t - 1}}} \quad (28)$$

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

$$r_{y,a} = \frac{P_{y,a} - \hat{P}_{y,a}}{\sqrt{\frac{\hat{P}_{y,a}(1-\hat{P}_{y,a})}{\hat{n}_y}}} \quad (29)$$

where n_y is the effective sample size. In addition, predicted average effective sample size for the catch and survey age composition data were compared to the observed starting values used in the model. Predicted average effective sample size ($\hat{\bar{t}}$) is calculated following McAllister and Ianelli (1997):

$$\hat{\bar{t}} = \frac{\sum_y \hat{t}_y}{d_y} \quad (30)$$

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 21, 56, 75, and 87, respectively.

The total log-likelihood of the model is

$$f = -L_l - L_p - L^U_{NYOHS} - L^U_{NTrawl} - L^U_{NYOHS} - L^U_{MDSSN} + P_{rdev} + P_{fdev} + P_{fadd} \quad (31)$$

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 1.3 and were selected based on trial-and-error.

Current Configuration

Based on the 2007 analyses and recommendations from the ASMFC's striped bass stock assessment and technical committees, the model contains four catch selectivity periods (using the Gompertz function), the total catch lambda weight=10, and all indices (except Massachusetts commercial index) and all survey selectivity functions. Initial starting values for all parameters are given in Table 1.2; there were 98 parameters estimated in the model.

Results

Resulting contributions to total likelihood are listed in Table 1.3. The converged total likelihood was 30,976. 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 2008 was 0.22 (Table 1.4). The 2008 average fishing mortality rate (F) for ages 8 through 11 equaled 0.21 (95% CI: 0.16-0.27) and is below the current target (0.30) but is not over the threshold (0.34). Average fishing mortality on ages 3-8, which are generally targeted in producer areas, was 0.15 (Table 1.5; Figure 1.3). Among the individual age groups, the highest values of F in 2008 (0.21-0.22) 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 2008 F weighted by N for ages 7-11 (age 7 to compare with tagged fish >28") was 0.20 (Table 1.5; Figure 1.3). 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 1.3).

Comparison of fishing mortality estimates between the 2007 and 2009 model runs indicated that fishing mortality for 2006 was over-estimated (Figure 1.4).

Population Abundance (January 1)

Striped bass abundance (1+) increased steadily from 1982 through 1997 when it first peaked around 68 million fish (Table 1.7, Figure 1.2). Total abundance declined through 2000, increased and peaked in 2004 at 70 million fish, and has since declined (Table 1.7; Figure 1.2). The 2003 cohort remained strong at 10 million fish in 2008 (ages 5) and exceeded the sizes of the strong 1993 and 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 6.4 million fish in 2007 (Table 1.7, Figure 1.2). Abundance of 8+ fish increased slightly in 2008 (Table 1.7; Figure 1.2). Projection of the current age-class abundances through 2015, assuming 2008 F and selectivity pattern, shows age 8+ abundance increasing through 2011 but then declining through 2014 (Figure 1.5A). A second projection trend for ages 8-12 (age 13+ abundance is over-estimated by the current model structure) shows similar trends (Figure 1.5A).

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 has remained at about 109 thousand mt (Figure 1.6). Female SSB grew steadily from 1982 through 2003 when it peaked at about 63 thousand mt (Table 1.8, Figure 1.6). Female SSB declined through 2006 but has increased slightly to 55 thousand mt (95% CI: 41,666-70,754 mt) in 2008. The estimated SSB in 2008 remained above the 1995 threshold level of 36 thousand mt and indicates that the population is not overfished. Projection of the spawning stock biomass through 2011, assuming 2008 F, selectivity pattern, and weight-at-age, shows spawning stock biomass increasing through 2011 (Figure 1.5B). A second progression trend for ages 8-12 (age 13+ abundance is over-estimated by the current model structure) shows a weaker increase in spawning stock biomass (Figure 1.5B).

Retrospective Analysis

Retrospective bias was evident in estimates of fully-recruited F, SSB, and age 8+ abundance of SCA (Figure 1.7). The retrospective pattern results in an over-estimation of fishing mortality and an under-estimation of abundance. This pattern suggests that the 2008 F estimate is likely over-estimated and could decrease with the addition of future years of data. Similar retrospective trends have been observed in the previous assessment of striped bass using the ADAPT VPA (ASMFC

2005). 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).

Alternate Model Structure

Based on recommendations from the 2007 SAW review committee, the 2007 model structure was altered in an attempt to correct the over-estimation of 13+ abundance (see Appendix 1, Figure 1). To correct the over-estimation, two addition selectivity periods were required. These periods were determined by trial-and-error comparison of likelihoods using the Thompson's exponential-logistic model (3 parameter model) to determine to appropriate shape. The 6 periods are as follows: 1982-1984, 1985-1986, 1987-1990, 1991-1994, 1995-2002, and 2003-2008.. Dome-shaped selectivity patterns were required for 1982-1984 and 1985-1986, and flat-topped selectivity patterns for the remaining periods (Appendix 2 Figure 1). Any flat-top selectivity functions estimated by using the Thompson function were replaced with a Gompertz function to reduce the number of parameters used in the model fit. Exploratory analyses revealed that a separate 13+ selectivity parameter was required during 1995-2008 (Appendix 2 Figure 1). A residual plot for the catch age composition showed that the model fit the age 13+ proportions well (Appendix 2 Figure 2). Estimates of fully-recruited fishing mortality from this new model structure were slightly lower than the current estimates of fully-recruited fishing mortality (Figure 1.8).

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	2-11
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 Components

                        Weight   RSS
 Total Catch        :    10     467.174
 YOY/Yearl Surveys
   NY YOY          :     1      1859.87
   NJ YOY          :     1      240.443
   MD YOY          :     1      566.982
   VA YOY          :     1      1561.34
   NY Age 1         :    1      136.263
   MD Age 1         :    1      266.683
 Aggregate Surveys
   MRFSS           :     1       58.245
   CT REC CPUE        :  1      106.369
   NEFSC           :     1      101.817
   CT Trawl         :    1      201.383
 Age Survey Indices
   NY OHS          :     1       827.28
   NJ Trawl         :    1      101.729
   MD SSN          :     1      236.448
   DE SSN          :     1      106.815

 Total RSS                      6838.84
 No. of Obs                         379
 Conc. Likelihood               548.193

 Catch Age Comps    :    1        21749
 Survey Age Comps
   NY OHS          :     1      1873.25
   NJ Trawl         :    1      788.161
   MD SSN          :     1      3499.33
   DE SSN          :     1      2492.78

Recr Devs           :    1      19.4567
F Devs              :    1      5.85305

Total Likelihood    :             30976
```

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

Year	F	SD	CV
1982	0.42	0.030	0.07
1983	0.64	0.208	0.32
1984	0.28	0.068	0.24
1985	0.19	0.041	0.22
1986	0.14	0.035	0.25
1987	0.07	0.015	0.21
1988	0.21	0.087	0.42
1989	0.12	0.030	0.25
1990	0.11	0.013	0.12
1991	0.10	0.014	0.14
1992	0.08	0.008	0.10
1993	0.10	0.011	0.11
1994	0.12	0.011	0.09
1995	0.16	0.013	0.08
1996	0.19	0.015	0.08
1997	0.23	0.016	0.07
1998	0.19	0.014	0.07
1999	0.16	0.011	0.07
2000	0.21	0.014	0.07
2001	0.18	0.011	0.06
2002	0.17	0.011	0.06
2003	0.21	0.016	0.07
2004	0.23	0.018	0.08
2005	0.25	0.020	0.08
2006	0.27	0.024	0.09
2007	0.23	0.023	0.10
2008	0.22	0.024	0.11

Catch Selectivity Parameters

	Estimate	SD	CV
1982-1984			
α	1.81	0.043	0.02
β	2.12	0.132	0.06
1985-1989			
α	4.04	0.206	0.05
β	0.51	0.034	0.07
1990-1995			
α	2.91	0.084	0.03
β	0.88	0.054	0.06
1996-2008			
α	3.43	0.086	0.03
β	0.62	0.027	0.04

Survey Selecitvity Parameters

	Estimate	SD	CV
NYOHS			
γ	0.93	0.026	0.03
α	-3.81	1.165	0.31
β	2.32	0.129	0.06
NJ Trawl			
α	1.46	0.409	0.28
β	0.35	0.092	0.27
DESSN			
α	3.11	0.133	0.04
β	0.79	0.097	0.12
MDSSN			
s_2	0.29	0.024	0.08

Year	R	SD	CV
1970	1.51E+07	5.59E+06	0.37
1971	3.09E+07	9.94E+06	0.32
1972	1.30E+07	4.12E+06	0.32
1973	8.16E+06	2.39E+06	0.29
1974	4.61E+06	1.29E+06	0.28
1975	3.36E+06	8.37E+05	0.25
1976	2.70E+06	5.63E+05	0.21
1977	2.01E+06	3.80E+05	0.19
1978	2.54E+06	3.97E+05	0.16
1979	4.47E+06	6.26E+05	0.14
1980	3.05E+06	4.48E+05	0.15
1981	2.11E+06	3.21E+05	0.15
1982	2.18E+06	2.35E+05	0.11
1983	4.73E+06	3.37E+05	0.07
1984	4.07E+06	2.70E+05	0.07
1985	4.05E+06	2.51E+05	0.06
1986	3.68E+06	2.22E+05	0.06
1987	4.85E+06	2.64E+05	0.05
1988	5.80E+06	2.97E+05	0.05
1989	6.74E+06	3.36E+05	0.05
1990	9.61E+06	4.38E+05	0.05
1991	7.93E+06	3.97E+05	0.05
1992	8.31E+06	4.24E+05	0.05
1993	1.07E+07	5.07E+05	0.05
1994	2.12E+07	8.00E+05	0.04
1995	1.37E+07	6.17E+05	0.05
1996	1.56E+07	6.94E+05	0.04
1997	1.78E+07	7.77E+05	0.04
1998	1.08E+07	5.77E+05	0.05
1999	1.06E+07	5.87E+05	0.06
2000	8.20E+06	5.28E+05	0.06
2001	1.36E+07	8.03E+05	0.06
2002	1.62E+07	1.02E+06	0.06
2003	9.44E+06	7.51E+05	0.08
2004	2.27E+07	1.73E+06	0.08
2005	1.00E+07	9.64E+05	0.10
2006	7.38E+06	8.87E+05	0.12
2007	5.77E+06	7.82E+05	0.14
2008	1.33E+07	1.98E+06	0.15

Catchability Coefficients

	Estimate	SD	CV
NY YOY	1.25E-06	1.03E-07	0.08
NJ YOY	9.89E-08	1.13E-08	0.11
MD YOY	4.36E-07	4.74E-08	0.11
VA YOY	1.00E-06	5.64E-08	0.06
NY Age 1	1.44E-07	2.63E-08	0.18
MD Age 1	3.61E-08	6.13E-09	0.17
MRFSS	3.45E-08	5.01E-09	0.15
CTCPUE	1.65E-07	2.74E-08	0.17
NEFSC	1.76E-08	3.39E-09	0.19
CT Trawl	1.68E-08	2.08E-09	0.12
NYOHS	2.31E-07	1.84E-08	0.08
NJ Trawl	1.15E-07	2.05E-08	0.18
MD SSN	1.93E-07	4.24E-08	0.22
DE SSN	1.04E-07	1.74E-08	0.17

Tabl;e 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	0.42	0.41	0.42	0.40
1983	0.64	0.63	0.64	0.62
1984	0.28	0.28	0.28	0.27
1985	0.18	0.11	0.16	0.06
1986	0.13	0.08	0.12	0.05
1987	0.07	0.04	0.06	0.03
1988	0.20	0.12	0.18	0.09
1989	0.11	0.07	0.10	0.05
1990	0.11	0.09	0.11	0.08
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	0.12	0.10	0.12	0.08
1995	0.16	0.13	0.16	0.11
1996	0.19	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	0.24	0.17	0.23	0.14
2006	0.26	0.18	0.25	0.14
2007	0.22	0.16	0.22	0.13
2008	0.21	0.15	0.20	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	0.21	0.39	0.41	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
1983	0.00	0.33	0.59	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
1984	0.00	0.15	0.26	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
1985	0.00	0.01	0.04	0.07	0.10	0.13	0.15	0.17	0.18	0.18	0.19	0.19	0.19
1986	0.00	0.01	0.03	0.05	0.08	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.14
1987	0.00	0.00	0.01	0.03	0.04	0.05	0.06	0.07	0.07	0.07	0.07	0.07	0.07
1988	0.00	0.01	0.04	0.08	0.11	0.14	0.17	0.18	0.19	0.20	0.20	0.21	0.21
1989	0.00	0.01	0.02	0.04	0.07	0.08	0.10	0.11	0.11	0.12	0.12	0.12	0.12
1990	0.00	0.01	0.04	0.07	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1991	0.00	0.01	0.04	0.07	0.09	0.10	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	0.08	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	0.10	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	0.12	0.12	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	0.19	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	0.15	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	0.18	0.19	0.20	0.20	0.20	0.21	0.21
2001	0.00	0.02	0.05	0.09	0.12	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	0.11	0.14	0.15	0.16	0.16	0.16	0.17	0.17	0.17
2003	0.00	0.02	0.06	0.10	0.14	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	0.12	0.17	0.20	0.22	0.23	0.24	0.24	0.24	0.25	0.25
2006	0.00	0.02	0.07	0.13	0.18	0.22	0.24	0.25	0.26	0.26	0.27	0.27	0.27
2007	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
2008	0.00	0.02	0.06	0.11	0.15	0.18	0.20	0.21	0.21	0.21	0.22	0.22	0.22

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	2,175	1,816	1,821	1,565	506	228	173	122	95	95	86	116	74	8,873	589
1983	4,730	1,869	1,262	1,066	891	287	129	98	69	54	54	49	108	10,667	432
1984	4,069	4,061	1,157	600	486	403	130	58	44	31	24	24	71	11,160	254
1985	4,047	3,498	3,023	767	390	315	262	84	38	29	20	16	62	12,552	249
1986	3,676	3,477	2,976	2,512	616	303	238	193	61	27	21	15	55	14,171	373
1987	4,850	3,160	2,968	2,497	2,056	492	237	183	147	46	21	16	53	16,724	465
1988	5,800	4,171	2,707	2,519	2,092	1,699	402	192	147	118	37	16	54	19,957	566
1989	6,740	4,982	3,545	2,242	2,010	1,607	1,266	293	138	105	83	26	50	23,086	694
1990	9,606	5,794	4,257	2,984	1,847	1,621	1,273	989	227	106	80	64	58	28,905	1,523
1991	7,934	8,264	4,929	3,509	2,384	1,449	1,260	985	764	175	82	62	94	31,890	2,162
1992	8,306	6,825	7,035	4,073	2,815	1,880	1,132	981	766	594	136	64	121	34,728	2,662
1993	10,724	7,147	5,824	5,865	3,319	2,263	1,501	902	780	609	472	108	147	39,659	3,017
1994	21,166	9,226	6,083	4,811	4,703	2,614	1,767	1,168	700	606	472	366	198	53,880	3,510
1995	13,684	18,208	7,841	4,996	3,820	3,660	2,015	1,356	894	536	463	361	431	58,265	4,042
1996	15,588	11,769	15,400	6,324	3,846	2,859	2,702	1,479	993	654	392	339	579	62,924	4,436
1997	17,823	13,387	9,958	12,583	4,951	2,903	2,105	1,959	1,063	710	466	279	653	68,842	5,131
1998	10,849	15,300	11,288	8,050	9,660	3,638	2,070	1,473	1,357	731	487	319	638	65,860	5,005
1999	10,598	9,318	12,948	9,227	6,307	7,301	2,682	1,503	1,060	972	522	347	682	63,468	5,087
2000	8,201	9,106	7,908	10,678	7,346	4,874	5,527	2,005	1,115	784	716	385	757	59,403	5,762
2001	13,603	7,042	7,695	6,436	8,298	5,490	3,546	3,955	1,421	786	551	503	801	60,126	8,016
2002	16,207	11,684	5,964	6,303	5,061	6,305	4,073	2,592	2,867	1,025	566	396	936	63,979	8,381
2003	9,435	13,923	9,908	4,905	4,993	3,884	4,734	3,017	1,905	2,098	748	412	970	60,934	9,151
2004	22,707	8,102	11,761	8,054	3,804	3,721	2,816	3,374	2,130	1,337	1,468	523	965	70,761	9,797
2005	10,020	19,493	6,830	9,502	6,177	2,791	2,649	1,967	2,332	1,463	916	1,003	1,016	66,158	8,696
2006	7,377	8,601	16,413	5,498	7,239	4,491	1,965	1,828	1,342	1,581	988	617	1,360	59,300	7,717
2007	5,769	6,330	7,228	13,136	4,145	5,187	3,108	1,331	1,223	891	1,046	652	1,304	51,350	6,447
2008	13,282	4,953	5,337	5,842	10,083	3,045	3,697	2,174	921	841	611	716	1,338	52,839	6,601

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	37	71	227	471	482	414	662	823	1,133	955	5,276
1983	0	0	0	24	113	212	281	340	321	314	418	448	1,072	3,542
1984	0	0	0	14	64	309	319	190	218	182	177	242	814	2,529
1985	0	0	0	25	51	268	650	316	193	176	151	136	805	2,772
1986	0	0	0	79	87	218	547	689	277	152	140	120	666	2,975
1987	0	0	0	81	354	363	488	570	647	240	127	124	653	3,646
1988	0	0	0	83	374	1,478	873	563	604	565	246	134	673	5,593
1989	0	0	0	69	347	1,668	3,601	1,096	607	611	528	218	624	9,369
1990	0	0	0	93	295	1,529	3,672	4,011	1,118	551	577	525	687	13,059
1991	0	0	0	108	386	1,090	3,310	3,719	3,931	904	550	445	1,259	15,703
1992	0	0	0	127	487	1,610	2,738	3,722	3,988	3,743	952	631	1,597	19,595
1993	0	0	0	186	536	1,979	3,856	3,538	4,125	3,939	3,721	1,011	2,010	24,902
1994	0	0	0	161	782	2,241	4,543	4,562	3,736	3,812	3,727	3,372	2,366	29,302
1995	0	0	0	188	657	3,236	5,320	5,333	4,947	3,584	3,111	3,194	6,726	36,297
1996	0	0	0	219	710	2,773	7,933	6,509	5,662	4,597	3,157	2,682	7,412	41,655
1997	0	0	0	468	877	2,720	5,757	7,908	6,021	5,143	3,942	2,458	8,978	44,272
1998	0	0	0	218	1,582	2,871	5,199	5,299	6,559	4,323	3,645	2,866	7,068	39,630
1999	0	0	0	238	774	4,768	5,148	5,212	5,330	6,129	3,634	2,747	7,654	41,634
2000	0	0	0	265	858	3,080	10,483	5,893	5,476	4,675	5,537	3,355	9,568	49,190
2001	0	0	0	175	1,035	3,801	7,313	12,448	6,652	5,032	3,904	4,086	8,133	52,579
2002	0	0	0	161	689	4,582	9,156	8,786	12,997	6,122	4,233	3,299	10,089	60,115
2003	0	0	0	117	633	2,807	10,355	10,006	9,040	11,856	5,312	3,447	9,944	63,516
2004	0	0	0	186	487	2,658	6,206	11,012	9,797	7,543	9,955	4,132	9,611	61,588
2005	0	0	0	215	752	2,124	5,650	6,706	10,796	7,973	6,097	7,711	11,036	59,059
2006	0	0	0	122	897	3,036	4,297	5,719	6,455	8,882	6,410	4,709	13,988	54,514
2007	0	0	0	271	473	3,517	6,267	4,289	5,720	5,320	7,485	5,347	15,886	54,574
2008	0	0	0	137	1,236	2,243	8,575	7,241	4,289	5,349	4,550	6,123	15,756	55,500

Figure 1.1. Schematic of population abundance-at-age

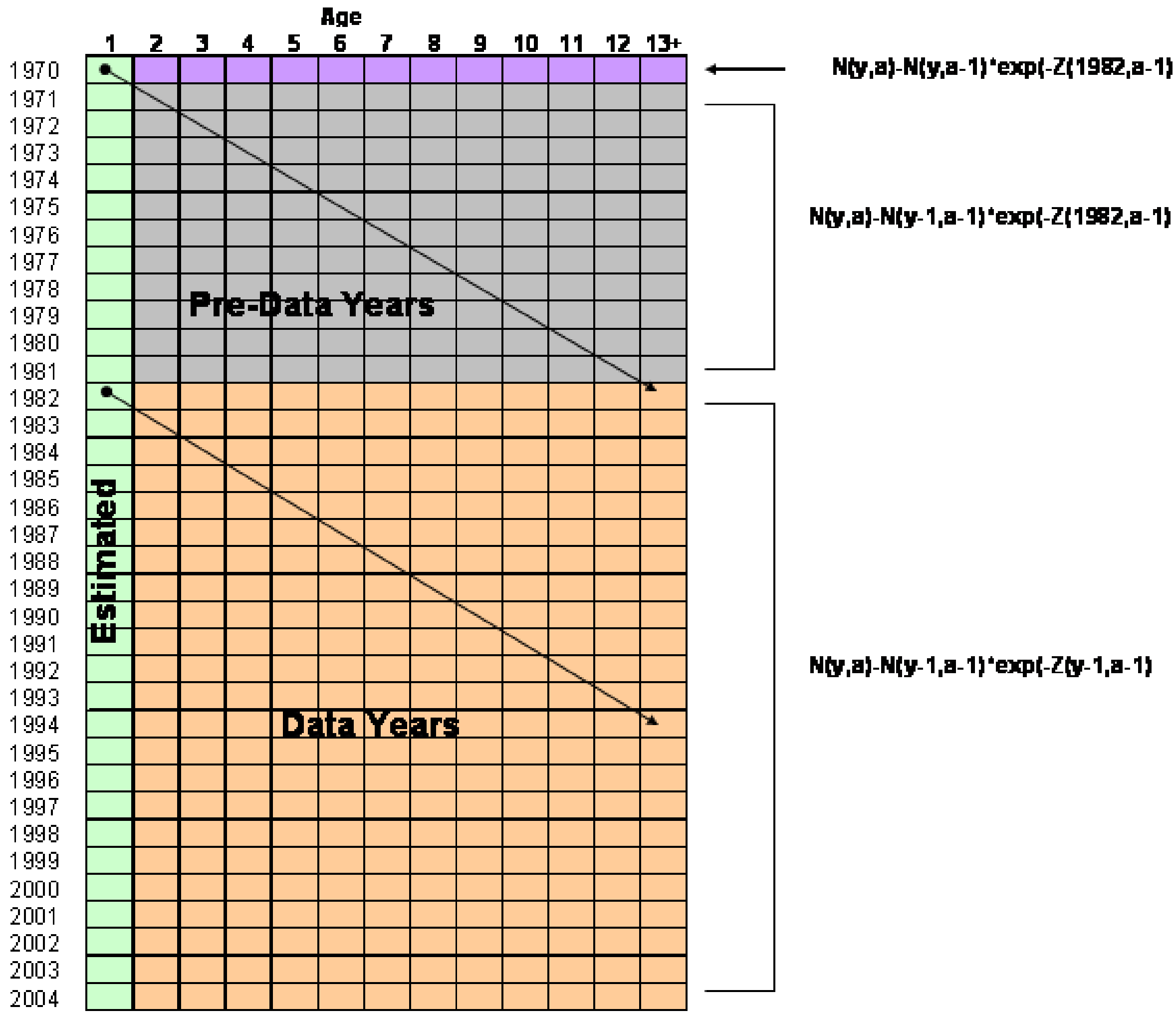


Figure 1.2. Estimates of fishing mortality (±95%CI), recruitment (±95%CI), total landings, period selectivity patterns, and abundance of ages 1+ and 8+ from the SCA model.

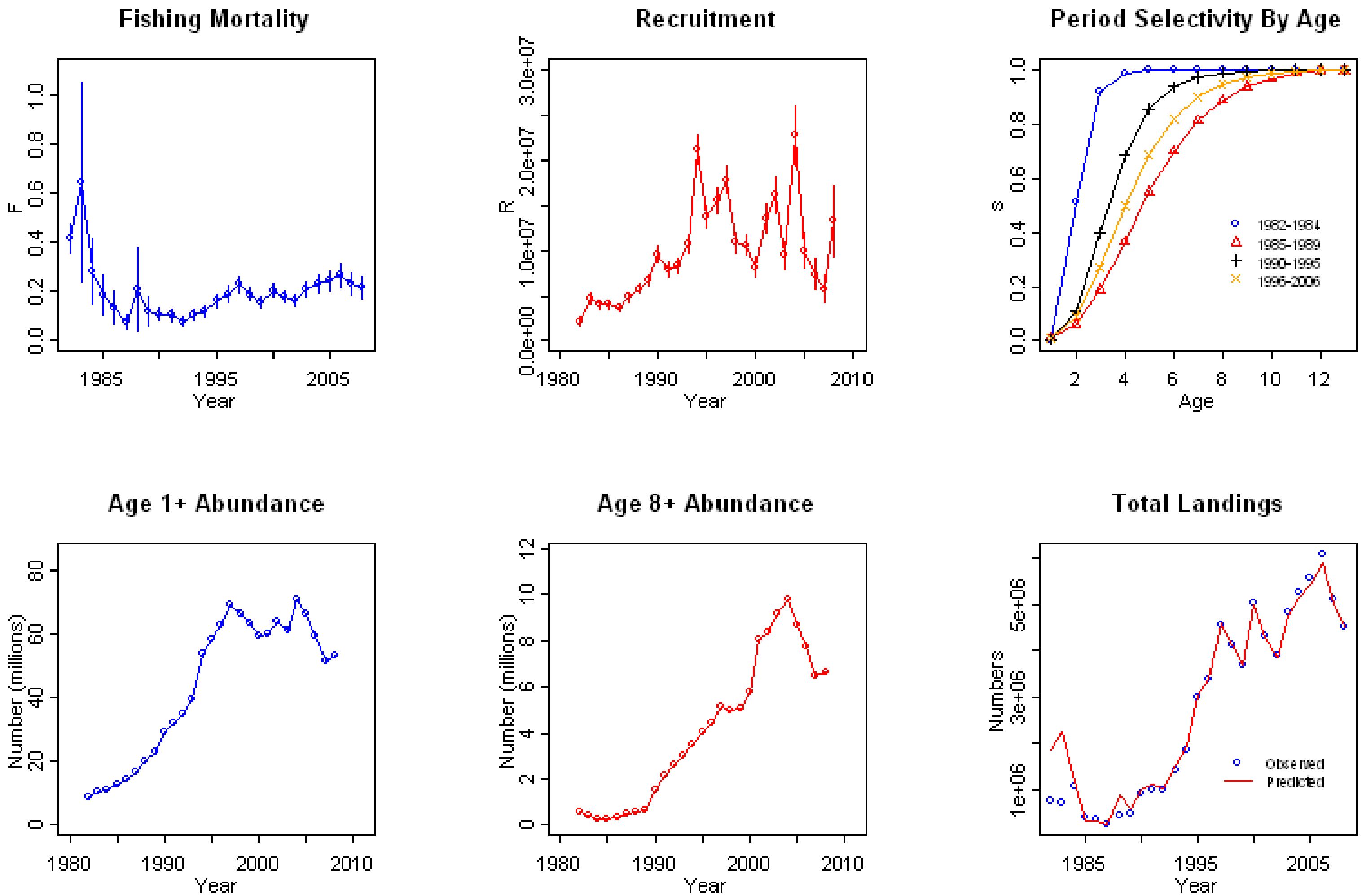


Figure 1.3. Comparison of fishing mortality estimates from the SCA model.

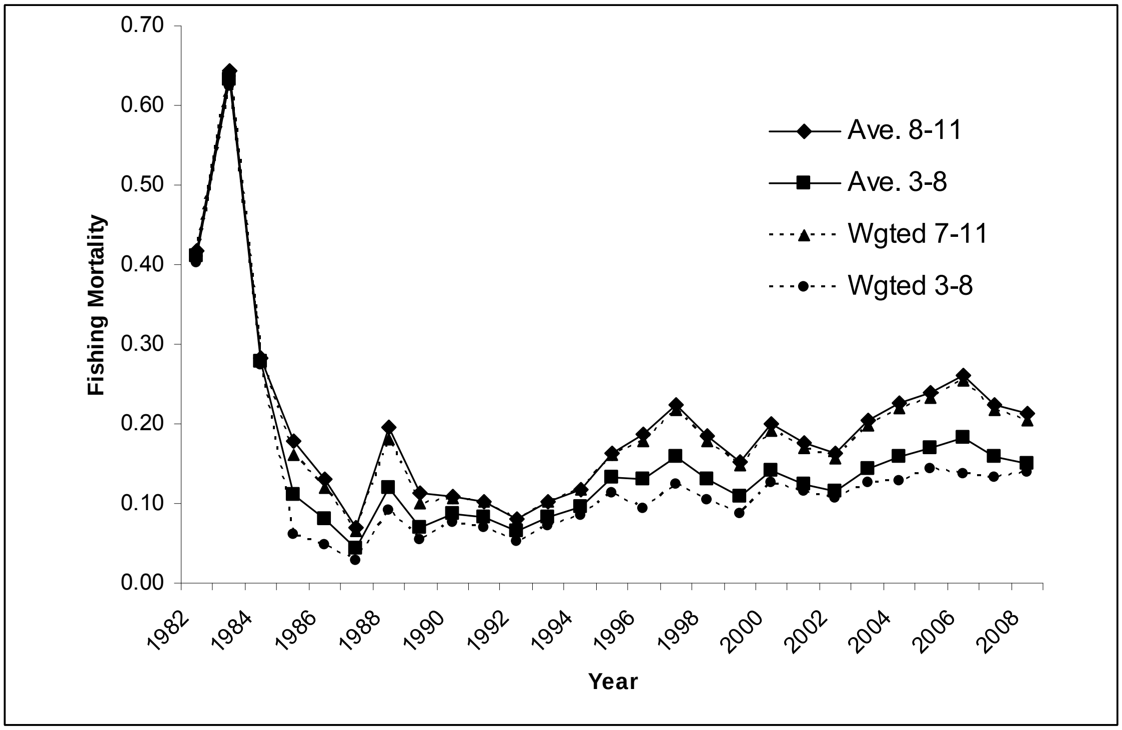


Figure 1.4. Comparison of fishing mortality estimates from SCA 2007 and 2009 runs.

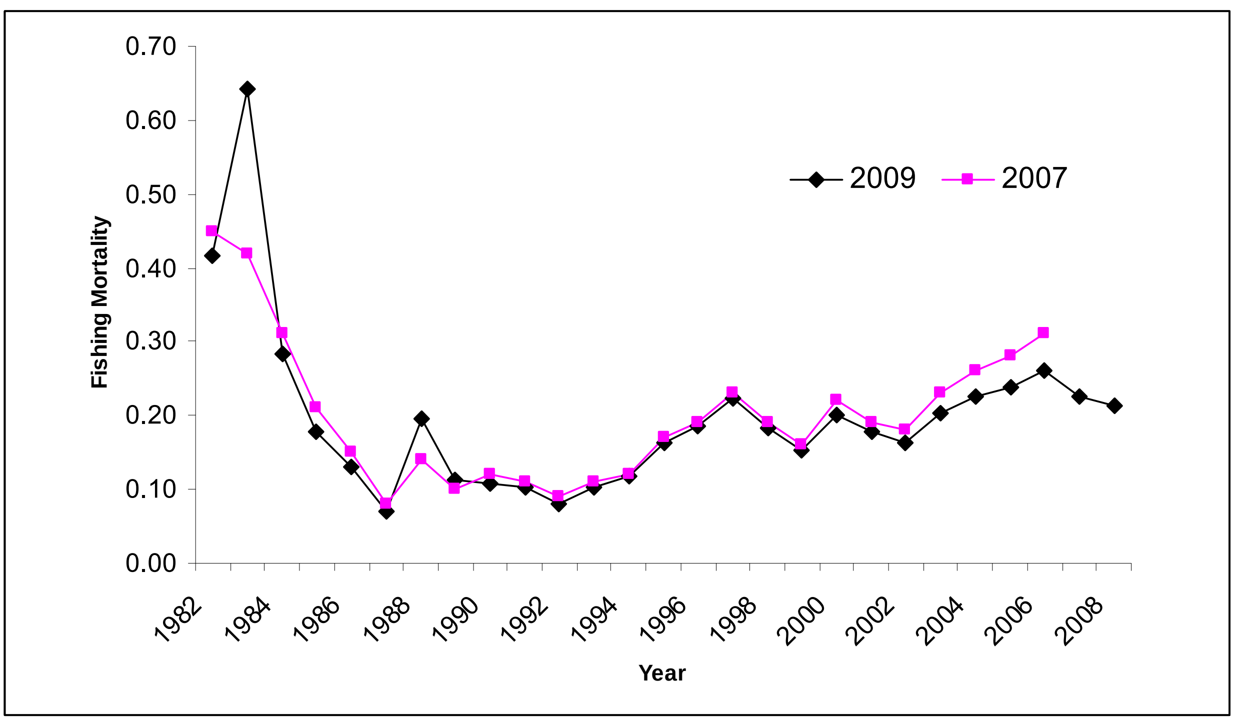


Figure 1.5. Projection of abundances of 8-13+ and 8-12 age classes and spawning stock biomass.

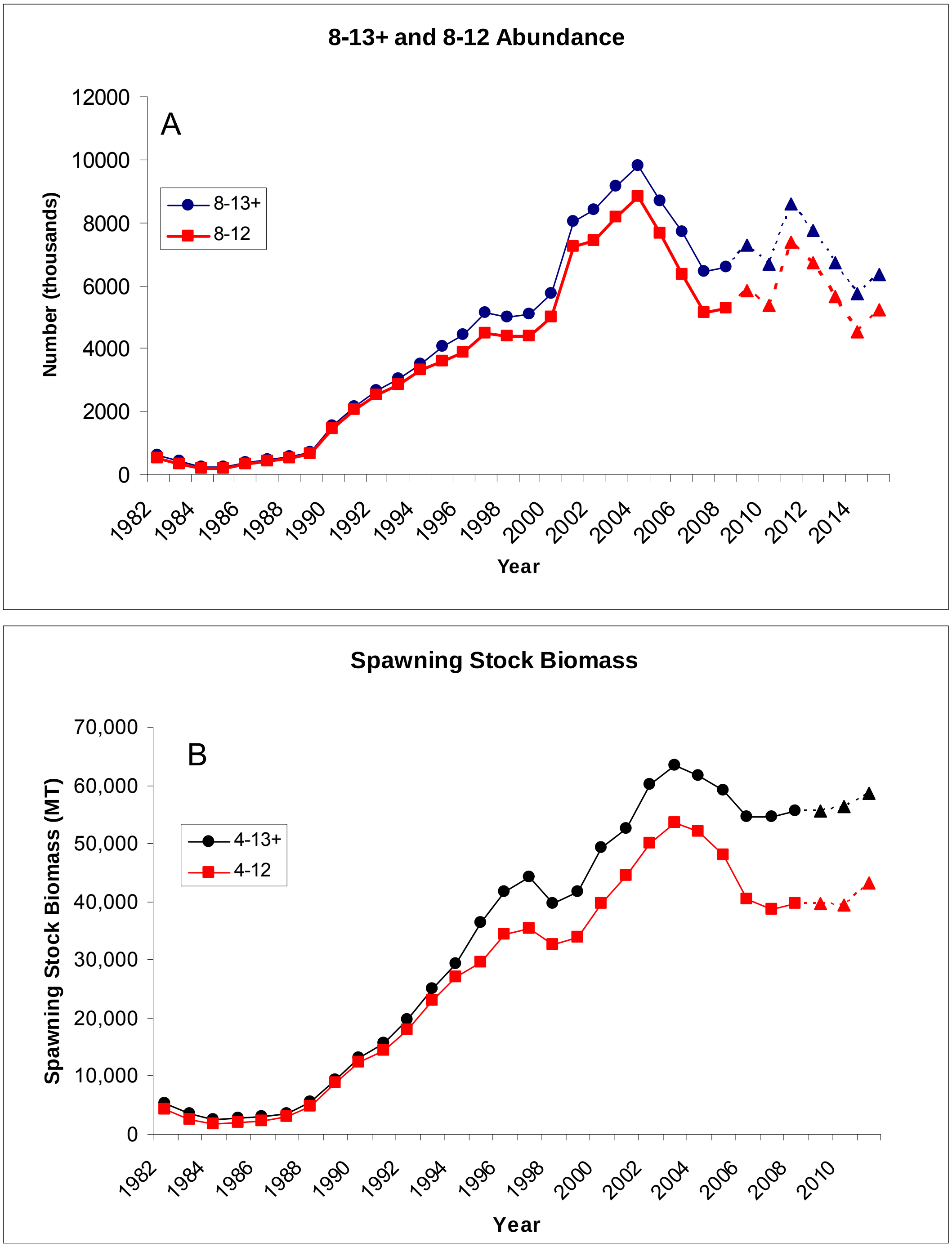


Figure 1.6. Trends in total and spawning stock biomass (metric tons), 1982-2008.

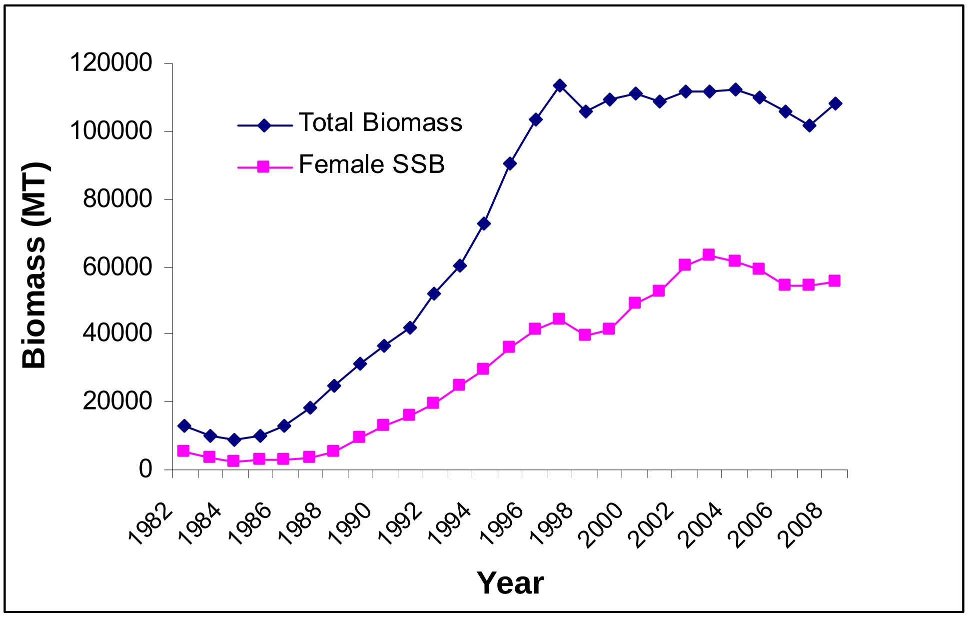


Figure 1.7. Retrospective analysis of fully-recruited fishing mortality, 8+ abundance and spawning stock biomass

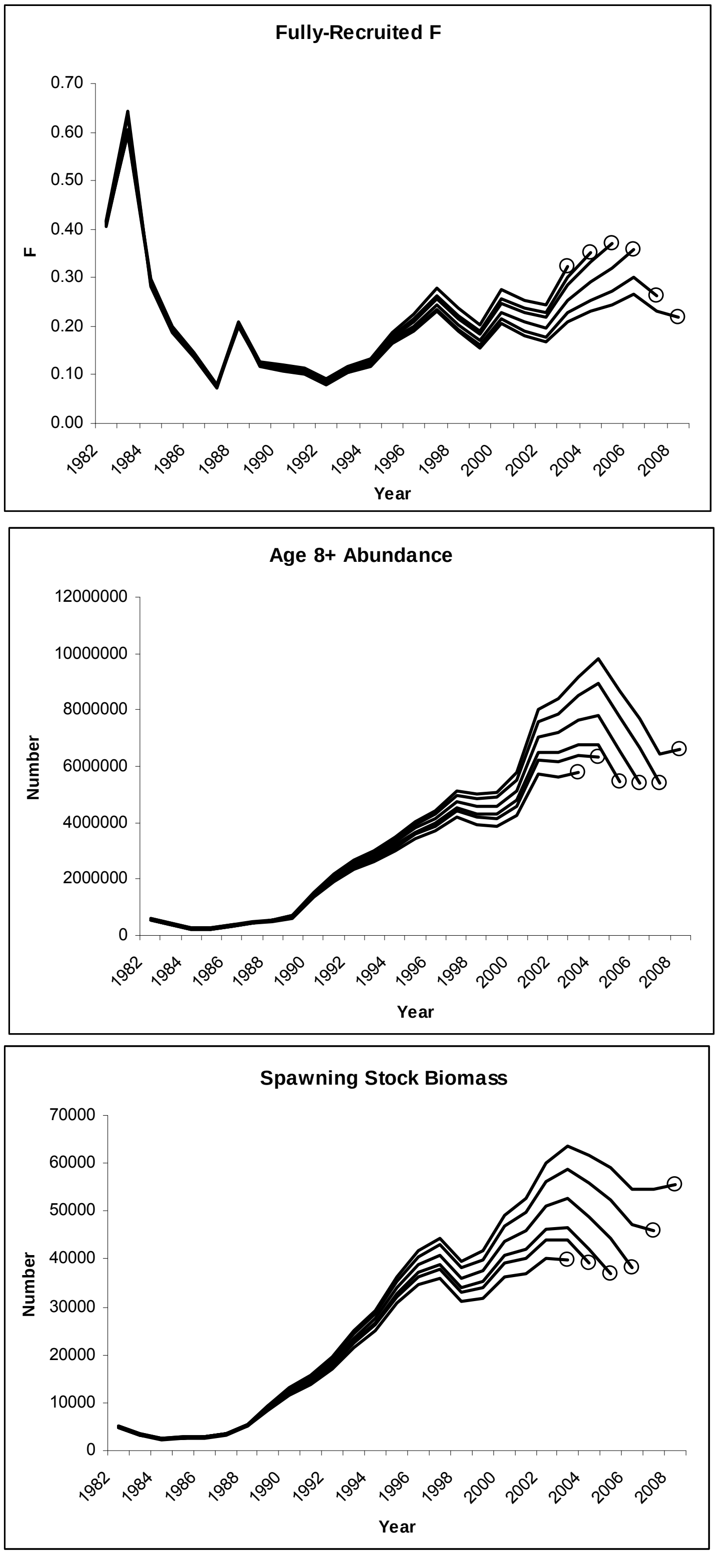
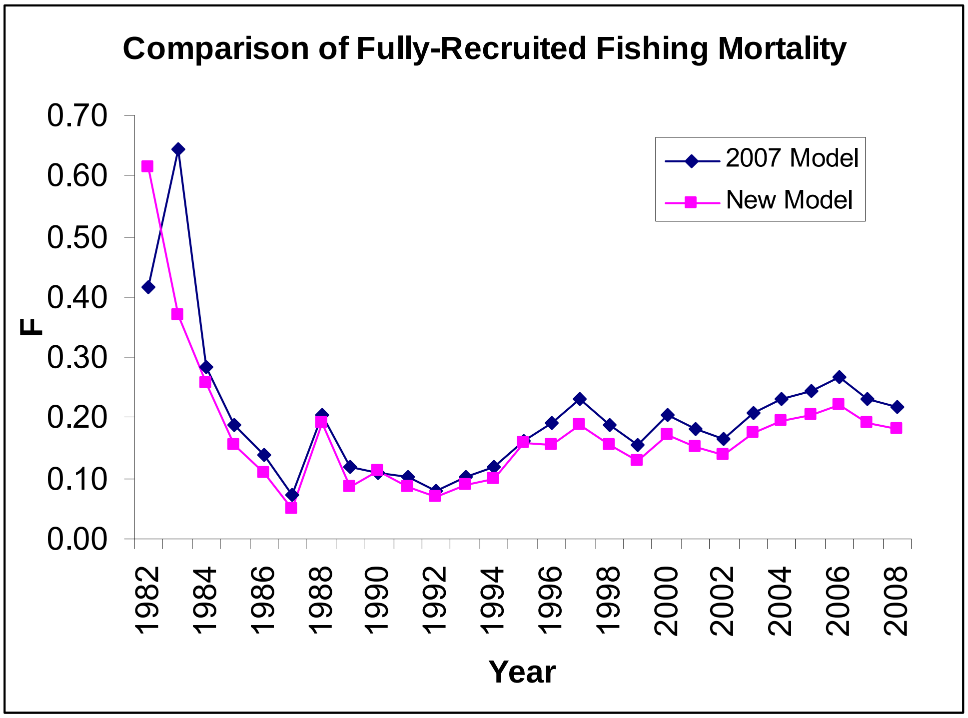


Figure 1.8. Comparison of fully-recruited fishing mortality estimates from the 2007 model structure and new model structure.



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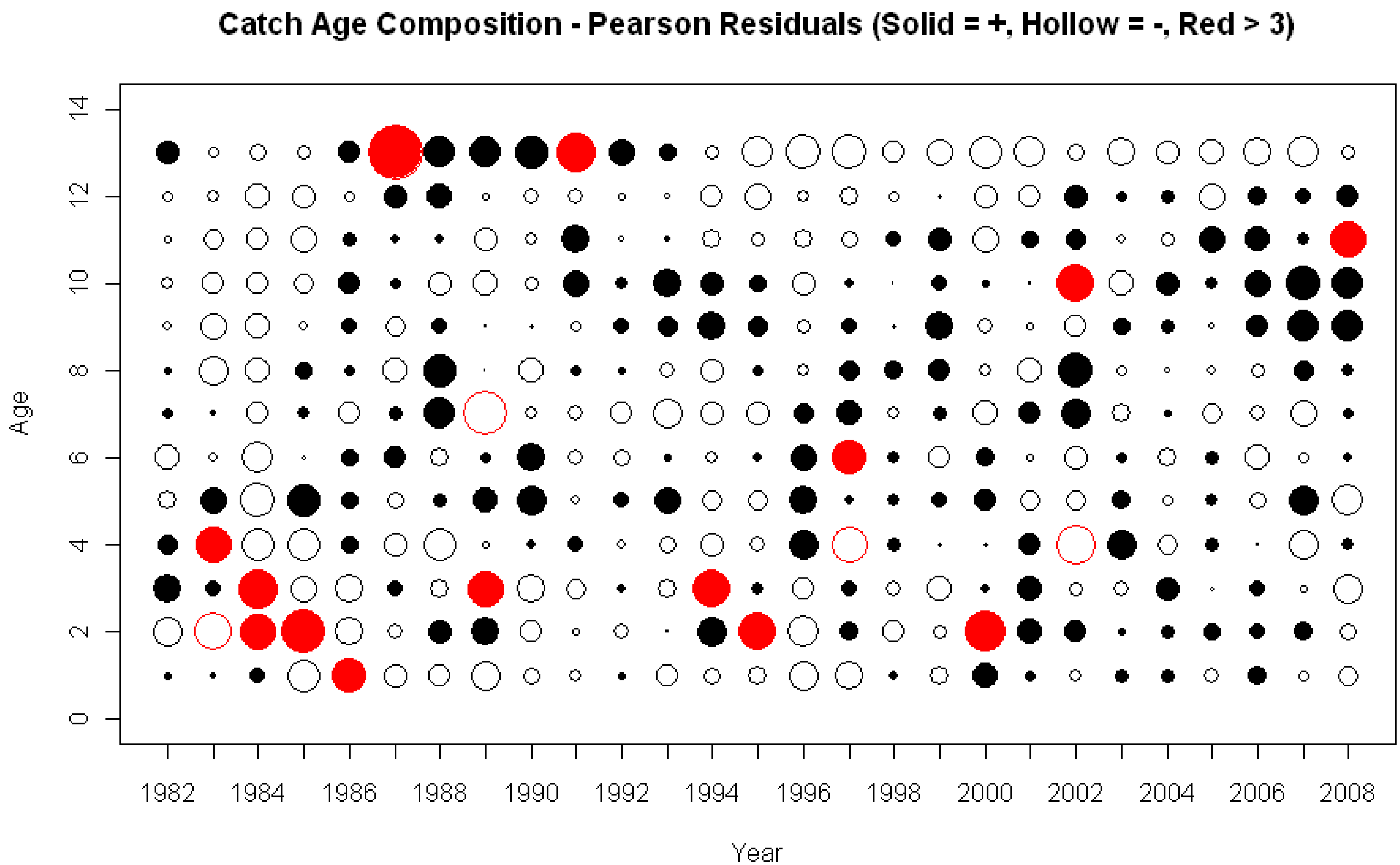
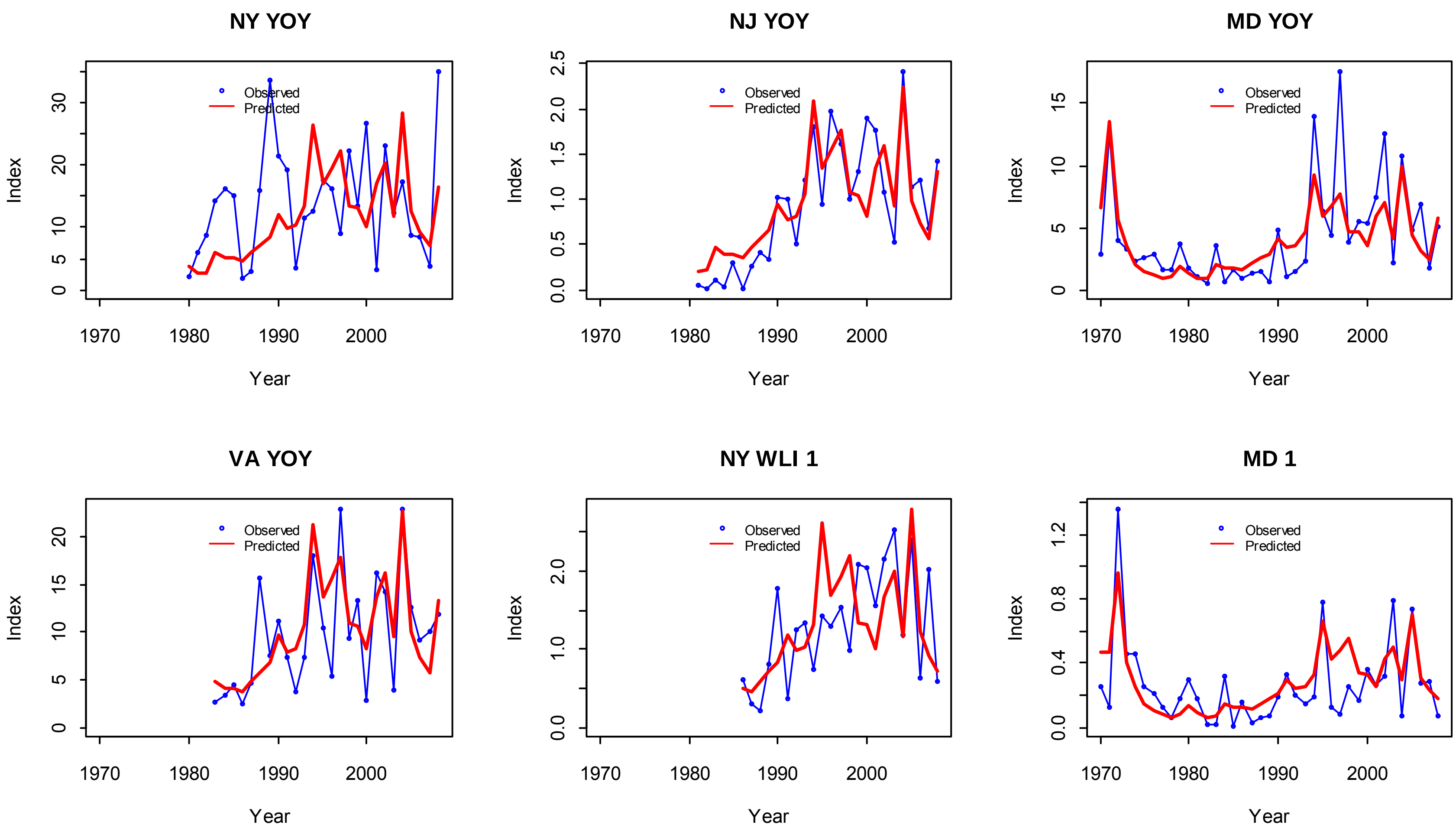
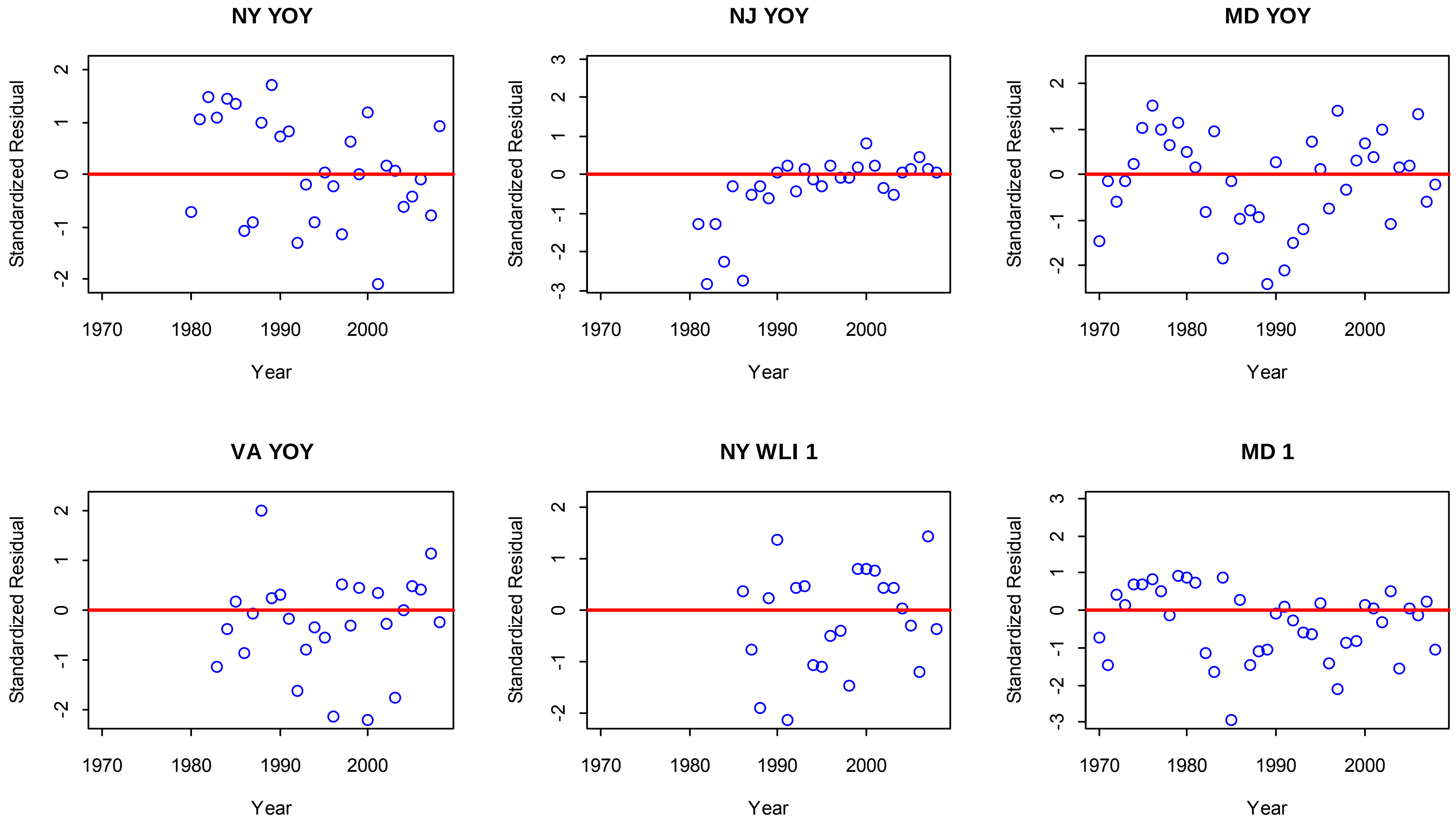
Appendix 1 Figure 1. Standardized residuals for the catch age composition from updated run of the 2007 SCA model.



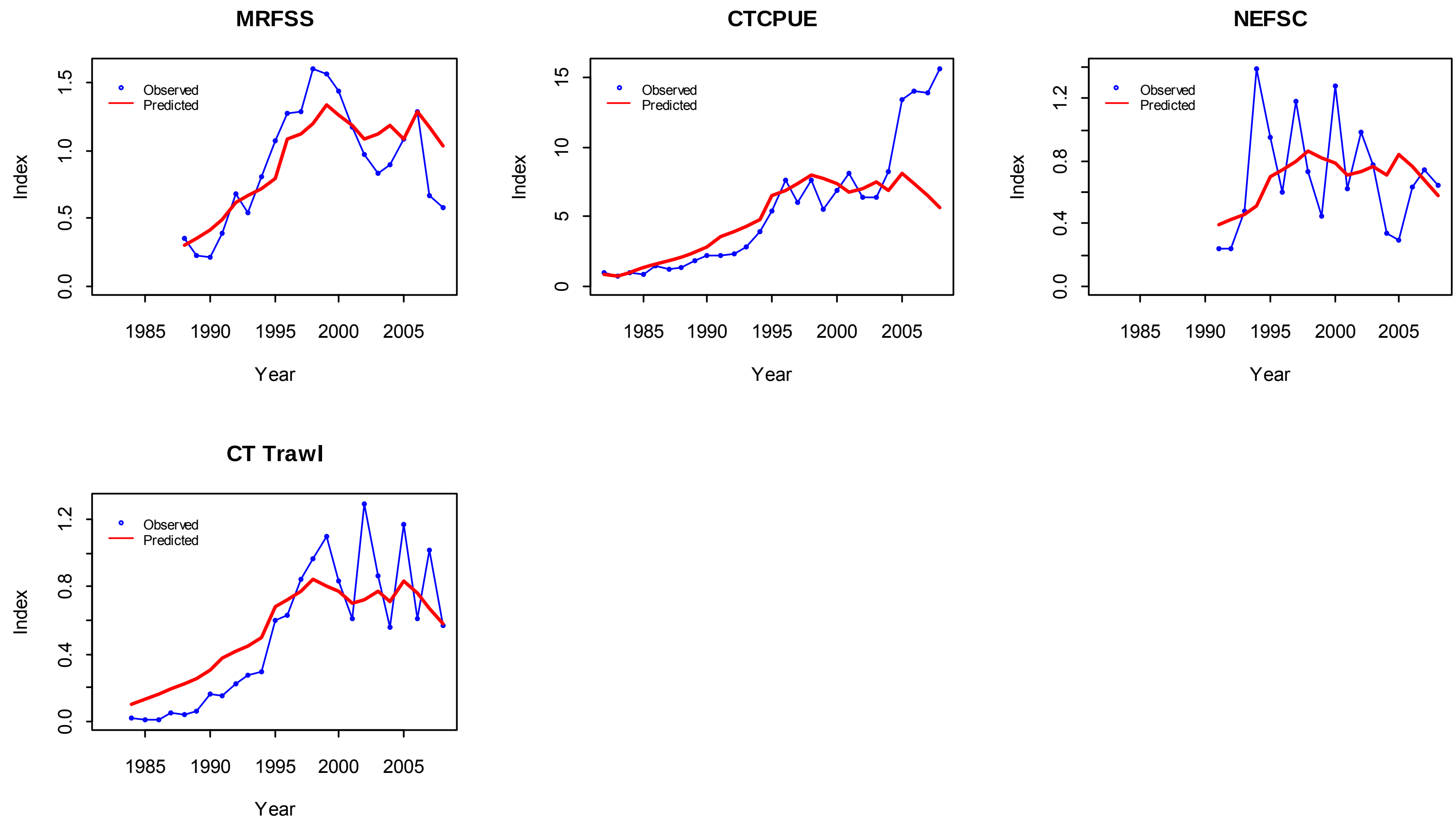
Appendix 1 Figure 2. Comparison of observed versus predicted values of the YOY and age1 indices of relative abundance from updated run of the 2007 SCA model.



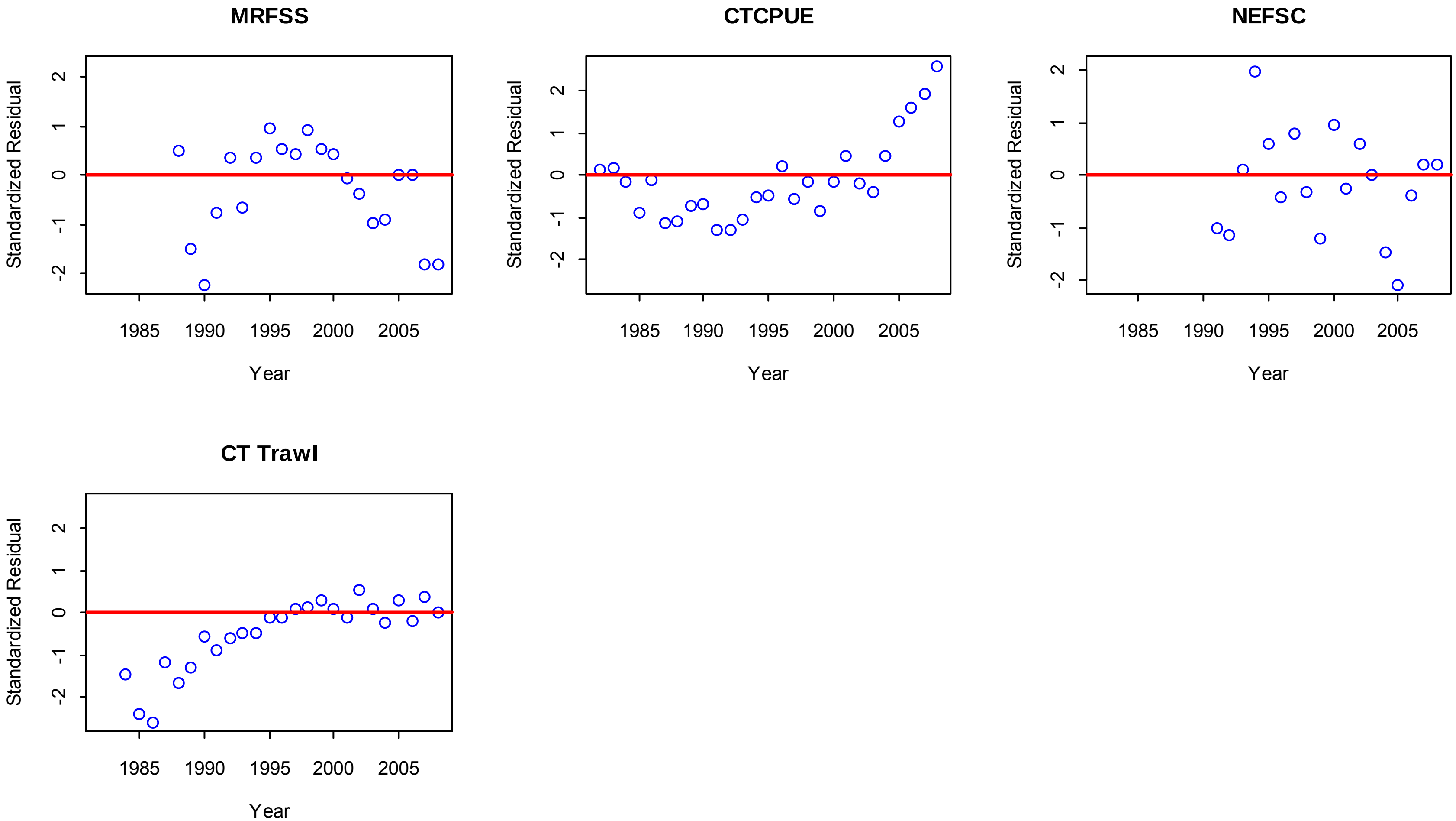
Appendix 1 Figure 3. Standardized residuals for the YOY and age 1 indices from updated run of the 2007 SCA model.



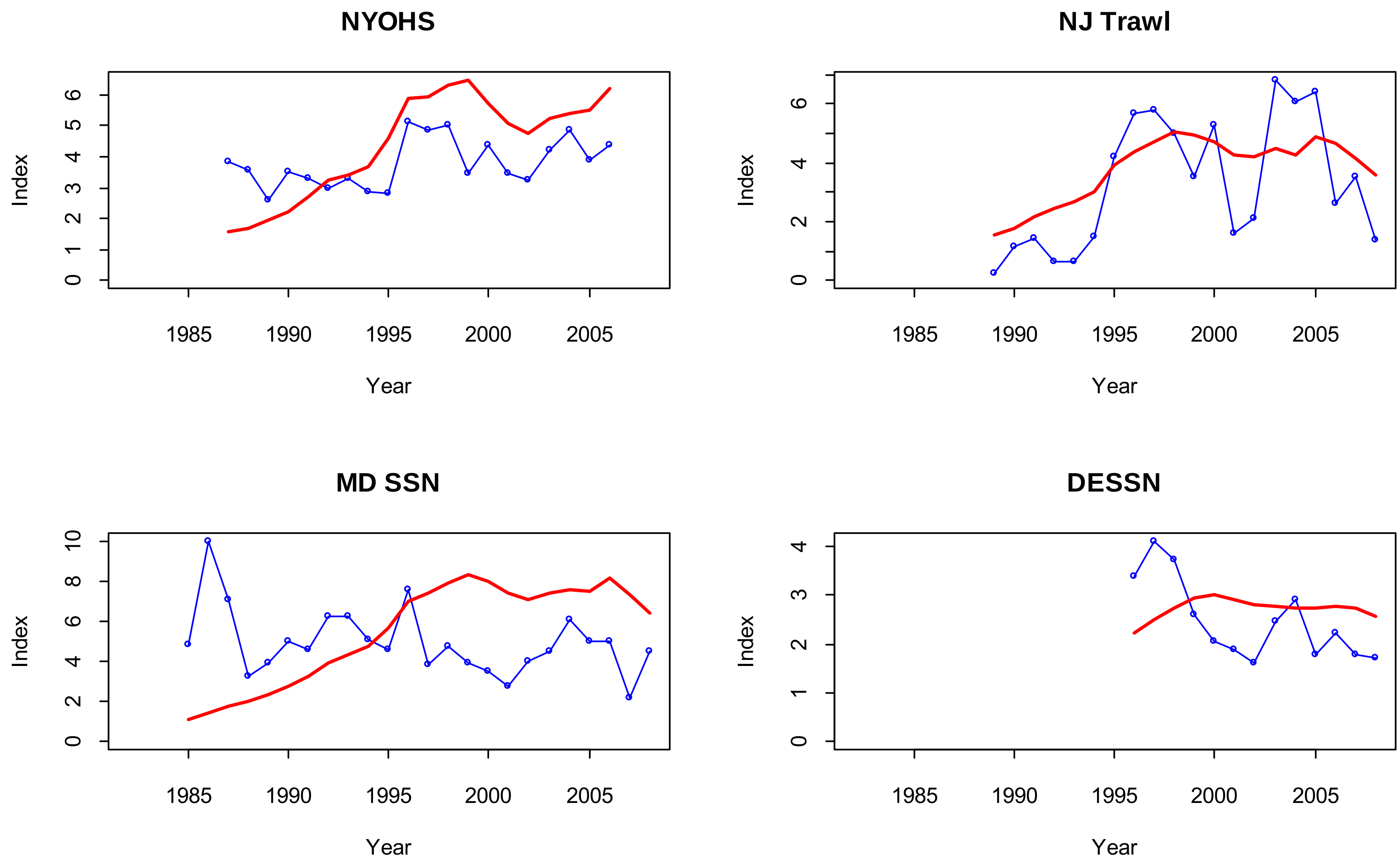
Appendix 1 Figure 4. Comparison of observed and predicted values of the aggregate abundance indices from updated run of the 2007 SCA model.



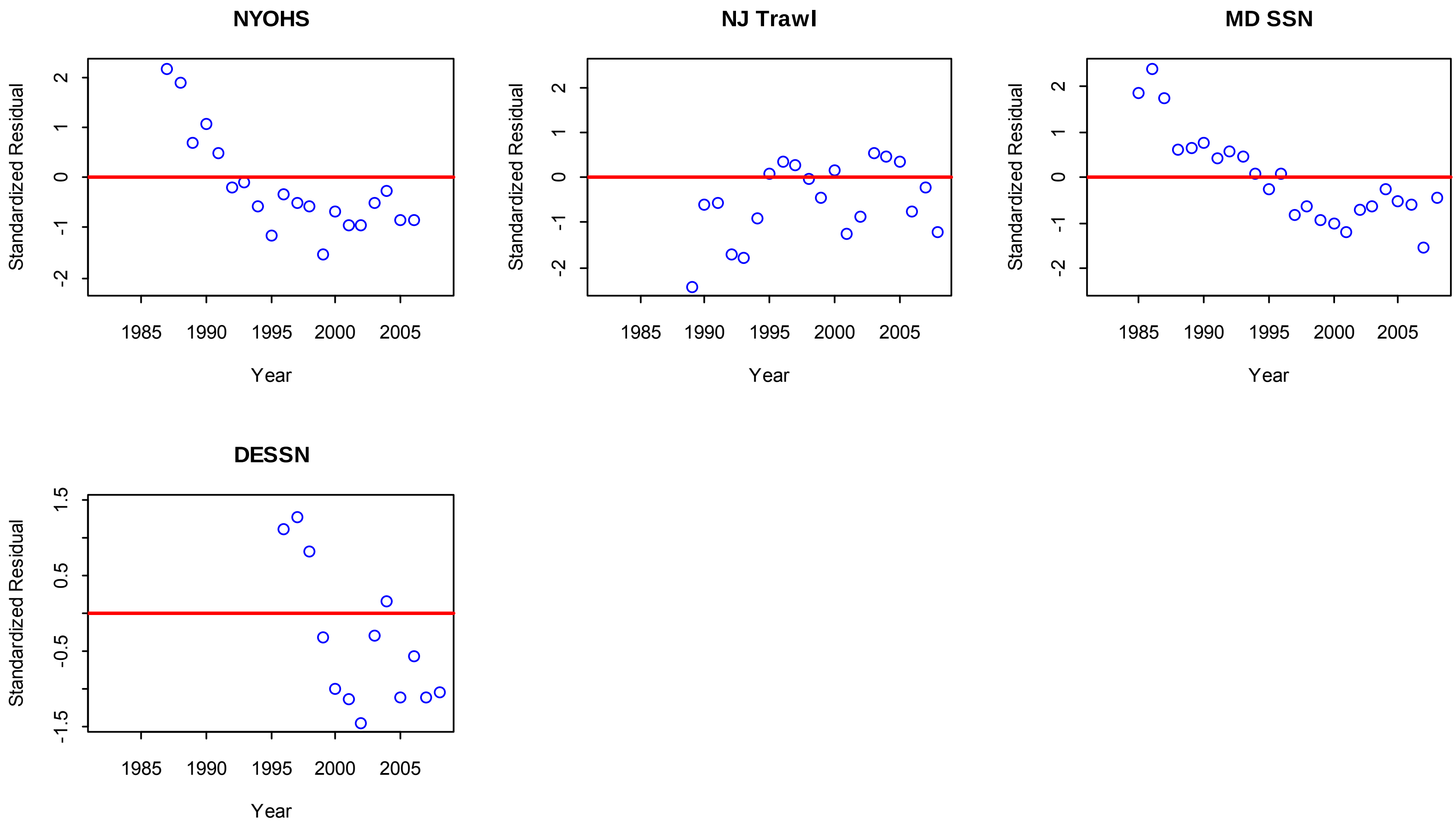
Appendix 1 Figure 5. Standardized residuals for aggregate indices from updated run of the 2007 SCA model.



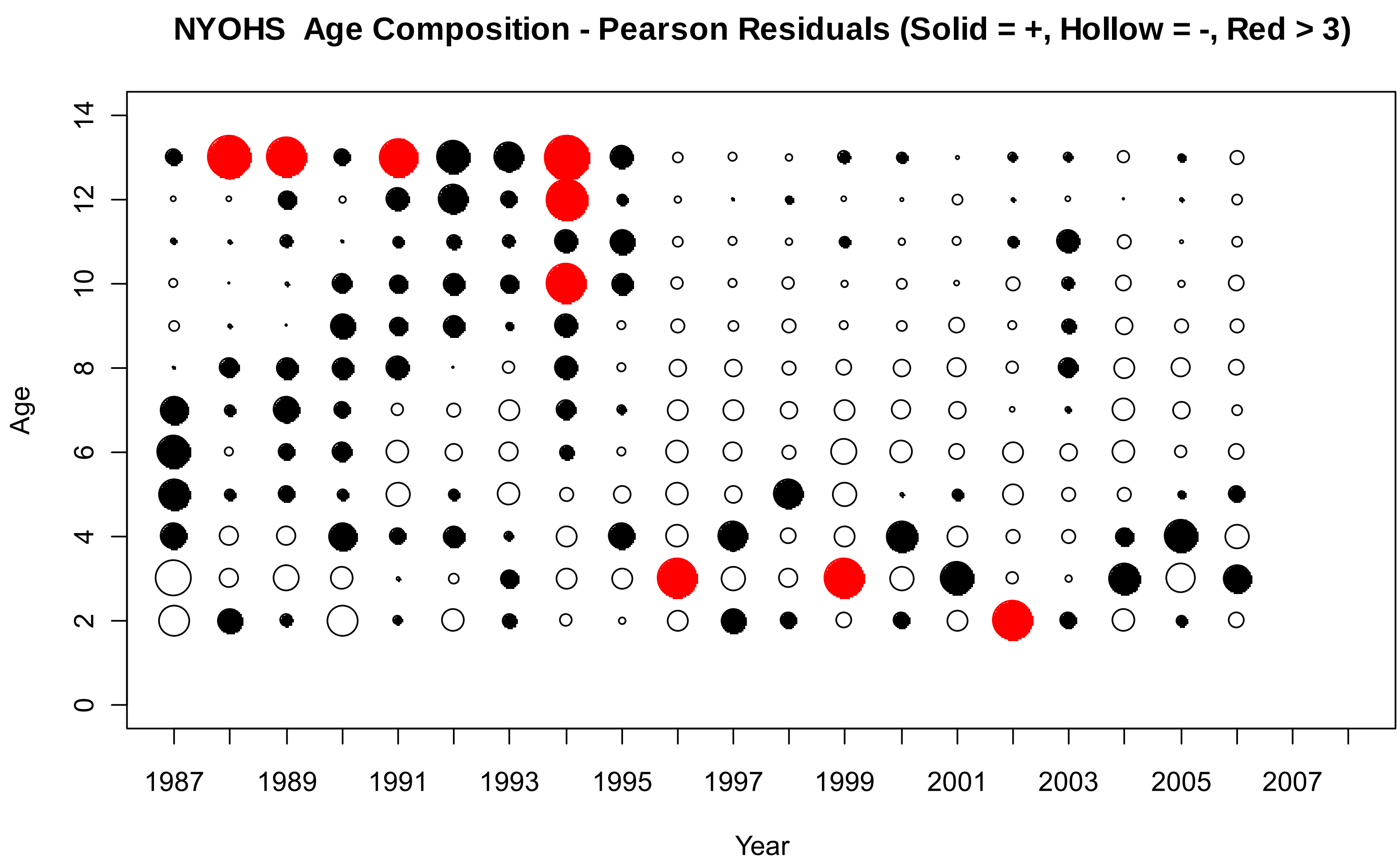
Appendix 1 Figure 6. Comparison of observed and predicted values of the survey indices with age data from updated run of the 2007 SCA model.



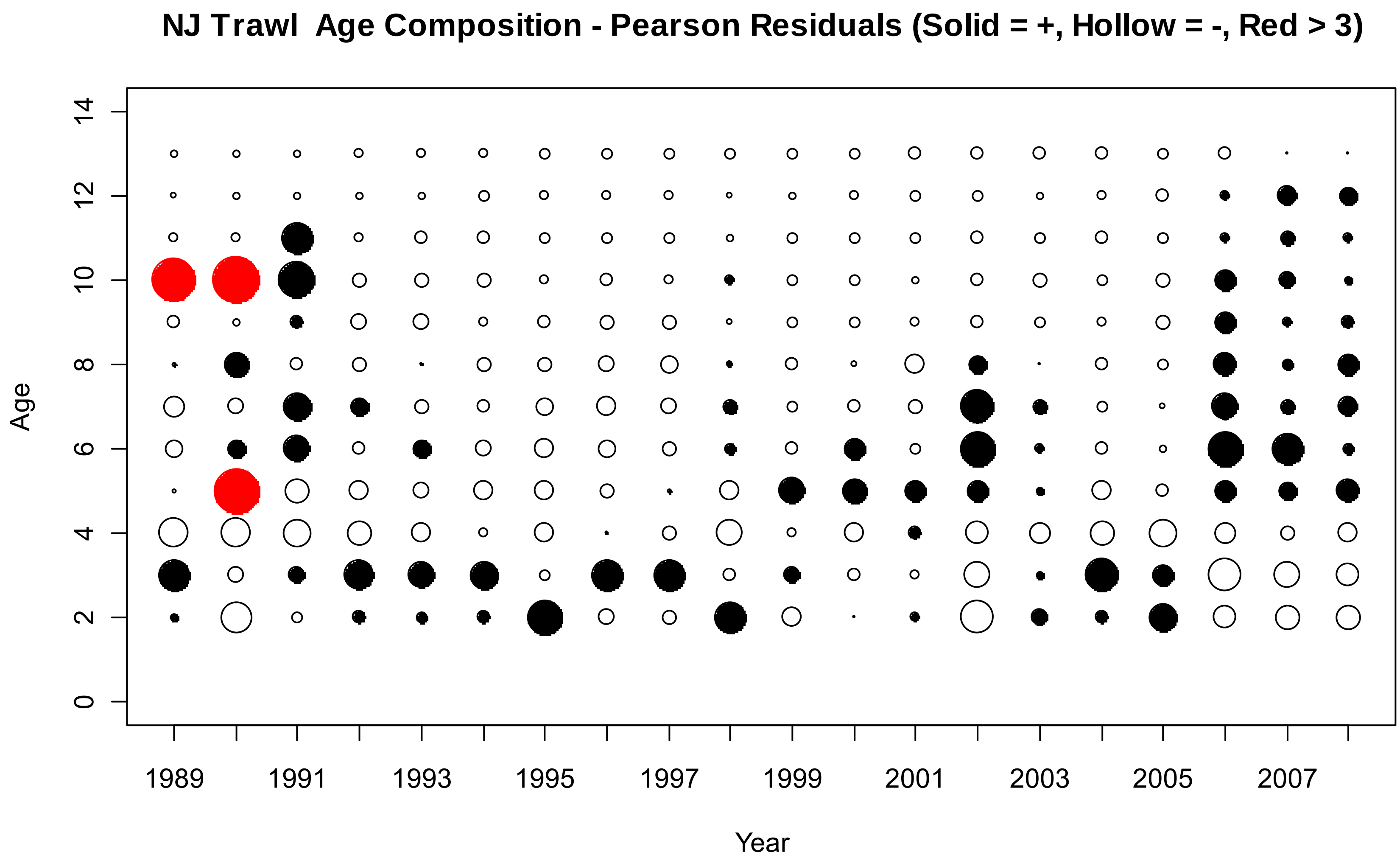
Appendix 1 Figure 7. Standardized residuals for survey indices with age data from updated run of the 2007 SCA model.



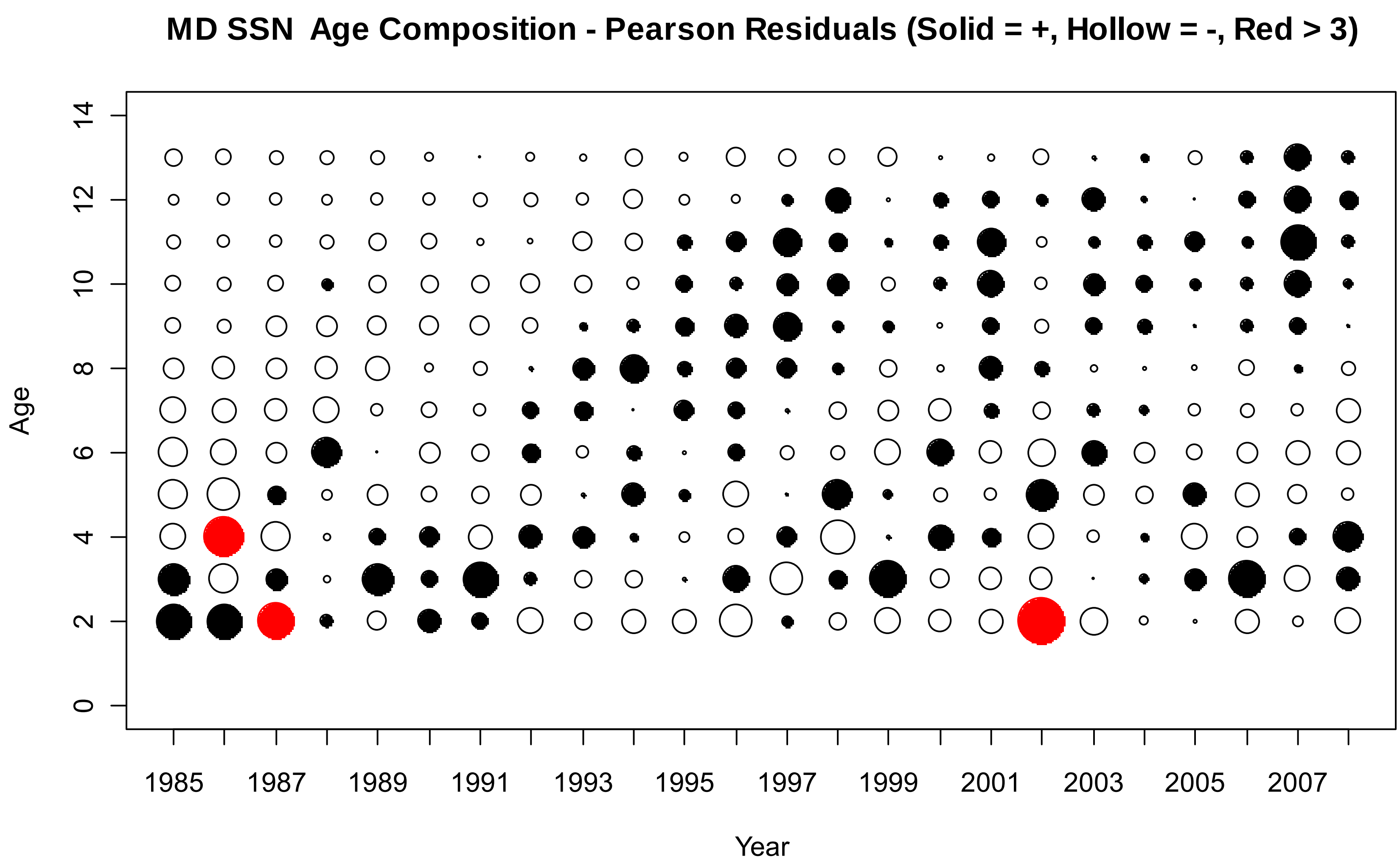
Appendix 1 Figure 8. Standardized residuals for the NYOHS age composition from updated run of the 2007 SCA model.



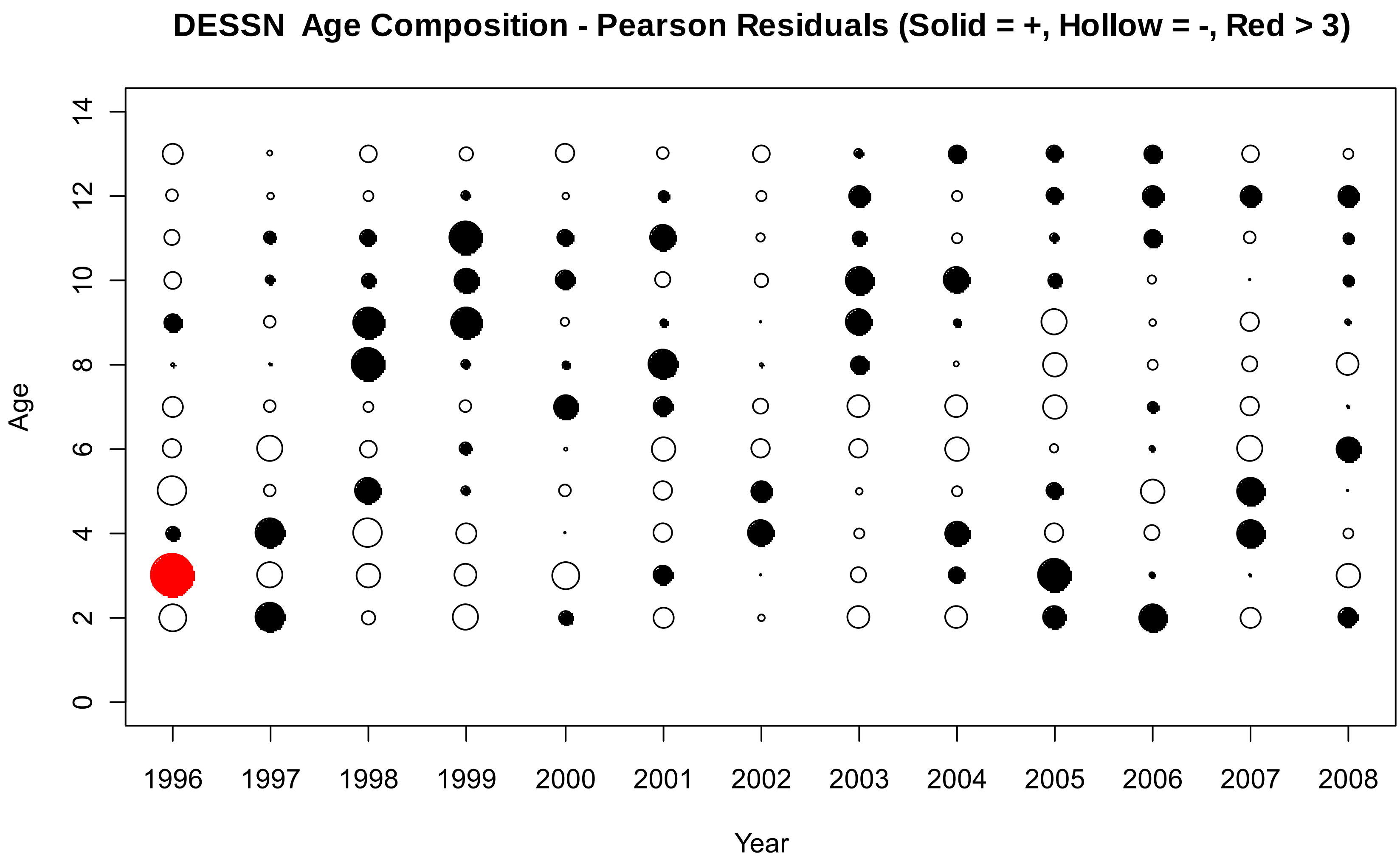
Appendix 1 Figure 9. Standardized residuals for the NJ Trawl age composition from updated run of the 2007 SCA model.



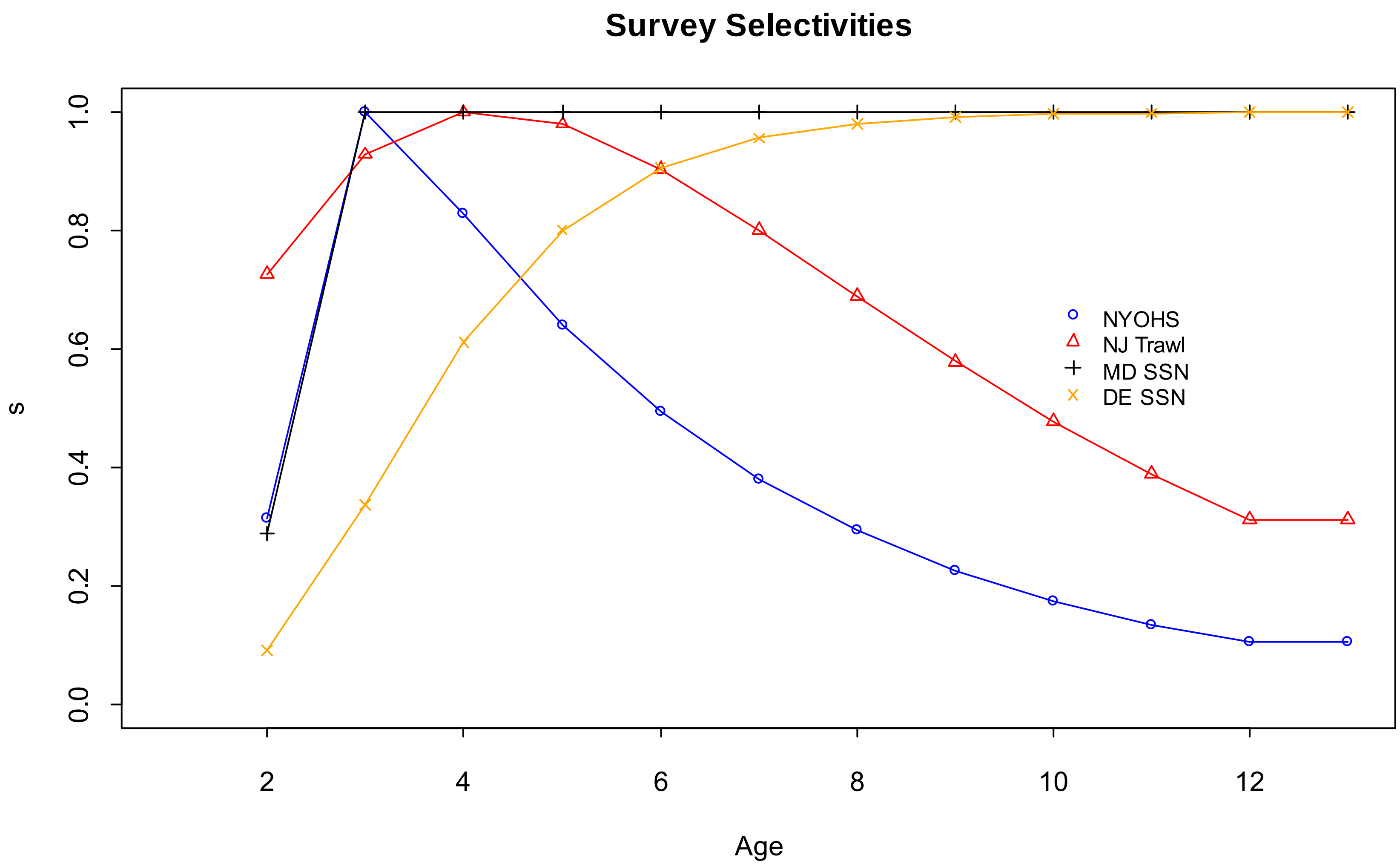
Appendix 1 Figure 10. Standardized residuals for the MD SSN age composition from updated run of the 2007 SCA model.



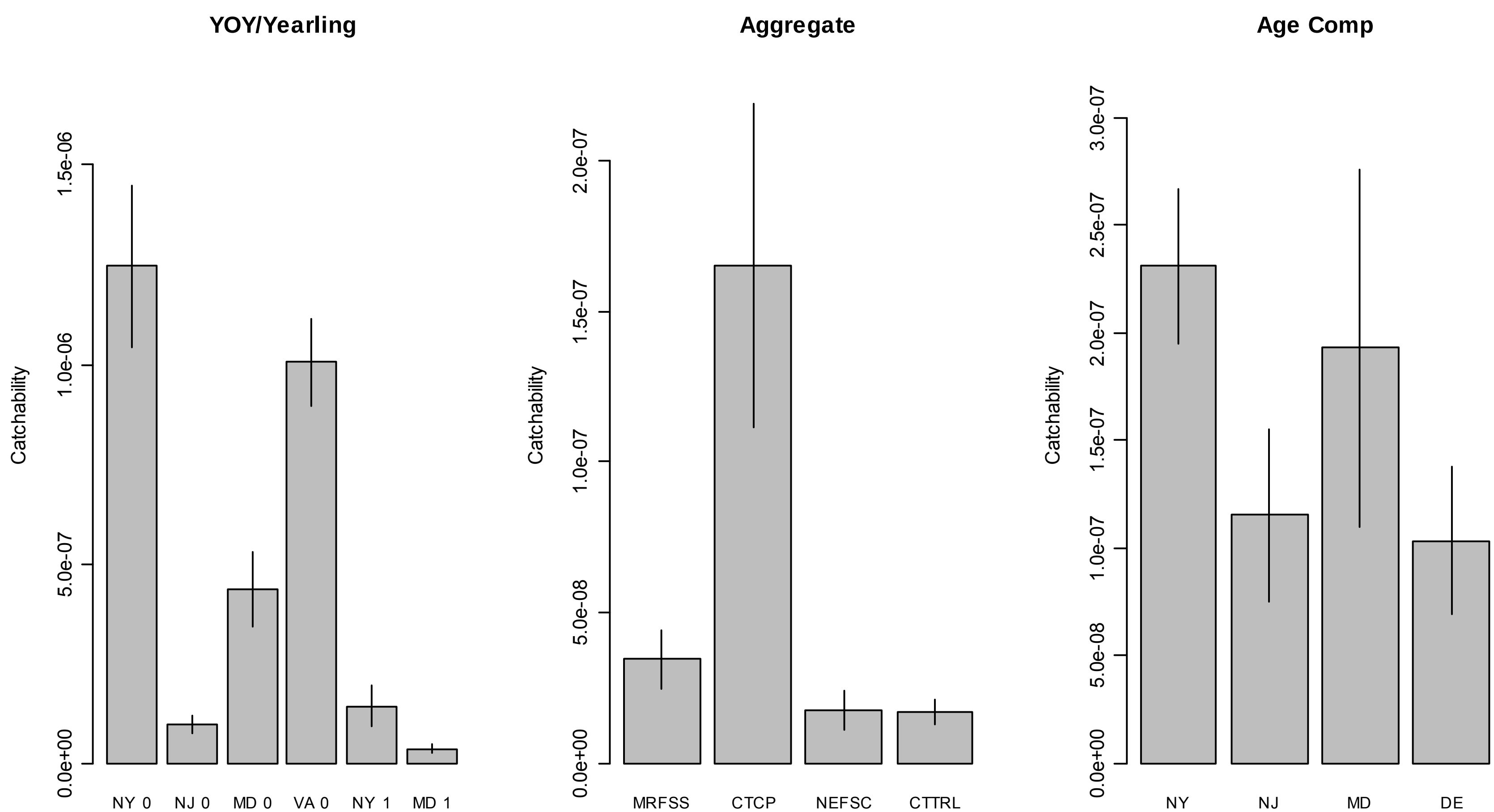
Appendix 1 Figure 11. Standardized residuals for the DE SSN age composition from updated run of the 2007 SCA model.



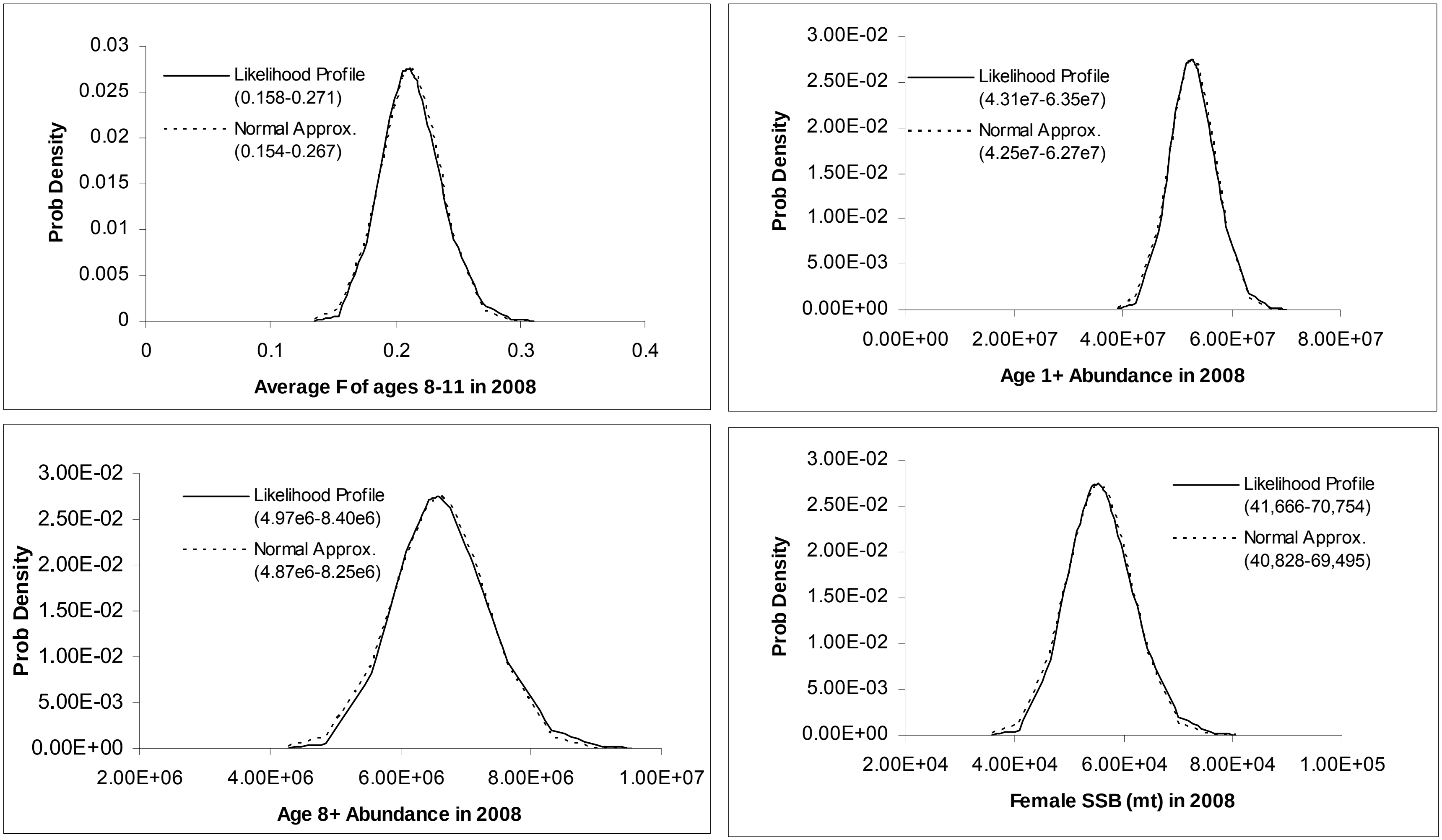
Appendix 1 Figure 12. Estimated selectivity patterns for the surveys with age data from updated run of the 2007 SCA model.



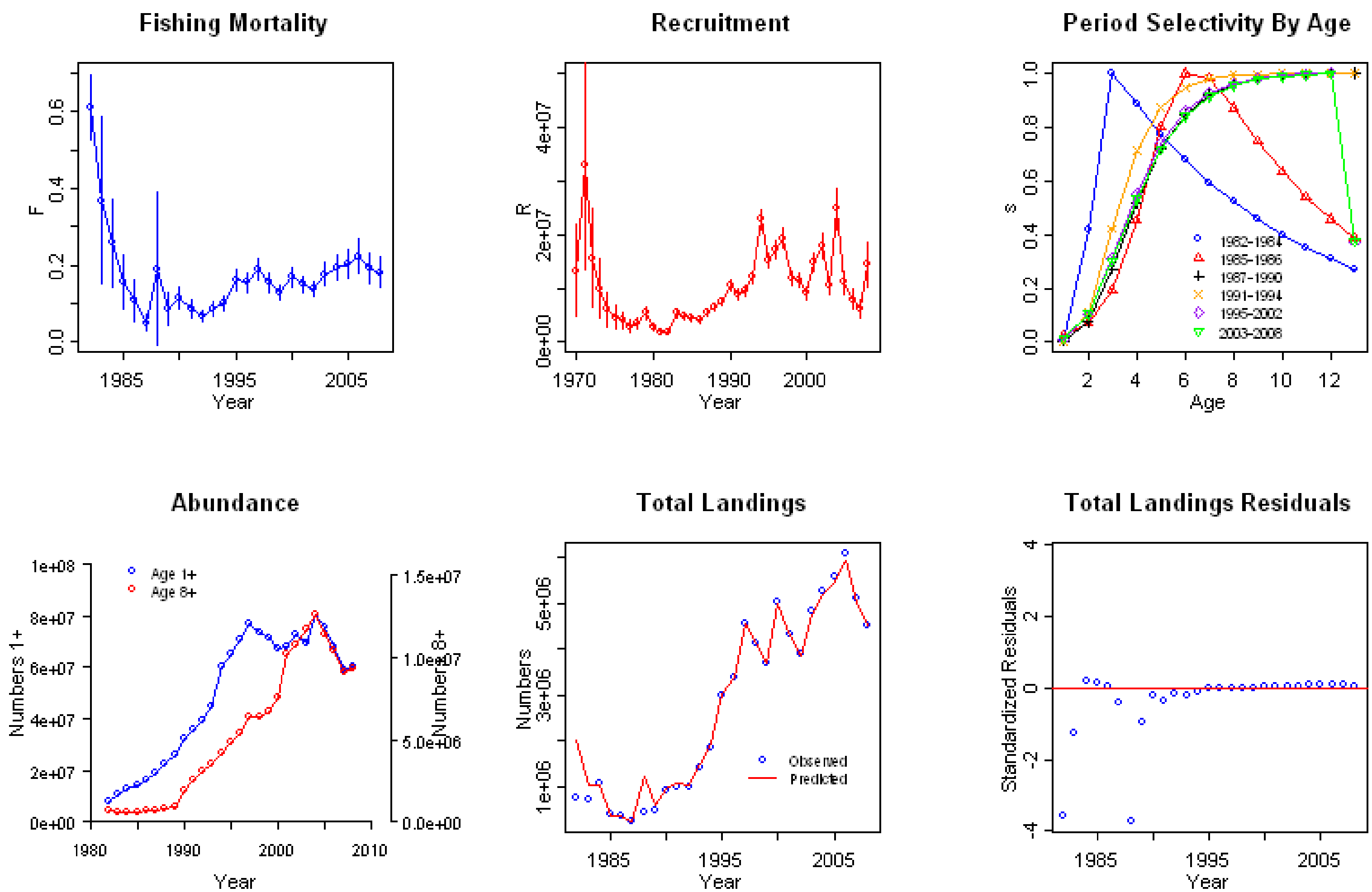
Appendix 1 Figure 13. Estimates of catchability coefficients for each survey index.



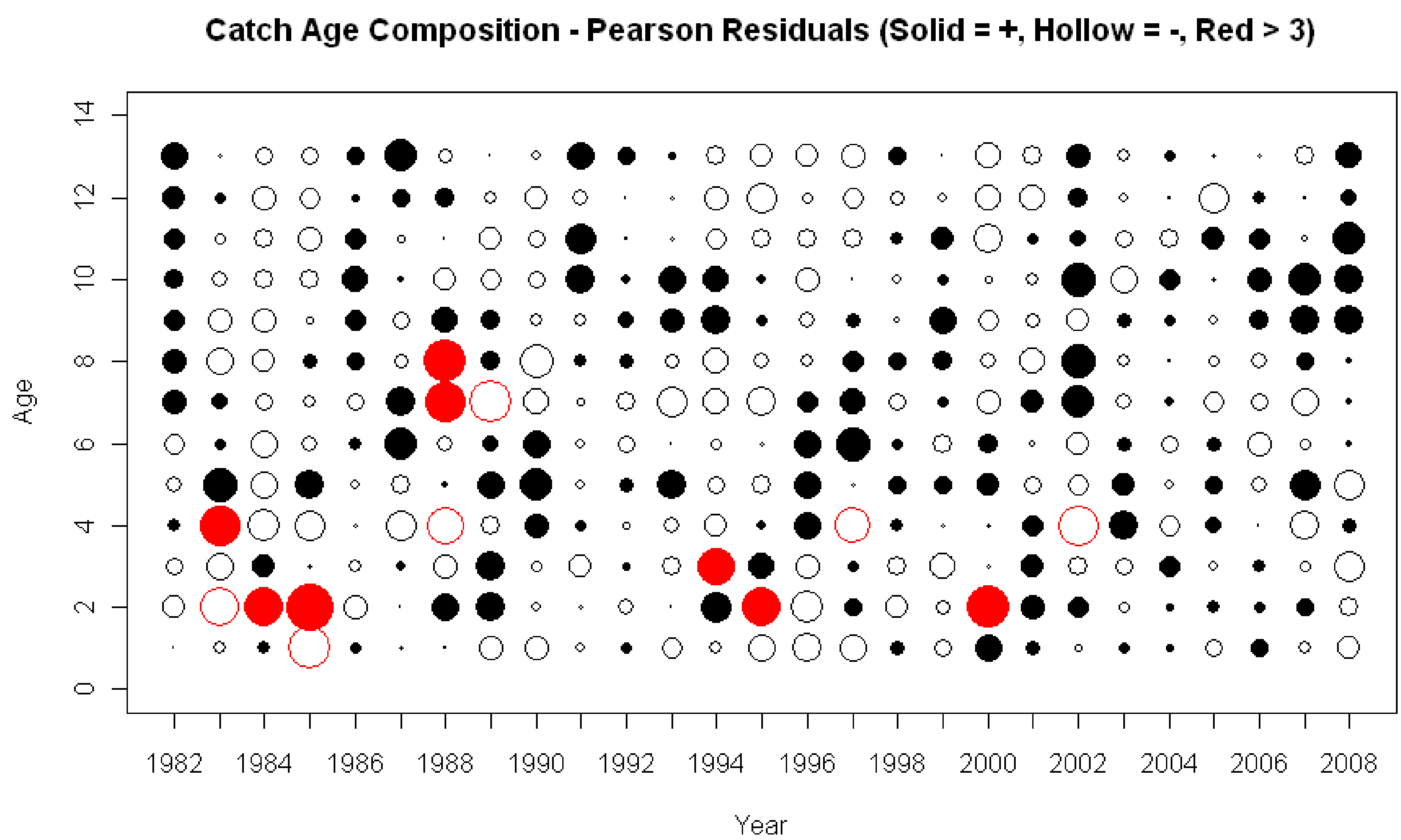
Appendix 1 Figure 14. Comparison of likelihood profile and normal approximation methods for determining confidence intervals of estimates of average F of ages 8-11, age 1+ abundance, age 8+ abundance, and spawning stock biomass in 2008 from the SCA model. Lower and upper 95% confidence limits are shown in parentheses.



Appendix 2. Figure 1. Output from new model structure.



Appendix 2. Figure 2. Standardized residuals for catch age composition.



A.S.M.F.C. Striped Bass Tagging Subcommittee
Summary of U.S.F.W.S. Cooperative Tagging Program Results

Final Report

January 5, 2010

Prepared by Philip Sadler,
Virginia Institute of Marine Science,
Chair

EXECUTIVE SUMMARY

This report summarizes the results of the eight tagging programs used to estimate the level of exploitation and fishing mortality of resident and migratory coastal stocks of striped bass among the Atlantic states. The Striped Bass Tagging Subcommittee uses multiple analyses (program MARK, catch equation and Instantaneous rates) of the tag recapture results to document the range of results under different model assumptions and limitations. Of particular concern to the Tagging Subcommittee is whether the estimate of the tag reporting rate is accurate (see Appendix D) and evidence that the level of natural mortality is increasing (see Appendix C). Thus, the Tagging Subcommittee recommends the results of the catch equation and the two-natural mortality period (2M) analyses as the most credible estimates of fishing mortality.

The tables below summarize the estimates of fishing mortality (F) from the catch equation and the 2M instantaneous rates analyses. The producer area average is a weighted mean among the four producer area programs (Hudson River 0.13, Delaware River 0.09 and Chesapeake Bay 0.78 apportioned between Maryland 0.67 and Virginia 0.33). The coastal program average is the arithmetic average of the four programs (Massachusetts, New York, New Jersey and North Carolina). The analyses are also segregated by size (≥18 inches total length and ≥ 28 inches total length).

Table 1. Estimates of F for striped bass greater than or equal to 18”

	striped bass > 18 inches total length					
	catch equation			**2M instantaneous rates**		
year	producer average	coastal average	combined mean	producer average	coastal average	combined mean
1987						
1988	0.02	0.03	0.02	0.02	0.02	0.02
1989	0.01	0.03	0.02	0.04	0.02	0.03
1990	0.08	0.06	0.07	0.07	0.07	0.07
1991	0.11	0.07	0.09	0.11	0.07	0.09
1992	0.14	0.05	0.10	0.14	0.07	0.10
1993	0.17	0.07	0.12	0.13	0.07	0.10
1994	0.18	0.06	0.12	0.13	0.06	0.10
1995	0.21	0.05	0.13	0.19	0.12	0.16
1996	0.20	0.08	0.14	0.18	0.12	0.15
1997	0.25	0.12	0.18	0.21	0.13	0.17
1998	0.24	0.11	0.18	0.23	0.13	0.18
1999	0.20	0.08	0.14	0.20	0.12	0.16
2000	0.20	0.08	0.14	0.16	0.11	0.13
2001	0.18	0.09	0.13	0.15	0.11	0.13
2001	0.17	0.10	0.13	0.13	0.11	0.12
2003	0.16	0.10	0.13	0.17	0.12	0.14
2004	0.15	0.10	0.12	0.15	0.12	0.13
2005	0.15	0.08	0.12	0.13	0.12	0.13
2006	0.17	0.09	0.13	0.15	0.12	0.13
2007	0.13	0.10	0.11	0.12	0.11	0.12
2008	0.13	0.11	0.12	0.13	0.12	0.12

Table 2. Estimates of F for striped bass greater than or equal to 28”

striped bass > 28 inches total length

	catch equation			2M instantaneous rates		
year	producer average	coastal averge	combined mean	producer average	coastal average	combined mean
1987				0.01		0.01
1988	0.11	0.06	0.09	0.03	0.04	0.03
1989	0.08	0.03	0.06	0.03	0.03	0.03
1990	0.16	0.07	0.12	0.13	0.11	0.12
1991	0.13	0.13	0.13	0.13	0.20	0.16
1992	0.14	0.07	0.11	0.13	0.11	0.12
1993	0.15	0.12	0.14	0.15	0.11	0.13
1994	0.18	0.07	0.13	0.15	0.09	0.12
1995	0.22	0.11	0.17	0.25	0.17	0.21
1996	0.23	0.15	0.19	0.25	0.19	0.22
1997	0.35	0.21	0.28	0.25	0.20	0.22
1998	0.28	0.20	0.24	0.25	0.23	0.24
1999	0.27	0.24	0.26	0.25	0.19	0.22
2000	0.22	0.12	0.17	0.15	0.14	0.14
2001	0.19	0.14	0.17	0.15	0.16	0.15
2001	0.16	0.12	0.14	0.15	0.15	0.15
2003	0.20	0.16	0.18	0.16	0.16	0.16
2004	0.16	0.17	0.17	0.16	0.16	0.16
2005	0.19	0.17	0.18	0.16	0.17	0.16
2006	0.21	0.15	0.18	0.16	0.15	0.15
2007	0.16	0.15	0.15	0.13	0.17	0.15
2008	0.16	0.15	0.15	0.14	0.19	0.16

Virginia and Maryland combine their data to produce a fishing mortality estimate for male striped bass between 18 and 28 inches total length in Chesapeake Bay. These striped bass are the principal target of the extensive commercial and recreational fisheries there. There is strong evidence of increased natural mortality, likely attributed to mycobacterial infection, of the resident striped bass population (see Appendix C). The catch equation and 2M instantaneous rates estimates of fishing mortality (F) and natural mortality (M) are:

Table 3. Estimates of F and M for striped bass 18-28" in the Chesapeake Bay

	catch equation		**2M IRCR**	
year	F	M	F	M
1987	0.01	0.15	0.00	0.27
1988	0.01	0.27	0.01	0.27
1989	0.00	0.03	0.00	0.27
1990	0.05	0.49	0.05	0.27
1991	0.07	0.28	0.07	0.27
1992	0.12	0.38	0.13	0.27
1993	0.10	0.52	0.10	0.27
1994	0.10	0.37	0.09	0.27
1995	0.15	0.55	0.11	0.27
1996	0.11	0.24	0.08	0.27
1997	0.13	0.62	0.11	0.80
1998	0.15	0.91	0.15	0.80
1999	0.11	0.83	0.12	0.80
2000	0.12	1.11	0.10	0.80
2001	0.14	0.83	0.10	0.80
2002	0.10	0.56	0.10	0.80
2003	0.11	0.41	0.12	0.80
2004	0.12	1.30	0.11	0.80
2005	0.12	0.98	0.08	0.80
2006	0.12	1.11	0.10	0.80
2007	0.11	1.21	0.06	0.80
2008	0.08	0.76	0.07	0.80

The estimates of fishing mortality are well below the threshold value of 0.30 regardless of the analytical method chosen. The Striped Bass Tagging Subcommittee will attempt to improve the validity of the analyses by resolving questions regarding the estimates of the reporting rate, possible tag loss and degradation, and changes in natural mortality.

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INTRODUCTION

This report summarizes the results of the United States Fish and Wildlife Service's (USFWS) Atlantic coastwide striped bass tagging program through the 2008 tagging year. The Striped Bass Tagging Subcommittee (SBTS) of the Striped Bass Technical Committee of ASMFC analyzes the data gathered by the tagging program. The subcommittee is comprised of members from participating state agencies and USFWS.

Two modeling approaches were used for the 2008 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 started 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 of several parameters are presented for fish $\geq$ 28 inches (approximating age 7+ fish) and fish $\geq$ 18 inches (approximating age 3+ fish).

METHODS

I. 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 14 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 months;
- New Jersey Delaware Bay (NJ/DEL) - fish tagged in March and April; and
- North Carolina winter trawl survey (NCCOOP) - fish tagged primarily in January.

II. 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 2009, a total of 308,479 striped bass have been tagged and released, with 58,974 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 (Appendix A).

III. 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 subcommittee 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 D.

IV. 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.

A. Program MARK and Baranov's Catch Equation

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 2008 (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).

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).

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 ≥ 18 inches TL and fish ≥ 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).

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.

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 Baronov'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);
$\text{var}(\bar{x}_{state})$ = 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;
$\text{var}(\bar{x}_{state})$ = 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 ≥ 18 inches TL, corresponding roughly to 3-year-old and older striped bass for fish ≥ 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.

B. 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.

The committee is now exploring the use of an instantaneous rates model. 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. published an expanded version of the instantaneous rates model in 2007 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) and can be found in Appendix B. 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.

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 (Appendix A). 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:

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

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.

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.

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).

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.

RESULTS

I. DATA

The data input for both Program MARK and the IRCR model are the observed recovery matrices from harvested fish (Appendix A). The number of twice-recaptured fish was examined to ensure that this phenomenon did not cause a bias in model results. Of 58,974 recaptured fish in the database, only 1,429 fish were recorded as twice recaptured. Since this was less than 5%, it was considered inconsequential.

Length frequencies (total length) of fish tagged in 2007 and 2008 were tabulated by program (Tables 4a,b). Length represents the length of fish at the time of tagging. The coastal program tagged predominated larger striped bass (≥ 28") especially the Massachusetts coastal program (90+% ≥28") while the producer programs tagged predominantly resident (≤28") striped bass.

Age distributions of fish recaptured in 2007 and 2008 were tabulated by program (Tables 5a,b). 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.

Geographic distributions of 2007 and 2008 recaptures (from fish tagged and released during the full time series) were organized by state and month for each tagging program (Table 6). Striped bass tagged in the coastal programs are generally recaptured along the Northeast coast between May and October and along coastal Maryland through North Carolina and within Chesapeake Bay between November and May. However, striped bass tagged in the North Carolina program are recaptured in Virginia and Maryland all 12 months. Striped bass tagged by the producer programs are 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. The striped bass tagged in the Hudson River are recaptured there from March – November and along the coast in the same temporal pattern as the other programs.

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 7). However, VARAP has shown high (up to 0.6) and erratic values. From 1999-2008, all programs have shown a steady decline in their estimated annual catch rate and the overall mean has declined from a peak of 0.34 in 1997 to the current value of 0.17.

Annual catch rates for ≥ 18 inches fish have less variability than the ≥ 28 inches fish (Table 8), 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 0.25 in 1997 to the current value of 0.16.

II. MODEL DIAGNOSTICS

A. Program MARK

The Akaike weights assigned to the candidate models are presented in Table 9 (fish ≥ 28 inches) and Table 10 (fish ≥ 18 inches). For fish ≥ 28 inches, multiple models are used by all programs. The constant survival models were used (> 0.05) by only two programs (Massachusetts and Hudson River) and the year-specific survival models were used only for the New York Ocean Haul Seine program. The period models received the majority of the weight for the producer area programs.

For fish ≥ 18 inches, the model selection and weighting was entirely different. One model received essentially all weight for the New York, New Jersey and North Carolina coastal programs and both Chesapeake Bay programs (Table 10). The models used for the Massachusetts program was similar to the ≥ 28" suite, but as previously noted, that program tags predominantly larger striped bass.

B. Baranov's Catch Equation

A retrospective analysis of catch equation results comparing the 2004 and 2006 analyses was presented in the 2006 assessment. The Tagging Subcommittee decided that a retrospective analysis of the instantaneous rates model would be more useful for the 2008 assessment. However the results of the 2006 retrospective analysis based on the catch equation is presented in Figure 1 (fish ≥ 28 inches) and Figure 2 (fish ≥ 18 inches) for reference.

C. Instantaneous Rates Model

The Akaike weights assigned to the candidate models are presented in Table 11 (fish ≥ 28 inches) and Table 12 (fish ≥ 18 inches). For fish ≥ 28 inches multiple models were used for every program except Massachusetts, Hudson River and Delaware River. The Vic period model (v, regulatory based model except for a separate terminal year) was exclusively used by Massachusetts, predominantly by the New York Ocean Haul Seine and Maryland programs and partially by Virginia and North Carolina. The Des model (d, regulatory period based model with a separate terminal two year period) was the predominant model for the Delaware River and of secondary importance in Virginia. The year-specific (time saturated) models were used by New Jersey and the other programs used different variations of the period models.

For fish ≥ 18 inches, the model selection was similar to the ≥ 28 inch fish for the coastal programs, but differed significantly among the producer programs, especially in 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 C.

III. ESTIMATES OF EXPLOITATION RATES

The exploitation rates for fish ≥ 28 inches are presented by program and as an unweighted coastwide mean (Table 13). The 2008 estimates of exploitation ranged from a maximum of 0.19 (NCCOOP) down to 0.07 (MADFW and NYOHS). The annual estimates of exploitation rate has declined for every program since the late 1990's. The 2008 overall coastwide mean exploitation rate was 0.13, which continued a decline since a peak value of 0.26 in 1997.

The exploitation rates for fish ≥ 18 inches (Table 14) were slightly lower than those for fish ≥ 28 inches, ranging from 0.03 (NYOHS) to 0.18 (NCCOOP). The temporal pattern of the annual exploitation estimates are similar to the ≥28 inches estimates with every program showing recent declines. The mean exploitation rate peaked in 1997 and 1998 (0.14) and has declined to the current value of 0.09.

IV. ESTIMATES OF S

A. 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 Table 15 (fish ≥ 28 inches) and Table 16 (fish ≥ 18 inches). The 2008 bias-corrected estimates of S for fish ≥ 28 inches ranged from 0.53 (NCCOOP) to 0.81 (MADFW) among the coastal programs. The survival estimates from the Massachusetts and New Jersey programs were quite stable over the past few years, but the estimates from the North Carolina and New York programs were lower in 2008 than in the previous few years. The bias-corrected survival estimates from the producer programs ranged from 0.55 (VARAP) to 0.73 (DE/PA). The annual estimates were stable over the past few years for all four producer programs, but the estimate from the Virginia program was much lower than for the others.

The 2008 bias-corrected estimates of S for fish ≥ 18 inches ranged from 0.57 (NCCOOP and NYOHS) to 0.78 (MADFW) among the coastal programs and from 0.49 (VARAP) to 0.69 (HUDSON) among the producer programs. The survival estimates for both size categories were equal to or lower than reported in the 2006 assessment.

B. Instantaneous Rates Model

The estimates of the annual survival rate produced by the Instantaneous Rates model for striped bass ≥ 28" in 2008 ranged from 0.70 (NCCOOP) to 0.82 (MADFW) among the coastal programs (Table 17). The unweighted average of these survival estimates was 0.77 and has varied from only 0.74-0.78 since 2000. The 2008 survival estimates for the producer areas ranged from 0.67 (VARAP) to 0.82 (DE/PA) and the weighted average was 0.75 and has varied from only 0.72-0.75 since 2000.

The estimates of the annual survival rate for striped bass ≥ 18" in 2008 ranged from 0.68 (NCCOOP) to 0.81 (MADFW) among the coastal programs (Table 18). The unweighted average of these survival estimates was 0.75 and have varied from only 0.73-0.75 since 2000. The 2008 survival estimates for the producer areas ranged from 0.56 (VARAP) to 0.75 (HUDSON and MDCB) and the weighted average was 0.70.

V. Estimates of F and M

A. 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.

Using constant M, the 2008 estimates of F for fish ≥ 28 inches among the coastal programs ranged from 0.06 (MADFW) to 0.49 (NCCOOP) with an unweighted average of 0.32 (Table 19). The F estimates from the Massachusetts program were much lower than from the other coastal programs while the annual estimates from the New York program were highly erratic and often negative. These negative values were not included in the area averages. The 2008 estimates of F for the producer area programs ranged from 0.17 (DE/PA) to 0.45 (VARAP) and had a weighted average of 0.28. These average values are very near the target value of 0.30.

Using constant M, the 2008 estimates of F for fish ≥ 18 inches among the coastal programs ranged from 0.09 (MADFW) to 0.42 (NYOHS) with an unweighted average of 0.29 (Table 20). The estimates from the Massachusetts program were again much lower than the other coastal programs. The 2008 estimates of F from the producer area programs ranged from 0.22 (HUDSON) to 0.56 (VARAP) and had a weighted average of 0.44. These values are notably higher than those reported in the 2006 assessment.

B. Program MARK and Baranov's catch equation

Results for each program are presented in Table 21 (fish ≥ 28 inches) and Table 22 (fish ≥ 18 inches), 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 2008 catch equation estimates of F for fish ≥ 28 inches among the coastal programs ranged from 0.08 (MADFW) to 0.26 (NCCOOP). The Massachusetts and New Jersey estimates showed temporal stability while the estimate for North Carolina has increased in recent years while the estimate for New York has decreased. However, all values are below the 0.30 target value for F. The F estimates for the producer programs ranged from 0.13 (MDCB) to 0.20 (VARAP). The Hudson River and Maryland estimates showed temporal stability while the Delaware and Virginia estimates of F decreased in recent years.

The 2008 catch equation estimates of F for fish ≥ 18 inches among the coastal programs ranged from 0.05 (NYOHS) to 0.24 (NCCOOP, Table 22). The New Jersey estimate has remained temporally stable while the Massachusetts and New York programs have shown a slight, but steady decline while the North Carolina program has shown a recent increase. The F estimates for the producer area programs were in a narrow range from 0.10 (HUDSON) to 0.15 (MDCB). Each program has shown a recent decline in their respective F estimates.

The unweighted mean fishing mortality in 2008 for fish ≥ 28 inches among the coastal programs was 0.15 (Table 23). The mean F has varied from only 0.12-0.17 since 2000 and has been constant since 2006. The weighted mean F in 2008 for fish ≥ 28 inches among the producer area programs was 0.16. The mean F peaked at 0.26 in 1998 and 1999, but has decreased steadily to 0.16 in 2007 and 2008.

The unweighted mean fishing mortality in 2008 for fish ≥ 18 inches among the coastal programs was 0.11 (Table 24). Although this is among the highest value in the 1987-2008 time series, the mean F has varied from only 0.06-0.12 since 1990. The weighted average among the producer programs was 0.13. The mean F peaked at 0.35 in 1997 and has decreased steadily to 0.16 in 2007 and 2008.

C. Instantaneous Rates Model

The 2008 IRCR estimates of F for fish ≥ 28 inches among the coastal area programs ranged from 0.08 (MADFW) to 0.17 (NJ/DEL) for an unweighted average F of 0.13 (Table 25). The annual estimates of F peaked at 0.25 in 1998, but have varied from only 0.12-0.17 since 2000. The F estimates for the producer area programs ranged from 0.08 (DE/PA and MDCB) to 0.18 (HUDSON) and a weighted average of 0.10. The

Delaware River F values were the highest reported among the producer areas in 2006 but were incorrectly estimated. The updated values in this assessment are more consistent with the other producer programs. The mean fishing mortality estimates from both the coastal and the producer area programs were well below the target value of 0.30.

The 2008 IRCR estimates of F for fish ≥ 18 inches among the coastal areas showed little variation, ranging from 0.05 (NYOHS) to 0.12 (NJ/DEL) for an unweighted average of 0.09 (Table 26). The average F value has declined from 0.15 in 1998 to 0.09 for 2006-2008. The estimates of F for the producer area programs also showed little variation, ranging from 0.07 (MDCB) to 0.12 (HUDSON) for a weighted average of 0.08.

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VI. ESTIMATES OF STOCK SIZE

A. Program MARK and constant M

Stock size estimates based on constant M for fish ≥ 18 inches (age 3+) was 11.7 million fish (Table 27), the lowest estimate of stocks size since 1994 and a decrease of 6.7 million fish since the peak estimate in 2003 at 18.4 million fish. The stock size estimate has varied from 11.7-18.4 million fish since1995.

The stock size estimates based on a constant M for fish ≥ 28 inches (age 7+) show a gradual increase to a peak of12.0 million fish in 2002 (Table 27). The 2008 estimate for fish ≥ 28 inches was 6.5 million fish, a decrease of 1.4 million from the estimated stock size in 2007 and 2 million less fish than in 2006.

B. Program MARK and Baranov's catch equation

Stock size estimates based on the catch equation method for fish ≥ 18 inches has shown a rapid growth from 34.9 million fish in 2003 to a peak of 49.9 million fish in 2007 (Table 28). However, the 2008 stock size estimate decreased to 34.8 million fish, the smallest stock size estimate since 2003.

The stock size estimates based on the catch equation method for fish ≥ 28 inches peaked at 15.2 million fish in 2002 (Table 28) but a decrease to 12.7 million fish in 2008.

C. Instantaneous Rates Model

The stock size estimates based on the instantaneous rates method for fish ≥ 18 inches also exhibit a rapid increase from 33.3 million fish in 2002 to a peak of 67.9 million fish in 2007 (Table 29). However, the estimate of stock size decreased to 49.9 million fish in 2008.

The stock size estimates based on the instantaneous rates method for fish ≥ 28 inches steadily increased from 10.0 million fish in 2001 to a peak of 18.9 million fish in 2007 (Table 29). The 2008 estimate of stock size was 16.8 million fish.

VII. 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 matries for Program MARK and the IRCR and 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

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A. Program MARK and constant M

The year-specific (time-saturated) model received 100% of the weight in the Program MARK analysis of the 18-28 inch, resident stock of striped bass in Chesapeake Bay (Table 30). This produced an adjusted survival estimate for 2008 of 0.44 (Table 31). The annual estimates of survival peaked in 1989 during the moratorium at 1.01, but decreased to 0.60-0.75 from 1990-1996, decreased further to 0.28-0.50 since (with the exception of 2003). The resulting estimates of fishing mortality were very high and have often exceeded 1.0

B. Program MARK and Baranov's catch equation

The combined (Virginia and Maryland) program estimate of the catch rate for 2008 was 0.08 (Table 32). The estimate of catch rate peaked at 0.19 in 1995, but has varied 0.08-0.13 since 2002. The estimate of exploitation rate for 2008 was 0.05 The estimates of exploitation rate have varied from only 0.05-0.08 since 2002.

The estimate of instantaneous fishing mortality resulting from using the estimates of survival and exploitation rate in the Baranov catch equation for 2008 was 0.08 with instantaneous natural mortality estimated as 0.76 (Table 33). The estimates of F have been stable, varying from only 0.08-0.12 since 2002, but the estimates of M were consistently high and since 2000 have often exceeded 1.0.

C. Instantaneous Rates Model

The instantaneous rates 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 1997-2008). The years of the time periods were determined by the lowest AIC value of multiple model runs (this methodology is described in Appendix C).

The year-specific (time-saturated) model received 100% of the weight in the constant M Instantaneous Rates model analysis (Table 30). The model produced a estimate of constant instantaneous natural mortality of 0.37 and survival estimates that varied from 0.59-0.69 (Table 34). Since 2000, the estimates of survival have varied from only 0.65-0.67. The estimate of instantaneous fishing mortality for 2008 was 0.03 and has varied from only 0.03-0.05 since 2001.

When two mortality periods are specified, the two-M suite received 100% of the weight, partitioned among two of the year-specific F models (Table 30). The two estimates of instantaneous natural mortality differ greatly between the two periods, 0.27 and 0.80 respectively (Table 35). The estimates of survival decrease slowly from 0.76-0.70 from 1987 to 1996, but then have values of 0.38-0.42 from 1997 to 2008. The estimates of instantaneous fishing mortality peaked at 0.15 in 1998, but have declined steadily to an estimate of 0.07 in 2008.

DISCUSSION

I. DATA

The number of striped bass tagged by each program, their respective length frequencies and age distributions were all fairly typical of the past five years, except that North Carolina released only 370 striped bass in 2007, their second lowest release total. 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.

II. *Model Diagnostics and Assumptions*

A. 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.

B. 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.

C. 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.

III. 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.

However, there is evidence that this estimate may be low. The most recent information for reporting rate is from a high reward tagging study implemented by Maryland Department of Natural Resources in the spring of 2006. In April and May of 2006 tagging efforts were increased to include marking striped bass with high reward tags concurrently with standard tags from the USFWS Cooperative Coastal Striped Bass Tagging Program. Fish were tagged in the upper Chesapeake Bay and the upper Potomac River. High reward tags were applied to every sixth fish resulting in approximately 20% of all fish tagged having high reward tags. Returns of tags with a $125 reward were used to estimate the tag-reporting rate. This value represented a 25% increase over the $100 high reward used by Nichols et al. (1991) and a considerable increase from their estimate of $70 to elicit 100% reporting. All tags reported within the 13-month period following tag deployment were included in analysis, so the reporting period was April 2006 through May 2007. A total of 772 striped bass were tagged with standard tags and 153 with high reward tags. Recoveries were used from both Chesapeake Bay and Atlantic coast fisheries for a total of 61 standard tag recoveries and 16 high reward tag recoveries. Tag reporting rate was estimated to be 0.756 (±0.045 SE) from all fisheries dependent sources and all areas of recovery. The recreational reporting rate was 0.826 (±0.070) and the commercial reporting rate was 0.545 (±0.101).

These Maryland results are from one release area, and will complement the expanded high reward tagging studies initiated in 2007. The expansion of the high reward study to additionally include the Rappahannock, Delaware and Hudson Rivers for tagging in 2007 will help address further precision and accuracy of tag reporting rates, both from an increased sample size perspective, and an assessment of possible geographic differences. Results from the high reward tag study are detailed in Appendix D.

However, for continuity to previous assessments, the SBTS chose to continue with current convention and use the 0.43 reporting rate estimate from Kahn and Shirey (2000) for the 2007-2008 analyses until the results and implications of the current high reward tag study have been fully evaluated and approved.

IV. ESTIMATES OF S

The bias-corrected estimates of S (Program MARK) spanned the same range (0.49 – 0.81) for both length groups of fish, although values for fish ≥ 18 inches fish were slightly lower than those for fish ≥ 28 inches. The survival estimates were consistently highest from Massachusetts among the coastal program and Hudson River among the producer area programs. Conversely, North Carolina and Virginia consistently had the lowest survival estimates.

The IRCR model estimates of S produced similar estimates of survival, ranging from 0.67-0.82 for striped bass ≥ 28 inches and 0.56-0.81 for striped bass ≥ 18 inches.

V. 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 10A and 10B).

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 3 and 4. 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 4.

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.

VI. 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 5 and 6. Estimates for age 7+ fish from the three methods are fairly similar through 2000, when the constant M estimates stablize 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.

VII. 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 0.08 - 0.15 $year^{-1}$ without trend since that time. The 2008 estimate of F for the Chesapeake Bay was 0.08 $year^{-1}$.

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" 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), the 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 year $^{-1}$. 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 partially 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 year^{-1} in 1992, fluctuated without trend through 1998, then declined to 0.03 year^{-1} in 2008. When two different periods of M were considered, similar patterns were observed, but values were lower from 1991-1998 and higher from 1999-2008. The IRCR model estimated levels of natural mortality that were up to five times the previously assumed value of 0.15 year^{-1} 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 year^{-1}). 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 and declined only slightly thereafter.

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.

VIII. 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 = {2003-2008}
** Periods (d)	1 = {1987-1989}, 2 = {1990-1994}, 3 = {1995- 1999}, 4 = {2000-2002}, 5 = {2003-2007}, 6 = {2008}
*** Periods (v)	1 = {1987-1989}, 2 = {1990-1994}, 3 = {1995- 1999}, 4 = {2000-2002}, 5 = {2003-2006}, 6 = {2007-2008}

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.
2003-2008	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, M87-08 (Global Model)	F and F' estimated each year, constant M for entire period
2	F87-89, F90-94, F95-99, F00-02, F03-08, F'y, M87-08	Constant F for each regulatory period, F' estimated each year, constant M for entire period
3	F87-08, F'y, M87-08	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'03-08,M87-08	F estimated each year, constant F' for each regulatory period, constant M for entire period
5	Fy, F'87-08,M87-08	F estimated each year, constant F' for entire period, constant M
6	F87-89, F90-94, F95-99,F00-02, F03-06, F87-89,F'90-94, F'95-99,F'00-02, F'03-08,M87-08	Constant F for each regulatory period, constant F' for each regulatory period, constant M for entire period
7	F87-08,F'87-08,M87-08	Constant F for entire period, constant F' for entire period, constant M for entire period
8	F87-89, F90-94, F95-99, F00-02, F03-07, F08; F'87-89, F'90-94, F'95-99, F'00-02, F'03-07, F'08, M87-08	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, F03-06, F07-08; F'87-89, F'90-94, F'95-99, F'00-02, F'03-06, F'07-08, M87-08	Constant F and F' for each regulatory period with separate estimate for terminal two years, constant M for entire period

Table 4a. Total length frequencies of fish tagged in 2007 by program.

	Coast programs				Producer Area programs			
TL (mm)	MADFW	NYOHS	NJDEP	NCCOOP	DE/PA	MDCB	VARAP	Hudson
<199	0	0	0	0	0	0	0	0
200-249	0	0	0	0	0	2	0	0
250-299	0	0	0	0	0	3	0	0
300-349	0	0	0	0	0	30	0	0
350-399	0	0	0	0	4	49	0	0
400-449	0	25	0	0	72	187	0	0
450-499	0	0	0	1	85	153	368	72
500-549	0	670	7	2	51	59	378	66
550-599	0	0	29	4	47	39	264	68
600-649	8	258	140	19	40	33	109	72
650-699	28	217	395	35	30	17	2	63
700-749	68	111	316	49	20	14	25	49
750-799	85	39	119	57	22	23	78	68
800-849	74	17	35	51	18	22	101	108
850-899	88	4	34	65	27	30	202	102
900-949	84	6	8	46	24	49	220	46
950-999	56	2	5	23	19	30	154	21
1000-1049	26	0	1	14	8	17	44	11
1050-1099	7	0	1	7	1	11	13	6
>1099	6	0	0	3	1	5	3	4

Table 4b. Total length frequencies of fish tagged in 2008 by program.

	Coast programs				Producer Area programs			
TL (mm)	MADFW	NYOHS	NJDEP	NCCOOP	DE/PA	MDCB	VARAP	Hudson
<199	0	0	0	0	0	0	0	0
200-249	0	0	0	0	0	0	0	0
250-299	0	0	0	0	0	3	0	0
300-349	0	0	0	0	1	18	0	0
350-399	0	0	0	0	6	29	0	0
400-449	0	1	0	0	82	117	0	0
450-499	0	0	2	0	107	117	176	111
500-549	1	141	14	1	72	69	137	150
550-599	1	0	171	12	67	41	97	134
600-649	10	71	357	18	47	31	36	146
650-699	39	24	298	64	28	38	2	135
700-749	76	15	246	99	22	26	5	100
750-799	78	5	162	133	21	16	9	132
800-849	84	3	119	169	10	19	12	106
850-899	62	2	71	146	19	28	13	118
900-949	48	4	32	172	17	32	14	58
950-999	35	1	3	115	19	19	15	27
1000-1049	12	0	0	52	10	13	4	12
1050-1099	7	1	1	26	3	8	2	4
>1099	3	0	0	15	4	4	1	5

Table 5a. Age frequencies of tagged fish recaptured in 2007 by program (N/A ages not available).

	Coast Programs				Producer Area Programs			
AGE	MADFW	NYOHS	NJDEP	NCCOOP	Hudson	De/Pa	MDCB	VARAP
1				N/A	N/A			
2		11						
3		108						
4		773	2			3	4	24
5		135	27			2	0	24
6	2	207	74			8	5	3
7	2	58	67			10	3	5
8	6	21	21			2	0	6
9	2	16	29			6	3	10
10	2		19			5	4	17
11	8	2	24			3	3	13
12	0	3	8			2	2	8
13	2		7			3	6	6
14	5		3			6	4	2
15	1		4			3	4	1
16	0		1			2	2	1
17	1		2			3	1	0
18	0		1			1	0	1
19	1		0				0	
20			2				1	
21								
22								
23								
Total	32	1334	291		0	59	42	121

Table 5b. Age frequencies of tagged fish recaptured in 2008 by program (N/A ages not available).

	Coast Programs				Producer Area Programs			
AGE	MADFW	NYOHS	NJDEP	NCCOOP	HUDSON	DE/PA	MDCB	VARAP
1			0	N/A	N/A			
2			0					
3	0	10	0			1		
4	0	43	9			7		8
5	0	165	31			13		17
6	1	19	21			11	1	6
7	8	15	67			12	1	0
8	5	5	46			6	2	3
9	3	3	24			5	3	3
10	7	2	25			2	3	5
11	10	1	15			2	0	9
12	4	1	24			2	4	13
13	3	1	9			3	6	9
14	1	1	7			2	3	1
15	0		6			1	1	1
16	0		0			1	2	
17	1		1			1	0	
18	0		1			1	2	
19	0		1			1	0	
20	1		0				2	
21	0		0			1		
22	0		0					
23	1		0					
Total	45	266	287		0	72	30	75

Table 6. Distribution of tag recaptures by state (program) and month.

Massachusetts (recaptures in 2007 from fish tagged and released during 1992-2007)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA					1	3	7	4	2	3			20
RI						1							1
CT													0
NY					5	3			1	1			10
NJ				2	3	1	1	1			3	1	12
PA													0
DE					1						1		2
MD			1	3	3							3	10
VA	12	1	1								1	4	19
NC												1	1
UN						1							1
Total	12	1	2	5	13	9	8	5	3	4	5	9	76

Massachusetts (recaptures in 2008 from fish tagged and released during 1992-2008)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA					4	5	4	5	2	1			21
RI					2		2	1					5
CT									1				1
NY		1		2	6	1	3			1	3	1	18
NJ					6	1				1	3		11
PA													0
DE			2	1							1		4
MD		1	6	10	5						2	4	28
VA	5	2	2								2	5	16
NC		1											1
UN	1		1	1				1				1	5
Total	6	5	11	14	23	7	9	7	3	3	11	11	110

Table 6 continued.

New York - Ocean Haul Seine (recaptures in 2007 from fish tagged/release during 1988-2007)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME						2	3	1					6
NH								1		1			2
MA					9	9	7	5	7	1			38
RI					2	4			1	2			9
CT					1		2		1				4
NY				1	7	8	5	3	3	6	2		35
NJ	2		3	7	8	3					8	4	35
PA													0
DE	2			1	1								4
MD	1			2	1								4
VA													0
NC		1											1
Total	5	1	3	11	29	26	17	10	12	10	10	4	138

New York - Ocean Haul Seine (recaptures in 2008 from fish tagged/release during 1988-2008)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME							1						1
NH						1							1
MA					5	6	11	3	8	1			34
RI					1	4	5	2	2	1			15
CT	1			1	1	2		2		1			8
NY			1	5	6	7	4	5	3	6	3		40
NJ			1	2	5	1		1		2	11		23
PA													0
DE													0
MD	3			3	2								8
VA	2	3	1								1		7
NC													0
Total	6	3	3	11	20	21	21	13	13	11	15	0	137

Table 6 continued.

New Jersey - Delaware Bay (recaptures in 2007 from fish tagged/release during 1989-2007)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME							2						2
NH						1		1					2
MA	1				7	21	24	13	7	3			76
RI					2	12	4	2	2	2			24
CT					7	10	3	3	2	1			26
NY			1	3	15	16	11	10	6	15	4	1	82
NJ				3	24	5	3		1	2	16	1	55
PA													0
DE			2	2							2	1	7
MD			1	12	14		1	1			1	4	34
VA	4	6	2		1							4	17
NC													0
Total	5	6	6	20	70	65	48	30	18	23	23	11	325

New Jersey - Delaware Bay (recaptures in 2008 from fish tagged/release during 1989-2008)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH						2							2
MA	1				4	22	24	19	10				80
RI					7	11	6	7	4	3			38
CT					5	5	6	2	2				20
NY			1	3	7	19	10	10	4	12	6		72
NJ				3	7	4	3		1	4	12		34
PA					1								1
DE			2	2							2		6
MD			1	12	10	1					5	1	30
VA	4	6	2								1		13
NC													0
Total	5	6	6	20	41	64	49	38	21	19	26	1	296

Table 6 continued.

North Carolina - Winter Trawl Survey (recaptures in 2007 from fish tagged and released during 1992-2007)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME						1		1					2
NH								1					1
MA					7	10	17	10	9	3			56
RI					1	4	5	2	2	3	1		18
CT					2	1	4	1	1	2	1		12
NY					9	12	7	4	6	7	5	1	51
NJ				4	10	10	2				10		36
PA													0
DE			1	1		1	1						4
MD			3	12	23	10	5	5	1	3	6	4	72
VA	9	6	3	1	1	1		1	2	2	2	12	40
NC				2	1			3					6
Total	9	6	7	20	54	50	41	28	21	20	25	17	298

North Carolina - Winter Trawl Survey (recaptures in 2008 from fish tagged and released during 1992-2008)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME						1							1
NH													0
MA					4	18	14	14	5	1			56
RI					2	5	2	1	3				13
CT					1	3	1	3	2				10
NY				2	13	11	5	4	3	8			46
NJ				1	9	8	1			2	7		28
PA													0
DE			1		1						2		4
MD	1	1	3	20	19	5	3	2		3	5	1	63
VA	6	13	2	1			1	1		2	4	6	36
NC	1	1									1	1	4
Total	8	15	6	24	49	51	27	25	13	16	19	8	261

Table 6 continued.

Producer Area Programs

Hudson River (recaptures in 2007 from fish tagged and released during 1992-2007)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH						1							1
MA					1	7	9	6	2	2			27
RI						5	6	2	1	1	1		16
CT						5	3	1	1	2	1		13
NY				4	28	33	13	5	9	9	10		111
NJ				1	2	10	4		2	3	18	4	44
PA													0
DE													0
MD			2	1								1	4
VA	3	2										3	8
NC													0
Total	3	2	2	6	31	61	35	14	15	17	30	8	224

Hudson River (recaptures in 2008 from fish tagged and released during 1992-2008)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME								1					1
NH													0
MA					1	10	12	14	2	1			40
RI						6		2	2				10
CT						3	4	3	1	2			13
NY				5	55	30	15	9	5	15	11	2	147
NJ					1	4	3			3	16	1	28
PA													0
DE			1								1	1	3
MD	1			1	1						1	1	5
VA	4	4	4									1	13
NC													0
Total	5	4	5	6	58	53	34	29	10	21	29	6	260

Table 6 continued.

Delaware / Pennsylvania - Delaware River (recaptures in 2007 from fish tagged and released during 1992-2007)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA						1	1						2
RI						1	1						2
CT						1							1
NY					1	1	2	1		1	1		7
NJ					7	7	5	1	5		6	4	35
PA					1								1
DE					6	3	6	1		2	2	1	21
MD			1		2	4	2		1	3	1		14
VA	1	1			1		1					4	8
NC													0
Total	1	1	1	0	18	18	18	3	6	6	10	9	91

Delaware / Pennsylvania - Delaware River (recaptures in 2008 from fish tagged and released during 1992-2008)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA							1	2	1				4
RI					1			1					2
CT					1								1
NY					1	1			1	2	2		7
NJ	1			1	3	17	5	1	1	2	7	1	39
PA			1	3		1							5
DE				1	1	1	2	2		1	3	1	12
MD			2		1	1	3	3	1	3	2	2	18
VA	1	1											2
NC													0
Total	2	1	3	5	8	21	11	9	4	8	14	4	90

Table 6 continued.

Maryland - Chesapeake Bay (recaptures in 2007 from fish tagged and released during 1992-2007)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA						3	4	2	2	1			12
RI								1	1				2
CT													0
NY					1					5			6
NJ						1	1			1	1		4
PA													0
DE					1							1	2
MD	1	3	2	1	7	12	14	10	5	6	1	2	64
DC					1								1
VA	5		1		1	1				2	3	7	20
NC	1		1										2
Total	7	3	4	1	11	17	19	13	8	15	5	10	113

Maryland - Chesapeake Bay (recaptures in 2008 from fish tagged and released during 1992-2008)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA							2	4	1				7
RI													0
CT							2						2
NY					2	1		1					4
NJ						3					1		4
PA													0
DE													0
MD			2	7	10	8	3	5	2	4	5		46
DC													0
VA	1	2	1		1	1				3	2	4	15
NC	1		1										2
Total	2	2	4	7	13	13	7	10	3	7	8	4	80

Table 6 continued.

Virginia - Rappahannock River (recaptures in 2007 from fish tagged and released during 1990-2007)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH						1							1
MA						3	12	3	5	1			24
RI						3	2		1				6
CT						1		1					2
NY					2	2	1	1	5	3	1		15
NJ						3					4		7
PA													0
DE						1					1		2
MD					2	11	10	5	3	2	3		36
VA	3		1	12	10	8	2	1	2	5	4	15	63
NC	1	1											2
Total	4	1	1	12	14	33	27	11	16	11	13	15	158

Virginia - Rappahannock River (recaptures in 2008 from fish tagged and released during 1990-2008)

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ME													0
NH													0
MA						3	2	2	1	1			9
RI					1	3			1	1	1		7
CT						2		1	2				5
NY					3	1	1	1	1	1			8
NJ					4	1					2		7
PA													0
DE					1	1							2
MD	2		2	2	3	9	2	1	1	2	2	2	28
VA	2	2	2		6	1			1	4	8	7	33
NC													0
Total	4	2	4	2	18	21	5	5	7	9	13	9	99

Table 7. 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	NJ/DEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP	**MEAN**
1987					*		0.08		
1988		0.28		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	0.15	0.33	0.21	0.25	0.30		0.24	0.58	**0.29**
1993	0.13	0.28	0.20	0.28	0.33	0.20	0.22	0.57	**0.28**
1994	0.11	0.23	0.20	0.20	0.27	0.20	0.22	0.36	**0.22**
1995	0.16	0.35	0.23	0.27	0.26	0.21	0.28	0.55	**0.29**
1996	0.19	0.32	0.32	0.15	0.31	0.41	0.26	0.21	**0.27**
1997	0.34	0.40	0.41	0.24	0.37	0.29	0.28	0.44	**0.34**
1998	0.17	0.17	0.39	0.26	0.29	0.34	0.28	0.60	**0.31**
1999	0.24	0.36	0.21	0.27	0.30	0.19	0.25	0.37	**0.27**
2000	0.14	0.33	0.22	0.13	0.22	0.36	0.20	0.41	**0.25**
2001	0.12	0.21	0.23	0.21	0.20	0.28	0.16	0.35	**0.22**
2002	0.15	0.38	0.17	0.15	0.24	0.24	0.13	0.44	**0.24**
2003	0.12	0.21	0.24	0.16	0.22	0.26	0.16	0.38	**0.22**
2004	0.12	0.26	0.26	0.17	0.27	0.28	0.11	0.23	**0.21**
2005	0.11	0.33	0.30	0.10	0.24	0.23	0.15	0.28	**0.22**
2006	0.15	0.21	0.26	0.17	0.20	0.26	0.17	0.27	**0.21**
2007	0.05	0.29	0.20	0.24	0.20	0.26	0.12	0.20	**0.20**
2008	0.10	0.13	0.21	0.25	0.22	0.14	0.13	0.15	**0.17**

Table 8. 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	NJ/DEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP	**MEAN**
1987					*		0.17		**0.17**
1988		0.18		0.19	0.15		0.10		**0.15**
1989		0.23	0.25	0.11	0.21		0.08		**0.17**
1990		0.20	0.38	0.16	0.27		0.14	0.38	**0.25**
1991		0.18	0.17	0.19	0.25		0.20	0.28	**0.21**
1992	0.16	0.19	0.19	0.25	0.24		0.24	0.54	**0.26**
1993	0.12	0.14	0.17	0.21	0.25	0.23	0.18	0.40	**0.21**
1994	0.12	0.17	0.17	0.17	0.22	0.24	0.23	0.37	**0.21**
1995	0.14	0.15	0.20	0.23	0.23	0.27	0.29	0.30	**0.23**
1996	0.18	0.17	0.24	0.14	0.27	0.34	0.28	0.26	**0.24**
1997	0.28	0.18	0.26	0.21	0.31	0.21	0.30	0.27	**0.25**
1998	0.18	0.15	0.28	0.24	0.25	0.25	0.33	0.24	**0.24**
1999	0.16	0.15	0.17	0.27	0.22	0.17	0.24	0.23	**0.20**
2000	0.11	0.14	0.20	0.15	0.21	0.25	0.27	0.24	**0.19**
2001	0.10	0.15	0.22	0.17	0.19	0.24	0.19	0.29	**0.19**
2002	0.15	0.19	0.13	0.18	0.18	0.19	0.17	0.29	**0.18**
2003	0.12	0.15	0.20	0.15	0.20	0.25	0.19	0.27	**0.19**
2004	0.11	0.14	0.25	0.17	0.22	0.21	0.16	0.17	**0.18**
2005	0.11	0.16	0.23	0.08	0.18	0.27	0.15	0.19	**0.17**
2006	0.14	0.18	0.18	0.16	0.17	0.23	0.20	0.22	**0.19**
2007	0.05	0.14	0.22	0.21	0.16	0.18	0.13	0.17	**0.16**
2008	0.09	0.12	0.19	0.23	0.17	0.21	0.16	0.11	**0.16**

Table 9. 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

Model	MADFW	NYOHS	NJ/DEL	NCCOOP
{S(.)r(.)}	0	0	0	0
{S(.)r(p)}	**0.226**	0.005	0	0.003
{S(.)r(t)}	0.001	0	0.009	0
{S(p)r(p)}	0.033	**0.071**	**0.439**	0.039
{S(p)r(t)}	0.001	0	**0.153**	0.004
{S(d)r(p)}	0.012	0.030	**0.178**	**0.269**
{S(v)r(p)}	**0.724**	**0.055**	**0.185**	**0.669**
{S(t)r(p)}	0.002	0.001	0	0.005
{S(t)r(t)}	0	**0.837**	0.036	0.012

Producer Area Programs

Model	HUDSON	DE/PA	MDCB	VARAP
{S(.)r(.)}	0	0.023	0	0
{S(.)r(p)}	**0.471**	0.037	0	0.035
{S(.)r(t)}	0	0.001	0	0.010
{S(p)r(p)}	**0.254**	**0.112**	**0.467**	**0.538**
{S(p)r(t)}	0	0	0.003	0.002
{S(d)r(p)}	**0.095**	**0.596**	**0.175**	**0.213**
{S(v)r(p)}	**0.177**	**0.229**	**0.349**	**0.199**
{S(t)r(p)}	0.002	0.001	0.005	0
{S(t)r(t)}	0	0	0	0.002

Table 10. 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

Model	MADFW	NYOHS	NJ/DEL	NCCOOP
{S(.)r(.)}	0	0	0	0
{S(.)r(p)}	**0.347**	0	0	0
{S(.)r(t)}	0.023	0	0	0
{S(p)r(p)}	**0.054**	0	0	0
{S(p)r(t)}	0.007	0	0	0
{S(d)r(p)}	0.021	0	0	0
{S(v)r(p)}	**0.543**	0	0	0
{S(t)r(p)}	0.005	0	0	0
{S(t)r(t)}	0	**1.000**	**1.000**	**1.000**

Producer Area Programs

Model	HUDSON	DE/PA	MDCB	VARAP
{S(.)r(.)}	0	0	0	0
{S(.)r(p)}	0.007	0	0	0
{S(.)r(t)}	0	0.013	0	0
{S(p)r(p)}	**0.450**	0.002	0	0
{S(p)r(t)}	0	**0.826**	**1.000**	0
{S(d)r(p)}	**0.186**	0.004	0	0
{S(v)r(p)}	**0.337**	0.004	0	0
{S(t)r(p)}	0.019	**0.149**	0	0
{S(t)r(t)}	0	0	0	**1.000**

Table 11. Akaike weights used to derive model averaged parameter estimates using the Instantaneous Rates model for striped bass ≥28 inches.

Coast Programs

Model	MADFW	NYOHS	NJ/DEL	NCCOOP
F(t), Ft(t), M(.)	0	0.001	**0.455**	**0.064**
F((5p), Ft(t), M(.)	0	0.008	0	**0.427**
F(.), Ft(t), M(.)	0	0	0	0
F(t), Ft(5p), M(.)	0.010	0.009	**0.545**	0.027
F(t), Ft(.), M(.)	0	0	0	0
F(5p), Ft(5p), M(.)	0.008	**0.086**	0	**0.176**
F(.). Ft(.), M(.)	0	0	0	0
F(d), Ft(d), M(.)	0.007	0.049	0	**0.153**
F(v), Ft(v), M(.)	**0.975**	**0.846**	0	**0.153**

Producer Area Programs

Model	HUDSON	DE/PA	MDCB	VARAP
F(t), Ft(t), M(.)	0.002	0.000	0.009	0
F((5p), Ft(t), M(.)	**0.998**	0.000	0.012	0
F(.), Ft(t), M(.)	0	0.000	0	0
F(t), Ft(5p), M(.)	0	0.010	**0.132**	0.049
F(t), Ft(.), M(.)	0	0.000	0	0
F(5p), Ft(5p), M(.)	0	0.008	**0.122**	**0.369**
F(.). Ft(.), M(,)	0	0.000	0	0
F(d), Ft(d), M(.)	0	**0.975**	0.078	**0.354**
F(v), Ft(v), M(.)	0	0.007	**0.647**	**0.228**

Table 12. Akaike weights used to derive model averaged parameter estimates using the Instantaneous Rates model for striped bass ≥18 inches.

Coast Programs

Model	MADFW	NYOHS	NJ/DEL	NCCOOP
{F(t)F'(t)}	0	0	**0.830**	0.024
{F(p)F'(t)}	0	0	**0.072**	**0.930**
{F(.)F'(t)}	0	0	0	0
{F(t)F'(p)}	**0.054**	0	**0.075**	0.001
{F(t)F'(.)}	0	0	0	0
{F(p)F'(p)}	0.025	**0.163**	0.013	0.025
{F(.)F'(.)}	0	0	0	0
{F(d)F'(d)}	0.014	**0.141**	0.005	0.011
{F(v)F'(v)}	**0.907**	**0.695**	0.005	0.009

Producer Area Programs

Model	HUDSON	DE/PA	MDCB	VARAP
{F(t)F'(t)}	0.012	0.000	**1**	0
{F(p)F'(t)}	**0.988**	0.002	0	0
{F(.)F'(t)}	0	0.005	0	0
{F(t)F'(p)}	0	0.001	0	**0.521**
{F(t)F'(.)}	0	0.000	0	0
{F(p)F'(p)}	0	**0.115**	0	**0.245**
{F(.)F'(.)}	0	**0.136**	0	0
{F(d)F'(d)}	0	**0.686**	0	**0.183**
{F(v)F'(v)}	0	**0.054**	0	**0.051**

Table 13. 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	NJ/DEL	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		0.14	0.18	0.07	0.10		0.12	0.36	**0.16**
1992	0.05	0.12	0.02	0.13	0.13		0.12	0.37	**0.13**
1993	0.07	0.14	0.09	0.11	0.17	0.13	0.12	0.37	**0.15**
1994	0.05	0.09	0.05	0.08	0.12	0.12	0.12	0.25	**0.11**
1995	0.05	0.22	0.11	0.14	0.15	0.14	0.21	0.41	**0.18**
1996	0.09	0.14	0.20	0.11	0.22	0.32	0.17	0.18	**0.18**
1997	0.17	0.31	0.25	0.18	0.31	0.27	0.23	0.38	**0.26**
1998	0.10	0.17	0.35	0.20	0.22	0.28	0.23	0.45	**0.25**
1999	0.13	0.34	0.08	0.24	0.21	0.15	0.21	0.28	**0.21**
2000	0.13	0.14	0.14	0.06	0.14	0.30	0.17	0.28	**0.17**
2001	0.09	0.11	0.15	0.15	0.13	0.27	0.11	0.24	**0.16**
2002	0.08	0.24	0.11	0.12	0.19	0.24	0.10	0.35	**0.18**
2003	0.11	0.17	0.15	0.11	0.14	0.17	0.11	0.27	**0.15**
2004	0.10	0.13	0.15	0.12	0.21	0.24	0.08	0.15	**0.15**
2005	0.07	0.26	0.15	0.07	0.17	0.15	0.11	0.21	**0.15**
2006	0.10	0.13	0.15	0.12	0.16	0.21	0.14	0.22	**0.15**
2007	0.04	0.02	0.13	0.19	0.21	0.20	0.09	0.15	**0.13**
2008	0.07	0.07	0.14	0.19	0.18	0.12	0.11	0.15	**0.13**

Table 14. 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	NJ/DEL	NCCOOP	HUDSON	DE/PA	MDCB	VARAP	**MEAN**
1987					*		0.01		**0.01**
1988		0.02		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	0.08		0.07	0.17	**0.08**
1991		0.07	0.03	0.08	0.07		0.10	0.14	**0.08**
1992	0.05	0.05	0.04	0.14	0.09		0.13	0.31	**0.11**
1993	0.06	0.04	0.03	0.11	0.10	0.13	0.11	0.23	**0.10**
1994	0.04	0.03	0.03	0.08	0.09	0.12	0.12	0.25	**0.10**
1995	0.04	0.06	0.06	0.14	0.12	0.12	0.19	0.19	**0.12**
1996	0.07	0.04	0.09	0.11	0.15	0.18	0.17	0.15	**0.12**
1997	0.12	0.05	0.08	0.15	0.24	0.11	0.21	0.20	**0.14**
1998	0.10	0.03	0.12	0.14	0.18	0.14	0.22	0.15	**0.14**
1999	0.09	0.06	0.05	0.22	0.14	0.10	0.17	0.13	**0.12**
2000	0.09	0.03	0.08	0.08	0.10	0.15	0.17	0.14	**0.10**
2001	0.06	0.05	0.09	0.11	0.09	0.15	0.12	0.18	**0.11**
2002	0.09	0.07	0.06	0.12	0.08	0.14	0.12	0.19	**0.11**
2003	0.08	0.06	0.08	0.11	0.10	0.15	0.13	0.18	**0.11**
2004	0.09	0.04	0.12	0.12	0.13	0.15	0.10	0.12	**0.11**
2005	0.07	0.04	0.09	0.06	0.09	0.10	0.11	0.13	**0.09**
2006	0.09	0.04	0.06	0.10	0.10	0.11	0.14	0.13	**0.10**
2007	0.03	0.02	0.11	0.16	0.13	0.08	0.09	0.12	**0.09**
2008	0.06	0.03	0.09	0.18	0.10	0.08	0.11	0.08	**0.09**

Table 15. 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 = 0.85 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	0.75	0.13	0.06	0.75	-0.11	**0.84**	**0.02**	-0.05	0.11
1993	0.75	0.13	0.07	0.57	-0.09	**0.83**	**0.04**	-0.03	0.13
1994	0.75	0.13	0.06	0.52	-0.07	**0.81**	**0.06**	-0.01	0.15
1995	0.71	0.19	0.07	0.38	-0.06	**0.76**	**0.13**	0.08	0.18
1996	0.71	0.19	0.09	0.26	-0.06	**0.76**	**0.13**	0.08	0.18
1997	0.71	0.19	0.10	0.22	-0.06	**0.76**	**0.13**	0.08	0.2
1998	0.71	0.19	0.09	0.28	-0.06	**0.76**	**0.12**	0.08	0.2
1999	0.71	0.19	0.08	0.28	-0.05	**0.75**	**0.13**	0.08	0.19
2000	0.72	0.18	0.07	0.21	-0.04	**0.75**	**0.14**	0.07	0.24
2001	0.72	0.18	0.06	0.33	-0.04	**0.75**	**0.14**	0.06	0.23
2002	0.72	0.18	0.07	0.32	-0.06	**0.76**	**0.13**	0.05	0.22
2003	0.74	0.15	0.05	0.18	-0.02	**0.75**	**0.13**	0.06	0.22
2004	0.74	0.15	0.05	0.22	-0.03	**0.76**	**0.13**	0.06	0.21
2005	0.74	0.15	0.05	0.27	-0.03	**0.77**	**0.12**	0.05	0.20
2006	0.74	0.15	0.06	0.35	-0.05	**0.78**	**0.10**	0.03	0.19
2007	0.79	0.08	0.03	0.23	-0.02	**0.81**	**0.07**	-0.03	0.23
2008	0.79	0.08	0.04	0.18	-0.02	**0.81**	**0.06**	-0.04	0.23

Table 15 continued.

New York - Ocean Haul Seine
C-hat adjustment = 1.066; bootstrap GOF probability = 0.096 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	0.12	0.88	-0.24	**0.92**	**-0.07**	0.26	-0.25
1989	0.87	-0.01	0.10	0.86	-0.19	**1.08**	**-0.23**	0.05	-0.32
1990	0.64	0.29	0.09	0.70	-0.14	**0.75**	**0.13**	0.43	-0.06
1991	0.53	0.49	0.12	0.51	-0.15	**0.62**	**0.33**	0.65	0.10
1992	0.82	0.05	0.14	0.64	-0.23	**1.06**	**-0.21**	0.10	-0.34
1993	0.49	0.56	0.11	0.54	-0.14	**0.57**	**0.41**	0.79	0.13
1994	0.66	0.27	0.11	0.68	-0.18	**0.81**	**0.06**	0.31	-0.10
1995	0.71	0.19	0.15	0.42	-0.17	**0.86**	**0.00**	0.39	-0.19
1996	0.70	0.20	0.14	0.60	-0.21	**0.89**	**-0.03**	0.45	-0.25
1997	0.83	0.04	0.15	0.25	-0.11	**0.93**	**-0.08**	0.22	-0.20
1998	0.42	0.71	0.11	0.00	0.00	**0.42**	**0.71**	1.41	0.25
1999	0.59	0.37	0.14	0.14	-0.06	**0.63**	**0.31**	0.79	0.03
2000	0.85	0.02	0.12	0.57	-0.16	**1.01**	**-0.16**	0.20	-0.28
2001	0.70	0.20	0.10	0.50	-0.13	**0.80**	**0.07**	0.54	-0.15
2002	0.86	0.01	0.12	0.43	-0.13	**0.98**	**-0.13**	0.13	-0.23
2003	0.63	0.31	0.09	0.29	-0.06	**0.67**	**0.25**	0.86	-0.05
2004	0.29	1.08	0.10	0.50	-0.13	**0.34**	**0.94**	1.91	0.26
2005	0.58	0.39	0.14	0.22	-0.09	**0.64**	**0.30**	1.16	-0.09
2006	0.83	0.03	0.11	0.40	-0.12	**0.94**	**-0.09**	0.63	-0.25
2007	0.88	-0.02	0.06	1.00	-0.12	**1.00**	**-0.15**	0.82	-0.27
2008	0.55	0.45	0.55		0.00	**0.55**	**0.45**	0.93	0.15

Table 15 continued.

New Jersey - Delaware Bay
C-hat adjustment = 0.62; bootstrap GOF probability = 0.93 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	**0.98**	**-0.04**	-0.13	0.40
1990	0.66	0.27	0.12	1.00	-0.26	**1.10**	**-0.02**	-0.25	0.37
1991	0.65	0.28	0.21	0.67	-0.36	**1.21**	**-0.17**	-0.34	0.09
1992	0.65	0.29	0.07	1.00	-0.16	**0.88**	**0.11**	-0.02	0.28
1993	0.64	0.29	0.10	0.63	-0.14	**0.86**	**0.14**	0.01	0.32
1994	0.65	0.28	0.10	0.81	-0.18	**0.87**	**0.09**	-0.02	0.22
1995	0.67	0.25	0.11	0.60	-0.15	**0.86**	**0.08**	0.00	0.17
1996	0.68	0.24	0.12	0.43	-0.14	**0.87**	**0.09**	-0.01	0.23
1997	0.66	0.26	0.08	0.42	-0.08	**0.81**	**0.18**	0.07	0.34
1998	0.67	0.25	0.16	0.10	-0.05	**0.76**	**0.20**	0.12	0.29
1999	0.67	0.25	0.10	0.67	-0.16	**0.85**	**0.08**	0.01	0.17
2000	0.74	0.15	0.09	0.41	-0.09	**0.90**	**0.05**	-0.04	0.17
2001	0.74	0.15	0.09	0.37	-0.08	**0.89**	**0.06**	-0.03	0.18
2002	0.74	0.16	0.08	0.41	-0.08	**0.87**	**0.08**	-0.01	0.19
2003	0.60	0.36	0.10	0.41	-0.11	**0.72**	**0.25**	0.18	0.33
2004	0.60	0.37	0.10	0.45	-0.12	**0.74**	**0.24**	0.15	0.35
2005	0.60	0.36	0.13	0.48	-0.16	**0.79**	**0.18**	0.09	0.29
2006	0.61	0.35	0.09	0.48	-0.10	**0.78**	**0.24**	0.10	0.42
2007	0.61	0.35	0.09	0.39	-0.08	**0.74**	**0.26**	0.15	0.40
2008	0.60	0.36	0.09	0.36	-0.08	**0.72**	**0.27**	0.17	0.39

Table 15 continued.

North Carolina - Cooperative Winter Trawl Survey
C-hat adjustment = 1.612; bootstrap GOF probability = 0.102 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	0.71	0.20	0.09	0.72	-0.16	**0.84**	**0.03**	-0.12	0.26
1989	0.70	0.20	0.06	0.78	-0.10	**0.78**	**0.09**	-0.05	0.32
1990	0.70	0.21	0.07	0.64	-0.11	**0.79**	**0.09**	0.03	0.16
1991	0.70	0.21	0.09	0.56	-0.12	**0.79**	**0.08**	0.02	0.15
1992	0.70	0.20	0.10	0.50	-0.12	**0.80**	**0.07**	-0.01	0.18
1993	0.70	0.21	0.09	0.47	-0.10	**0.78**	**0.10**	0.03	0.18
1994	0.70	0.21	0.08	0.50	-0.09	**0.77**	**0.11**	0.04	0.20
1995	0.65	0.29	0.10	0.34	-0.09	**0.71**	**0.19**	0.09	0.31
1996	0.64	0.29	0.05	0.28	-0.03	**0.67**	**0.26**	0.19	0.33
1997	0.64	0.29	0.09	0.27	-0.06	**0.68**	**0.23**	0.15	0.33
1998	0.64	0.29	0.11	0.22	-0.07	**0.69**	**0.22**	0.14	0.31
1999	0.65	0.29	0.10	0.23	-0.06	**0.69**	**0.22**	0.13	0.34
2000	0.69	0.23	0.05	0.31	-0.04	**0.71**	**0.19**	0.08	0.33
2001	0.69	0.22	0.09	0.24	-0.05	**0.73**	**0.17**	0.08	0.29
2002	0.69	0.22	0.06	0.31	-0.05	**0.72**	**0.17**	0.08	0.30
2003	0.60	0.36	0.06	0.3	-0.04	**0.62**	**0.32**	0.26	0.39
2004	0.60	0.36	0.07	0.27	-0.05	**0.63**	**0.31**	0.19	0.45
2005	0.60	0.37	0.05	0.27	-0.03	**0.62**	**0.34**	0.25	0.43
2006	0.60	0.37	0.08	0.28	-0.05	**0.63**	**0.31**	0.23	0.42
2007	0.52	0.50	0.11	0.23	-0.07	**0.56**	**0.43**	0.21	0.71
2008	0.49	0.56	0.11	0.23	-0.06	**0.53**	**0.49**	0.28	0.75

Table 15 continued.

Producer Area Programs

Hudson River

C-hat adjustment = 1.069; bootstrap GOF probability = 0.164 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	0.21	0.09	0.56	-0.12	**0.79**	**0.08**	-0.04	0.26
1989	0.70	0.21	0.11	0.74	-0.19	**0.85**	**0.00**	-0.12	0.18
1990	0.64	0.29	0.13	0.66	-0.21	**0.81**	**0.06**	0.02	0.11
1991	0.64	0.29	0.11	0.49	-0.13	**0.73**	**0.16**	0.12	0.20
1992	0.64	0.29	0.13	0.56	-0.19	**0.78**	**0.09**	0.04	0.13
1993	0.64	0.29	0.13	0.48	-0.16	**0.76**	**0.12**	0.08	0.17
1994	0.64	0.29	0.12	0.51	-0.16	**0.76**	**0.12**	0.08	0.17
1995	0.65	0.28	0.11	0.35	-0.10	**0.72**	**0.17**	0.14	0.20
1996	0.65	0.28	0.13	0.25	-0.09	**0.71**	**0.19**	0.16	0.22
1997	0.65	0.28	0.16	0.30	-0.14	**0.75**	**0.13**	0.10	0.17
1998	0.65	0.28	0.13	0.23	-0.08	**0.71**	**0.20**	0.16	0.23
1999	0.65	0.28	0.13	0.30	-0.11	**0.73**	**0.16**	0.13	0.19
2000	0.66	0.26	0.08	0.34	-0.07	**0.71**	**0.19**	0.14	0.25
2001	0.66	0.26	0.07	0.26	-0.05	**0.69**	**0.22**	0.17	0.27
2002	0.66	0.26	0.11	0.34	-0.10	**0.74**	**0.16**	0.11	0.21
2003	0.65	0.28	0.10	0.33	-0.08	**0.71**	**0.20**	0.16	0.24
2004	0.65	0.28	0.11	0.24	-0.07	**0.70**	**0.21**	0.17	0.25
2005	0.65	0.28	0.10	0.28	-0.07	**0.70**	**0.20**	0.16	0.25
2006	0.65	0.28	0.10	0.28	-0.07	**0.70**	**0.20**	0.16	0.25
2007	0.66	0.27	0.09	0.24	-0.06	**0.70**	**0.21**	0.15	0.29
2008	0.66	0.27	0.09	0.26	-0.06	**0.70**	**0.21**	0.14	0.29

Table 15 continued.

Delaware / Pennsylvania - Delaware River
C-hat adjustment = 1.02; bootstrap GOF probability = 0.79 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	0.84	0.03	0.11	29	-0.08	**0.91**	**-0.05**	-0.29	0.26
1994	0.84	0.03	0.11	33	-0.09	**0.92**	**-0.07**	-0.31	0.25
1995	0.59	0.38	0.12	40	-0.12	**0.67**	**0.25**	0.16	0.35
1996	0.59	0.38	0.14	28	-0.11	**0.66**	**0.27**	0.18	0.37
1997	0.59	0.38	0.11	31	-0.09	**0.64**	**0.29**	0.20	0.39
1998	0.59	0.38	0.15	18	-0.08	**0.64**	**0.30**	0.21	0.40
1999	0.59	0.38	0.09	19	-0.04	**0.61**	**0.34**	0.25	0.44
2000	0.63	0.32	0.14	17	-0.07	**0.67**	**0.25**	0.13	0.38
2001	0.63	0.32	0.13	10	-0.04	**0.65**	**0.28**	0.17	0.41
2002	0.63	0.32	0.09	20	-0.05	**0.66**	**0.27**	0.16	0.40
2003	0.58	0.39	0.11	33	-0.10	**0.65**	**0.29**	0.18	0.41
2004	0.58	0.39	0.11	24	-0.07	**0.63**	**0.32**	0.21	0.44
2005	0.58	0.39	0.10	25	-0.06	**0.62**	**0.32**	0.21	0.45
2006	0.58	0.39	0.11	18	-0.06	**0.62**	**0.33**	0.12	0.60
2007	0.61	0.34	0.11	29	-0.08	**0.67**	**0.25**	0.00	0.59
2008	0.72	0.18	0.06	10	-0.01	**0.73**	**0.17**	0.17	0.17

Table 15 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	0.17
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	0.27	0.12	0.60	-0.18	**0.80**	**0.07**	0.02	0.12
1992	0.66	0.27	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	0.64	0.30	0.12	0.27	-0.09	**0.70**	**0.21**	0.17	0.26
1996	0.64	0.30	0.10	0.29	-0.07	**0.69**	**0.23**	0.18	0.27
1997	0.64	0.30	0.11	0.23	-0.07	**0.68**	**0.23**	0.19	0.28
1998	0.64	0.30	0.11	0.20	-0.06	**0.68**	**0.24**	0.19	0.29
1999	0.64	0.30	0.12	0.19	-0.07	**0.68**	**0.23**	0.19	0.28
2000	0.63	0.31	0.08	0.19	-0.04	**0.66**	**0.27**	0.18	0.38
2001	0.63	0.31	0.07	0.24	-0.04	**0.66**	**0.27**	0.18	0.38
2002	0.63	0.31	0.06	0.36	-0.05	**0.66**	**0.26**	0.17	0.37
2003	0.64	0.29	0.08	0.20	-0.04	**0.67**	**0.25**	0.16	0.36
2004	0.65	0.29	0.04	0.17	-0.02	**0.66**	**0.27**	0.18	0.38
2005	0.65	0.29	0.06	0.22	-0.03	**0.67**	**0.26**	0.17	0.36
2006	0.64	0.29	0.07	0.22	-0.04	**0.67**	**0.25**	0.16	0.36
2007	0.67	0.25	0.05	0.23	-0.03	**0.69**	**0.23**	0.09	0.43
2008	0.67	0.25	0.05	0.15	-0.02	**0.68**	**0.23**	0.07	0.46

Table 15 continued.

Virginia - Rappahannock River
C-hat adjustment = 1; bootstrap GOF probability = 0.258 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**	**0.21**	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	0.39	0.13	0.20	-0.08	**0.64**	**0.30**	0.21	0.41
1996	0.58	0.39	0.05	0.13	-0.02	**0.59**	**0.37**	0.29	0.47
1997	0.58	0.39	0.08	0.17	-0.04	**0.61**	**0.35**	0.26	0.45
1998	0.59	0.39	0.13	0.22	-0.08	**0.64**	**0.30**	0.21	0.40
1999	0.58	0.39	0.10	0.20	-0.06	**0.62**	**0.33**	0.24	0.43
2000	0.68	0.24	0.08	0.35	-0.07	**0.73**	**0.17**	0.06	0.30
2001	0.68	0.24	0.07	0.30	-0.05	**0.71**	**0.19**	0.08	0.32
2002	0.68	0.24	0.10	0.30	-0.08	**0.73**	**0.16**	0.06	0.29
2003	0.54	0.47	0.09	0.25	-0.06	**0.57**	**0.42**	0.30	0.55
2004	0.53	0.48	0.06	0.32	-0.05	**0.56**	**0.42**	0.32	0.55
2005	0.54	0.48	0.05	0.24	-0.03	**0.55**	**0.44**	0.33	0.57
2006	0.54	0.48	0.06	0.28	-0.05	**0.56**	**0.43**	0.32	0.55
2007	0.53	0.48	0.06	0.23	-0.04	**0.56**	**0.44**	0.30	0.60
2008	0.53	0.49	0.08	0.16	-0.04	**0.55**	**0.45**	0.26	0.70

Table 16. 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= 1.05, bootstrap GOF probability = 0.52 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	0.75	0.14	0.07	0.76	-0.11	**0.85**	**0.02**	-0.05	0.10
1993	0.75	0.14	0.06	0.59	-0.08	**0.82**	**0.05**	-0.01	0.13
1994	0.75	0.14	0.06	0.58	-0.08	**0.81**	**0.06**	0.00	0.14
1995	0.72	0.17	0.06	0.47	-0.06	**0.77**	**0.11**	0.07	0.15
1996	0.72	0.17	0.09	0.43	-0.10	**0.80**	**0.07**	0.03	0.12
1997	0.72	0.17	0.08	0.28	-0.06	**0.77**	**0.11**	0.07	0.16
1998	0.72	0.17	0.08	0.33	-0.07	**0.78**	**0.10**	0.07	0.15
1999	0.72	0.17	0.06	0.32	-0.05	**0.76**	**0.13**	0.09	0.17
2000	0.73	0.16	0.06	0.24	-0.03	**0.75**	**0.13**	0.07	0.21
2001	0.73	0.16	0.05	0.35	-0.04	**0.76**	**0.12**	0.06	0.20
2002	0.73	0.16	0.07	0.29	-0.05	**0.77**	**0.12**	0.05	0.19
2003	0.73	0.17	0.05	0.23	-0.03	**0.75**	**0.14**	0.08	0.21
2004	0.73	0.17	0.05	0.22	-0.02	**0.75**	**0.14**	0.08	0.21
2005	0.73	0.17	0.05	0.29	-0.04	**0.76**	**0.13**	0.07	0.20
2006	0.73	0.17	0.06	0.34	-0.05	**0.76**	**0.12**	0.06	0.19
2007	0.77	0.12	0.04	0.27	-0.02	**0.78**	**0.09**	0.00	0.24
2008	0.77	0.12	0.04	0.25	-0.02	**0.78**	**0.09**	0.00	0.24

Table 16 continued.

New York Ocean Haul Seine
C-hat adjustment = 1.923; bootstrap GOF probability = 0 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	0.54	0.47	0.08	0.94	-0.16	**0.64**	**0.30**	0.49	0.14
1989	0.91	-0.05	0.09	0.93	-0.19	**1.12**	**-0.27**	-0.25	-0.28
1990	0.57	0.40	0.07	0.80	-0.13	**0.66**	**0.26**	0.48	0.10
1991	0.76	0.12	0.08	0.67	-0.13	**0.88**	**-0.02**	0.25	-0.16
1992	0.93	-0.08	0.07	0.79	-0.12	**1.06**	**-0.21**	-0.19	-0.22
1993	0.48	0.58	0.06	0.75	-0.09	**0.53**	**0.48**	0.68	0.31
1994	0.69	0.22	0.07	0.86	-0.13	**0.79**	**0.09**	0.31	-0.06
1995	0.85	0.02	0.06	0.67	-0.10	**0.94**	**-0.09**	0.40	-0.22
1996	0.81	0.06	0.06	0.81	-0.11	**0.92**	**-0.06**	0.46	-0.22
1997	0.70	0.20	0.06	0.79	-0.11	**0.79**	**0.09**	0.48	-0.11
1998	0.45	0.65	0.05	0.83	-0.10	**0.50**	**0.55**	0.86	0.30
1999	0.71	0.20	0.07	0.63	-0.10	**0.79**	**0.09**	0.48	-0.11
2000	0.60	0.36	0.05	0.80	-0.08	**0.66**	**0.27**	0.61	0.05
2001	0.69	0.22	0.06	0.71	-0.09	**0.76**	**0.12**	0.49	-0.08
2002	0.63	0.31	0.06	0.69	-0.10	**0.70**	**0.21**	0.63	-0.03
2003	0.68	0.23	0.06	0.66	-0.09	**0.75**	**0.14**	0.70	-0.11
2004	0.52	0.49	0.05	0.74	-0.09	**0.58**	**0.40**	0.86	0.10
2005	0.41	0.75	0.06	0.79	-0.10	**0.45**	**0.64**	1.04	0.33
2006	0.82	0.05	0.08	0.86	-0.15	**0.96**	**-0.11**	0.93	-0.29
2007	0.48	0.59	0.05	0.92	-0.11	**0.53**	**0.48**	1.11	0.08
2008	0.57	0.42	0.57	missing	0.00	**0.57**	**0.42**	0.64	0.24

Table 16 continued.

New Jersey - Delaware Bay
C-hat adjustment = 0.97; bootstrap GOF probability = 0.63 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	0.89	-0.04	0.11	0.92	-0.22	**1.14**	**-0.28**	-0.31	-0.25
1990	0.89	-0.03	0.11	0.89	-0.22	**1.14**	**-0.28**	-0.31	-0.25
1991	0.70	0.21	0.06	0.91	-0.13	**0.80**	**0.07**	-0.11	0.37
1992	0.48	0.58	0.05	0.87	-0.10	**0.54**	**0.47**	0.30	0.67
1993	0.55	0.45	0.08	0.91	-0.15	**0.65**	**0.28**	0.17	0.41
1994	0.66	0.27	0.08	0.88	-0.15	**0.77**	**0.11**	0.02	0.22
1995	0.85	0.01	0.09	0.76	-0.15	**1.00**	**-0.15**	-0.23	-0.03
1996	0.89	-0.04	0.11	0.68	-0.18	**1.08**	**-0.23**	-0.24	-0.22
1997	0.45	0.65	0.07	0.76	-0.13	**0.51**	**0.52**	0.39	0.66
1998	0.71	0.20	0.12	0.62	-0.17	**0.86**	**0.01**	-0.11	0.18
1999	0.67	0.26	0.07	0.74	-0.13	**0.76**	**0.12**	0.02	0.25
2000	0.71	0.20	0.08	0.69	-0.13	**0.82**	**0.05**	-0.05	0.18
2001	0.79	0.08	0.09	0.63	-0.13	**0.91**	**-0.05**	-0.16	0.11
2002	0.55	0.45	0.06	0.62	-0.09	**0.60**	**0.36**	0.23	0.50
2003	0.55	0.45	0.09	0.68	-0.14	**0.64**	**0.30**	0.18	0.44
2004	0.67	0.25	0.10	0.58	-0.14	**0.78**	**0.10**	-0.04	0.28
2005	0.58	0.39	0.09	0.67	-0.15	**0.68**	**0.23**	0.07	0.43
2006	0.58	0.40	0.08	0.71	-0.12	**0.66**	**0.27**	0.10	0.50
2007	0.68	0.24	0.09	0.55	-0.12	**0.77**	**0.11**	-0.08	0.44
2008	0.59	0.37	0.08	0.58	-0.11	**0.67**	**0.25**	0.22	0.29

Table 16 continued.

North Carolina - Cooperative Winter Trawl Survey
C-hat adjustment = 2.88; 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	0.52
1993	0.78	0.10	0.09	0.50	-0.10	**0.87**	**-0.01**	-0.19	0.48
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	0.41	0.05	0.42	-0.05	**0.60**	**0.36**	0.13	0.70
1997	0.50	0.54	0.08	0.37	-0.07	**0.54**	**0.46**	0.17	0.88
1998	0.67	0.25	0.10	0.36	-0.09	**0.74**	**0.15**	-0.10	0.66
1999	0.92	-0.06	0.09	0.34	-0.07	**0.99**	**-0.14**	-0.17	-0.11
2000	0.31	1.03	0.06	0.47	-0.06	**0.33**	**0.96**	0.73	1.22
2001	0.59	0.38	0.08	0.41	-0.07	**0.64**	**0.30**	0.11	0.57
2002	0.54	0.46	0.07	0.41	-0.07	**0.58**	**0.39**	0.18	0.66
2003	0.63	0.32	0.07	0.36	-0.06	**0.67**	**0.27**	0.06	0.56
2004	0.94	-0.08	0.07	0.37	-0.06	**0.99**	**-0.14**	-0.16	-0.13
2005	0.26	1.18	0.03	0.40	-0.03	**0.27**	**1.15**	0.93	1.40
2006	0.37	0.85	0.07	0.39	-0.07	**0.39**	**0.78**	0.40	1.27
2007	0.55	0.45	0.10	0.36	-0.09	**0.60**	**0.35**	-0.03	1.08
2008	0.52	0.50	0.10	0.33	-0.09	**0.57**	**0.41**	0.25	0.60

Table 16 continued.

Producer Area Programs

Hudson River
C-hat adjustment = 1.09; bootstrap GOF probability =0.01 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	0.07	0.75	-0.11	**0.83**	**0.04**	-0.03	0.13
1989	0.73	0.16	0.09	0.79	-0.16	**0.87**	**-0.01**	-0.08	0.09
1990	0.64	0.30	0.11	0.72	-0.19	**0.78**	**0.09**	0.06	0.13
1991	0.64	0.30	0.10	0.60	-0.15	**0.75**	**0.14**	0.10	0.18
1992	0.64	0.30	0.10	0.63	-0.16	**0.76**	**0.13**	0.10	0.17
1993	0.64	0.30	0.10	0.56	-0.14	**0.74**	**0.15**	0.12	0.19
1994	0.64	0.30	0.10	0.58	-0.13	**0.74**	**0.16**	0.12	0.19
1995	0.67	0.26	0.09	0.41	-0.10	**0.74**	**0.16**	0.12	0.19
1996	0.67	0.26	0.11	0.33	-0.10	**0.74**	**0.16**	0.12	0.19
1997	0.67	0.26	0.13	0.36	-0.12	**0.75**	**0.13**	0.09	0.17
1998	0.67	0.26	0.11	0.28	-0.08	**0.73**	**0.17**	0.14	0.21
1999	0.67	0.26	0.10	0.34	-0.09	**0.73**	**0.16**	0.13	0.20
2000	0.68	0.23	0.08	0.45	-0.09	**0.75**	**0.14**	0.09	0.19
2001	0.68	0.23	0.07	0.37	-0.06	**0.73**	**0.17**	0.12	0.22
2002	0.68	0.23	0.07	0.43	-0.08	**0.74**	**0.15**	0.10	0.21
2003	0.63	0.31	0.09	0.46	-0.10	**0.69**	**0.21**	0.17	0.26
2004	0.63	0.32	0.09	0.37	-0.08	**0.68**	**0.23**	0.19	0.28
2005	0.63	0.32	0.08	0.43	-0.08	**0.68**	**0.23**	0.19	0.28
2006	0.63	0.31	0.09	0.38	-0.08	**0.68**	**0.23**	0.18	0.28
2007	0.64	0.30	0.08	0.37	-0.07	**0.69**	**0.22**	0.15	0.31
2008	0.64	0.29	0.08	0.38	-0.07	**0.69**	**0.22**	0.14	0.32

Table 16 continued.

Delaware / Pennsylvania - Delaware River
C-hat adjustment = 0.89; bootstrap GOF probability = 0.74 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	0.67	0.25	0.10	0.42	-0.10	**0.75**	**0.14**	0.00	0.31
1994	0.67	0.25	0.11	0.58	-0.15	**0.79**	**0.09**	-0.05	0.25
1995	0.61	0.34	0.12	0.56	-0.16	**0.73**	**0.17**	0.10	0.23
1996	0.60	0.36	0.12	0.54	-0.17	**0.72**	**0.18**	0.10	0.26
1997	0.62	0.33	0.08	0.52	-0.10	**0.69**	**0.23**	0.15	0.31
1998	0.60	0.36	0.11	0.53	-0.14	**0.69**	**0.21**	0.14	0.30
1999	0.62	0.33	0.08	0.53	-0.11	**0.69**	**0.22**	0.15	0.29
2000	0.61	0.34	0.09	0.42	-0.10	**0.67**	**0.24**	0.17	0.33
2001	0.61	0.34	0.09	0.41	-0.09	**0.67**	**0.25**	0.16	0.34
2002	0.62	0.33	0.07	0.4	-0.07	**0.67**	**0.25**	0.18	0.34
2003	0.49	0.56	0.11	0.46	-0.12	**0.56**	**0.43**	0.34	0.54
2004	0.50	0.54	0.07	0.38	-0.06	**0.53**	**0.48**	0.39	0.58
2005	0.49	0.56	0.11	0.51	-0.14	**0.57**	**0.42**	0.32	0.53
2006	0.49	0.56	0.09	0.53	-0.12	**0.56**	**0.44**	0.33	0.56
2007	0.50	0.54	0.08	0.45	-0.09	**0.55**	**0.45**	0.32	0.61
2008	0.50	0.54	0.09	0.51	-0.11	**0.56**	**0.42**	0.31	0.55

Table 16 continued.

Maryland - Chesapeake Bay Spring Spawning Stock
C-hat adjustment = 1.34; bootstrap GOF probability =0.04 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**	-0.18	-0.09
1988	0.84	0.02	0.04	0.84	-0.08	**0.92**	**-0.06**	-0.11	-0.01
1989	0.84	0.02	0.03	0.93	-0.07	**0.91**	**-0.05**	-0.09	0.00
1990	0.63	0.31	0.06	0.59	-0.07	**0.68**	**0.23**	0.20	0.26
1991	0.63	0.31	0.09	0.47	-0.10	**0.70**	**0.20**	0.18	0.23
1992	0.63	0.31	0.11	0.43	-0.12	**0.72**	**0.18**	0.15	0.21
1993	0.63	0.31	0.09	0.38	-0.08	**0.69**	**0.22**	0.19	0.25
1994	0.63	0.31	0.10	0.43	-0.11	**0.71**	**0.19**	0.16	0.22
1995	0.57	0.41	0.12	0.33	-0.11	**0.64**	**0.29**	0.25	0.34
1996	0.57	0.41	0.11	0.35	-0.10	**0.64**	**0.30**	0.26	0.34
1997	0.57	0.41	0.12	0.27	-0.08	**0.62**	**0.32**	0.28	0.36
1998	0.57	0.41	0.13	0.26	-0.09	**0.63**	**0.31**	0.27	0.36
1999	0.57	0.41	0.11	0.21	-0.06	**0.61**	**0.34**	0.30	0.39
2000	0.50	0.54	0.11	0.33	-0.09	**0.55**	**0.44**	0.35	0.54
2001	0.50	0.54	0.08	0.32	-0.06	**0.54**	**0.47**	0.38	0.57
2002	0.50	0.54	0.07	0.32	-0.06	**0.53**	**0.48**	0.39	0.58
2003	0.54	0.47	0.09	0.24	-0.05	**0.57**	**0.41**	0.32	0.52
2004	0.54	0.47	0.06	0.25	-0.04	**0.56**	**0.43**	0.33	0.53
2005	0.54	0.47	0.06	0.27	-0.04	**0.56**	**0.43**	0.34	0.53
2006	0.54	0.47	0.08	0.27	-0.05	**0.57**	**0.41**	0.32	0.52
2007	0.54	0.47	0.06	0.29	-0.04	**0.56**	**0.43**	0.33	0.53
2008	0.54	0.47	0.07	0.23	-0.04	**0.56**	**0.43**	0.34	0.53

Table 16 continued.

Virginia - Rappahannock River
C-hat adjustment = 1.37; bootstrap GOF probability = 0.092 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	0.82	0.05	0.11	0.48	-0.14	**0.95**	**-0.10**	-0.23	0.21
1991	0.28	1.14	0.06	0.52	-0.08	**0.30**	**1.05**	0.73	1.42
1992	0.80	0.07	0.12	0.41	-0.14	**0.94**	**-0.09**	-0.27	0.71
1993	0.60	0.35	0.09	0.46	-0.11	**0.68**	**0.24**	-0.05	0.78
1994	0.57	0.42	0.09	0.38	-0.09	**0.62**	**0.32**	0.01	0.86
1995	0.68	0.23	0.08	0.26	-0.05	**0.72**	**0.17**	-0.07	0.71
1996	0.64	0.30	0.06	0.27	-0.04	**0.67**	**0.26**	-0.02	0.79
1997	0.57	0.42	0.07	0.33	-0.06	**0.60**	**0.36**	0.08	0.80
1998	0.41	0.73	0.06	0.36	-0.06	**0.44**	**0.67**	0.36	1.08
1999	0.37	0.85	0.08	0.29	-0.06	**0.39**	**0.79**	0.49	1.15
2000	0.43	0.70	0.07	0.44	-0.07	**0.46**	**0.62**	0.37	0.94
2001	0.46	0.62	0.07	0.37	-0.07	**0.50**	**0.55**	0.23	1.01
2002	0.63	0.31	0.07	0.37	-0.06	**0.67**	**0.25**	-0.03	0.78
2003	0.80	0.07	0.07	0.27	-0.05	**0.85**	**0.02**	-0.15	0.61
2004	0.35	0.89	0.05	0.28	-0.04	**0.37**	**0.85**	0.52	1.26
2005	0.45	0.65	0.04	0.28	-0.03	**0.47**	**0.62**	0.28	1.08
2006	0.42	0.72	0.06	0.36	-0.06	**0.45**	**0.66**	0.31	1.12
2007	0.44	0.66	0.06	0.31	-0.05	**0.46**	**0.62**	0.22	1.21
2008	0.48	0.59	0.06	0.21	-0.03	**0.49**	**0.56**	0.39	0.76

Table 17. 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.

Coast Programs

Year	MADFW	NYOHS	NJDEL	NCCOOP	**Unweighted average**
1987					
1988		0.87		0.78	**0.83**
1989		0.87	0.99	0.78	**0.82**
1990		0.78	0.80	0.73	**0.77**
1991		0.78	0.61	0.73	**0.71**
1992	0.82	0.78	0.88	0.73	**0.77**
1993	0.82	0.78	0.80	0.73	**0.78**
1994	0.82	0.78	0.84	0.73	**0.79**
1995	0.74	0.69	0.80	0.67	**0.72**
1996	0.74	0.69	0.72	0.68	**0.71**
1997	0.74	0.69	0.73	0.67	**0.71**
1998	0.74	0.69	0.65	0.67	**0.69**
1999	0.74	0.69	0.73	0.67	**0.71**
2000	0.78	0.73	0.76	0.71	**0.74**
2001	0.78	0.73	0.74	0.70	**0.74**
2002	0.78	0.73	0.75	0.71	**0.74**
2003	0.80	0.74	0.72	0.71	**0.74**
2004	0.80	0.74	0.74	0.71	**0.75**
2005	0.80	0.74	0.73	0.71	**0.75**
2006	0.80	0.74	0.79	0.71	**0.76**
2007	0.82	0.81	0.77	0.71	**0.78**
2008	0.82	0.81	0.75	0.70	**0.77**

Values in red excluded from averages.

Table 17 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	**Weighted average***
1987			0.83		**0.83**
1988	0.82		0.83		**0.82**
1989	0.80		0.83		**0.82**
1990	0.75		0.74	0.64	**0.72**
1991	0.75		0.74	0.64	**0.71**
1992	0.75	0.82	0.74	0.64	**0.72**
1993	0.75	0.82	0.74	0.64	**0.72**
1994	0.75	0.82	0.74	0.64	**0.72**
1995	0.68	0.74	0.65	0.59	**0.65**
1996	0.68	0.74	0.66	0.59	**0.65**
1997	0.68	0.74	0.65	0.59	**0.65**
1998	0.68	0.74	0.65	0.59	**0.65**
1999	0.68	0.74	0.65	0.59	**0.65**
2000	0.74	0.78	0.73	0.66	**0.72**
2001	0.74	0.78	0.73	0.66	**0.72**
2002	0.74	0.78	0.74	0.66	**0.72**
2003	0.74	0.80	0.76	0.66	**0.74**
2004	0.74	0.80	0.76	0.66	**0.74**
2005	0.74	0.80	0.77	0.66	**0.74**
2006	0.74	0.80	0.76	0.66	**0.74**
2007	0.74	0.82	0.78	0.67	**0.75**
2008	0.74	0.82	0.78	0.67	**0.75**

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

Table 18. 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 using the Instantaneous Rates model.

Coast Programs

Year	MADFW	NYOHS	NJDEL	NCCOOP	**Unweighted average**
1987					
1988		0.79		0.74	**0.76**
1989		0.79	0.82	0.73	**0.78**
1990		0.75	0.79	0.67	**0.74**
1991		0.75	0.78	0.67	**0.74**
1992	0.82	0.75	0.81	0.67	**0.76**
1993	0.82	0.75	0.81	0.67	**0.76**
1994	0.82	0.75	0.82	0.67	**0.76**
1995	0.76	0.73	0.78	0.63	**0.72**
1996	0.76	0.73	0.74	0.64	**0.71**
1997	0.75	0.73	0.72	0.63	**0.71**
1998	0.75	0.73	0.70	0.63	**0.70**
1999	0.75	0.73	0.75	0.63	**0.72**
2000	0.78	0.75	0.74	0.67	**0.74**
2001	0.79	0.75	0.73	0.67	**0.73**
2002	0.79	0.75	0.75	0.67	**0.74**
2003	0.79	0.75	0.73	0.68	**0.74**
2004	0.80	0.75	0.73	0.68	**0.74**
2005	0.80	0.75	0.73	0.68	**0.74**
2006	0.80	0.75	0.76	0.68	**0.75**
2007	0.82	0.77	0.75	0.68	**0.75**
2008	0.81	0.77	0.75	0.68	**0.75**

Table 18 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	**Weighted average***
1987			0.80		
1988	0.81		0.79		**0.80**
1989	0.80		0.80		**0.80**
1990	0.76		0.74	0.58	**0.70**
1991	0.76		0.71	0.57	**0.67**
1992	0.76		0.66	0.55	**0.64**
1993	0.76	0.67	0.68	0.56	**0.66**
1994	0.76	0.67	0.68	0.55	**0.65**
1995	0.69	0.66	0.62	0.53	**0.61**
1996	0.69	0.66	0.64	0.55	**0.63**
1997	0.69	0.66	0.60	0.54	**0.60**
1998	0.69	0.66	0.57	0.54	**0.59**
1999	0.69	0.66	0.60	0.54	**0.60**
2000	0.74	0.65	0.64	0.57	**0.64**
2001	0.75	0.65	0.68	0.56	**0.66**
2002	0.74	0.65	0.71	0.57	**0.67**
2003	0.75	0.67	0.69	0.56	**0.66**
2004	0.75	0.67	0.72	0.56	**0.68**
2005	0.75	0.67	0.73	0.57	**0.69**
2006	0.75	0.67	0.73	0.56	**0.68**
2007	0.75	0.70	0.75	0.56	**0.70**
2008	0.75	0.70	0.75	0.56	**0.70**

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

Table 19. 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.

Coast Programs

Year	MADFW	NYOHS	NJDEL	NCCOOP	**Unweighted average**
1987					
1988		-0.07		0.03	**0.03**
1989		-0.23	-0.04	0.09	**0.09**
1990		0.13	-0.02	0.09	**0.11**
1991		0.33	-0.17	0.08	**0.21**
1992	0.02	-0.21	0.11	0.07	**0.07**
1993	0.04	0.41	0.14	0.10	**0.17**
1994	0.06	0.06	0.09	0.11	**0.08**
1995	0.13	0.00	0.08	0.19	**0.11**
1996	0.13	-0.03	0.09	0.26	**0.16**
1997	0.13	-0.08	0.18	0.23	**0.18**
1998	0.12	0.71	0.20	0.22	**0.31**
1999	0.13	0.31	0.08	0.22	**0.19**
2000	0.14	-0.16	0.05	0.19	**0.13**
2001	0.14	0.07	0.06	0.17	**0.11**
2002	0.13	-0.13	0.08	0.17	**0.13**
2003	0.13	0.25	0.25	0.32	**0.24**
2004	0.13	0.94	0.24	0.31	**0.41**
2005	0.12	0.30	0.18	0.34	**0.23**
2006	0.10	-0.09	0.24	0.31	**0.22**
2007	0.07	-0.15	0.26	0.43	**0.25**
2008	0.06	0.45	0.27	0.49	**0.32**

Values in red excluded from averages.

Table 19 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	**Weighted average***	* negative values not included in ave.
1987			-0.05			
1988	0.08		-0.11		**0.08**	
1989	0.00		-0.15			
1990	0.06		0.17	0.18	**0.15**	
1991	0.16		0.07	0.17	**0.11**	
1992	0.09		0.11	0.12	**0.11**	
1993	0.12	-0.05	0.14	0.21	**0.16**	
1994	0.12	-0.07	0.15	0.24	**0.17**	
1995	0.17	0.25	0.21	0.30	**0.23**	
1996	0.19	0.27	0.23	0.37	**0.26**	
1997	0.13	0.29	0.23	0.35	**0.26**	
1998	0.20	0.30	0.24	0.30	**0.25**	
1999	0.16	0.34	0.23	0.33	**0.26**	
2000	0.19	0.25	0.27	0.17	**0.23**	
2001	0.22	0.28	0.27	0.19	**0.24**	
2002	0.16	0.27	0.26	0.16	**0.22**	
2003	0.20	0.29	0.25	0.42	**0.29**	
2004	0.21	0.32	0.27	0.42	**0.31**	
2005	0.20	0.32	0.26	0.44	**0.30**	
2006	0.20	0.33	0.25	0.43	**0.30**	
2007	0.21	0.25	0.23	0.44	**0.28**	
2008	0.21	0.17	0.23	0.45	**0.28**	

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

Table 20. 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.

Coast Programs

Year	MADFW	NYOHS	NJDEL	NCCOOP	**Unweighted average**
1987					
1988		0.30		-0.24	**0.30**
1989		-0.27	-0.28	0.24	**0.24**
1990		0.26	-0.28	0.36	**0.31**
1991		-0.02	0.07	0.18	**0.12**
1992	0.02	-0.21	0.47	-0.03	**0.24**
1993	0.05	0.48	0.28	-0.01	**0.27**
1994	0.06	0.09	0.11	0.48	**0.18**
1995	0.11	-0.09	-0.15	-0.17	**0.11**
1996	0.07	-0.06	-0.23	0.36	**0.22**
1997	0.11	0.09	0.52	0.46	**0.30**
1998	0.10	0.55	0.01	0.15	**0.20**
1999	0.13	0.09	0.12	-0.14	**0.11**
2000	0.13	0.27	0.05	0.96	**0.35**
2001	0.12	0.12	-0.05	0.30	**0.18**
2002	0.12	0.21	0.36	0.39	**0.27**
2003	0.14	0.14	0.30	0.26	**0.21**
2004	0.14	0.40	0.10	-0.14	**0.21**
2005	0.13	0.64	0.23	1.15	**0.33**
2006	0.12	-0.11	0.27	0.78	**0.39**
2007	0.09	0.48	0.11	0.35	**0.26**
2008	0.09	0.42	0.25	0.41	**0.29**

Values in red excluded from averages.

Table 20 continued.

Producer Area Programs*

Year	HUDSON	DE/PA	MDCB	VARAP	Weighted Average	* negative values not included in ave.
1987			-0.14			
1988	0.04		-0.06		**0.04**	
1989	-0.01		-0.05			
1990	0.09		0.23	-0.10	**0.20**	
1991	0.14		0.20	1.05	**0.18**	
1992	0.13		0.18	-0.09	**0.16**	
1993	0.15	0.14	0.22	0.24	**0.21**	
1994	0.16	0.09	0.19	0.32	**0.21**	
1995	0.16	0.17	0.29	0.17	**0.23**	
1996	0.16	0.18	0.30	0.26	**0.26**	
1997	0.13	0.23	0.32	0.36	**0.30**	
1998	0.17	0.21	0.31	0.67	**0.38**	
1999	0.16	0.22	0.34	0.79	**0.42**	
2000	0.14	0.24	0.44	0.62	**0.43**	
2001	0.17	0.25	0.47	0.55	**0.43**	
2002	0.15	0.25	0.48	0.25	**0.36**	
2003	0.21	0.43	0.41	0.02	**0.29**	
2004	0.23	0.48	0.43	0.85	**0.52**	
2005	0.23	0.42	0.43	0.62	**0.45**	
2006	0.23	0.44	0.41	0.66	**0.45**	
2007	0.22	0.45	0.43	0.62	**0.45**	
2008	0.22	0.42	0.43	0.56	**0.44**	

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

Table 21. 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 Table 11. 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	0.17	0.16	0.05	**0.06**	0.11
1993	0.19	0.17	0.07	**0.08**	0.11
1994	0.21	0.19	0.05	**0.05**	0.16
1995	0.28	0.24	0.05	**0.06**	0.22
1996	0.28	0.24	0.09	**0.11**	0.17
1997	0.28	0.24	0.17	**0.20**	0.08
1998	0.27	0.24	0.10	**0.12**	0.16
1999	0.28	0.25	0.13	**0.15**	0.14
2000	0.29	0.25	0.13	**0.15**	0.14
2001	0.29	0.25	0.09	**0.10**	0.19
2002	0.28	0.24	0.08	**0.09**	0.19
2003	0.28	0.25	0.11	**0.13**	0.16
2004	0.28	0.24	0.10	**0.11**	0.17
2005	0.27	0.23	0.07	**0.08**	0.19
2006	0.25	0.22	0.10	**0.11**	0.14
2007	0.22	0.19	0.04	**0.04**	0.18
2008	0.21	0.19	0.07	**0.08**	0.13
Average	**0.26**	**0.23**	**0.09**	**0.10**	**0.15**

New York Ocean Haul Seine Fall Tagging

Year	Z	A	U	F	M
1988	0.08	0.08	0.05	**0.06**	0.03
1989	-0.08	-0.08	0.04	**0.04**	-0.12
1990	0.28	0.25	0.07	**0.08**	0.20
1991	0.48	0.38	0.14	**0.18**	0.30
1992	-0.06	-0.06	0.12	**0.12**	-0.18
1993	0.56	0.43	0.14	**0.18**	0.38
1994	0.21	0.19	0.09	**0.10**	0.12
1995	0.15	0.14	0.22	**0.24**	-0.08
1996	0.12	0.11	0.14	**0.15**	-0.03
1997	0.07	0.07	0.31	**0.32**	-0.25
1998	0.86	0.58	0.17	**0.25**	0.61
1999	0.46	0.37	0.34	**0.43**	0.04
2000	-0.01	-0.01	0.14	**0.14**	-0.15
2001	0.22	0.20	0.11	**0.12**	0.09
2002	0.02	0.02	0.24	**0.24**	-0.22
2003	0.40	0.33	0.17	**0.20**	0.20
2004	1.09	0.66	0.13	**0.22**	0.88
2005	0.45	0.36	0.26	**0.33**	0.12
2006	0.06	0.06	0.13	**0.13**	-0.07
2007	0.00	0.00	0.02	**0.02**	-0.03
2008	0.60	0.45	0.07	**0.09**	0.51
Average	**0.28**	**0.21**	**0.16**	**0.19**	**0.10**

Table 21 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	0.13	0.12	0.04	**0.04**	0.08
1991	-0.02	-0.02	0.17	**0.17**	-0.18
1992	0.26	0.23	0.02	**0.02**	0.24
1993	0.29	0.25	0.09	**0.10**	0.19
1994	0.24	0.21	0.04	**0.05**	0.19
1995	0.23	0.21	0.10	**0.12**	0.11
1996	0.24	0.22	0.19	**0.22**	0.02
1997	0.33	0.28	0.18	**0.21**	0.12
1998	0.35	0.30	0.35	**0.41**	-0.06
1999	0.23	0.21	0.08	**0.09**	0.15
2000	0.20	0.18	0.14	**0.15**	0.05
2001	0.21	0.19	0.15	**0.17**	0.04
2002	0.23	0.20	0.11	**0.12**	0.11
2003	0.40	0.33	0.15	**0.18**	0.22
2004	0.39	0.32	0.15	**0.18**	0.21
2005	0.33	0.28	0.15	**0.18**	0.15
2006	0.39	0.32	0.14	**0.17**	0.22
2007	0.41	0.34	0.13	**0.16**	0.25
2008	0.42	0.35	0.14	**0.17**	0.25
Average	**0.25**	**0.22**	**0.13**	**0.14**	**0.11**

North Carolina Winter Trawl Survey

Year	Z	A	U	F	M
1988	0.18	0.16	0.06	**0.07**	0.11
1989	0.24	0.22	0.04	**0.05**	0.20
1990	0.24	0.21	0.09	**0.10**	0.14
1991	0.23	0.21	0.07	**0.08**	0.15
1992	0.22	0.20	0.13	**0.14**	0.08
1993	0.25	0.22	0.11	**0.13**	0.12
1994	0.26	0.23	0.08	**0.09**	0.17
1995	0.34	0.29	0.14	**0.17**	0.17
1996	0.41	0.33	0.11	**0.14**	0.27
1997	0.38	0.32	0.18	**0.22**	0.16
1998	0.37	0.31	0.20	**0.24**	0.13
1999	0.37	0.31	0.24	**0.28**	0.09
2000	0.34	0.29	0.06	**0.07**	0.27
2001	0.32	0.27	0.15	**0.17**	0.14
2002	0.32	0.28	0.12	**0.14**	0.19
2003	0.47	0.38	0.11	**0.14**	0.33
2004	0.46	0.37	0.12	**0.15**	0.31
2005	0.49	0.38	0.07	**0.09**	0.39
2006	0.46	0.37	0.12	**0.15**	0.31
2007	0.58	0.44	0.19	**0.25**	0.33
2008	0.64	0.47	0.19	**0.26**	0.39
Average	**0.33**	**0.28**	**0.12**	**0.14**	**0.20**

Table 21 continued.

Producer Area Programs

Hudson River Spring Spawning Stock

Year	Z	A	U	F	M
1988	0.23	0.21	0.10	**0.11**	0.12
1989	0.15	0.14	0.07	**0.08**	0.08
1990	0.21	0.19	0.11	**0.12**	0.09
1991	0.31	0.27	0.10	**0.12**	0.19
1992	0.24	0.21	0.13	**0.14**	0.09
1993	0.27	0.24	0.17	**0.19**	0.08
1994	0.27	0.24	0.12	**0.14**	0.13
1995	0.32	0.27	0.15	**0.18**	0.14
1996	0.34	0.29	0.22	**0.26**	0.08
1997	0.28	0.25	0.31	**0.36**	-0.07
1998	0.35	0.29	0.22	**0.26**	0.08
1999	0.31	0.27	0.21	**0.25**	0.07
2000	0.34	0.29	0.14	**0.17**	0.18
2001	0.37	0.31	0.13	**0.16**	0.21
2002	0.31	0.26	0.19	**0.22**	0.08
2003	0.35	0.29	0.14	**0.17**	0.18
2004	0.36	0.30	0.21	**0.25**	0.11
2005	0.35	0.30	0.17	**0.20**	0.15
2006	0.35	0.30	0.16	**0.18**	0.17
2007	0.36	0.30	0.16	**0.20**	0.17
2008	0.36	0.30	0.15	**0.18**	0.18
Average	**0.31**	**0.26**	**0.16**	**0.19**	**0.12**

Delaware River - Delaware/Pennsylvania Spring Spawning Stock

Year	Z	A	U	F	M
1988					
1989					
1990					
1991					
1992					
1993	0.10	0.09	0.13	**0.14**	-0.04
1994	0.08	0.08	0.12	**0.13**	-0.04
1995	0.40	0.33	0.14	**0.17**	0.24
1996	0.42	0.34	0.32	**0.39**	0.03
1997	0.44	0.36	0.27	**0.33**	0.11
1998	0.45	0.36	0.28	**0.35**	0.10
1999	0.49	0.39	0.15	**0.19**	0.29
2000	0.40	0.33	0.30	**0.36**	0.03
2001	0.43	0.35	0.27	**0.33**	0.10
2002	0.42	0.34	0.24	**0.29**	0.13
2003	0.44	0.35	0.17	**0.21**	0.23
2004	0.47	0.37	0.24	**0.30**	0.17
2005	0.47	0.38	0.15	**0.19**	0.28
2006	0.48	0.38	0.21	**0.26**	0.22
2007	0.40	0.33	0.20	**0.24**	0.16
2008	0.32	0.27	0.12	**0.14**	0.18
Average	**0.39**	**0.32**	**0.21**	**0.25**	**0.14**

Table 21 continued.

Maryland - Chesapeake Bay Spring Spawning Stock						Virginia - Rappahannock River Spring Spawning Stock					
Year	**Z**	**A**	**U**	**F**	**M**	**Year**	**Z**	**A**	**U**	**F**	**M**
1987	0.10	0.10			0.10	1987					
1988	0.04	0.04	0.07	**0.08**	-0.04	1988					
1989	0.00	0.00	0.04	**0.04**	-0.03	1989					
1990	0.32	0.27	0.09	**0.10**	0.22	1990	0.33	0.28	0.25	**0.30**	0.03
1991	0.22	0.20	0.12	**0.13**	0.08	1991	0.32	0.28	0.36	**0.43**	-0.10
1992	0.26	0.23	0.12	**0.14**	0.12	1992	0.27	0.24	0.37	**0.42**	-0.15
1993	0.29	0.25	0.12	**0.14**	0.15	1993	0.36	0.31	0.37	**0.44**	-0.08
1994	0.30	0.26	0.12	**0.13**	0.17	1994	0.39	0.32	0.25	**0.31**	0.08
1995	0.36	0.30	0.21	**0.25**	0.12	1995	0.45	0.36	0.41	**0.51**	-0.06
1996	0.38	0.31	0.17	**0.20**	0.17	1996	0.52	0.41	0.18	**0.23**	0.29
1997	0.38	0.32	0.23	**0.28**	0.10	1997	0.50	0.39	0.38	**0.48**	0.02
1998	0.39	0.32	0.23	**0.27**	0.12	1998	0.45	0.36	0.45	**0.56**	-0.12
1999	0.38	0.32	0.21	**0.26**	0.13	1999	0.48	0.38	0.28	**0.35**	0.13
2000	0.42	0.34	0.17	**0.21**	0.21	2000	0.32	0.27	0.28	**0.33**	-0.01
2001	0.42	0.34	0.11	**0.13**	0.29	2001	0.34	0.29	0.24	**0.28**	0.06
2002	0.41	0.34	0.10	**0.12**	0.29	2002	0.31	0.27	0.35	**0.41**	-0.10
2003	0.40	0.33	0.11	**0.13**	0.27	2003	0.57	0.43	0.27	**0.35**	0.22
2004	0.42	0.34	0.08	**0.10**	0.32	2004	0.57	0.44	0.15	**0.20**	0.37
2005	0.41	0.33	0.11	**0.14**	0.27	2005	0.59	0.45	0.21	**0.28**	0.31
2006	0.40	0.33	0.14	**0.17**	0.23	2006	0.58	0.44	0.22	**0.29**	0.29
2007	0.38	0.31	0.09	**0.11**	0.27	2007	0.59	0.44	0.15	**0.20**	0.39
2008	0.38	0.32	0.11	**0.13**	0.25	2008	0.60	0.45	0.15	**0.20**	0.40
Average	**0.32**	**0.26**	**0.13**	**0.16**	**0.16**	**Average**	**0.43**	**0.35**	**0.30**	**0.36**	**0.07**

Table 22. 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 12. 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	0.17	0.15	0.05	**0.06**	0.11
1993	0.20	0.18	0.06	**0.06**	0.14
1994	0.21	0.19	0.04	**0.05**	0.16
1995	0.26	0.23	0.04	**0.04**	0.21
1996	0.22	0.20	0.07	**0.08**	0.15
1997	0.26	0.23	0.12	**0.13**	0.13
1998	0.25	0.22	0.10	**0.12**	0.14
1999	0.28	0.24	0.09	**0.10**	0.18
2000	0.28	0.25	0.09	**0.11**	0.18
2001	0.27	0.24	0.06	**0.07**	0.20
2002	0.27	0.23	0.09	**0.10**	0.17
2003	0.29	0.25	0.08	**0.09**	0.20
2004	0.29	0.25	0.09	**0.10**	0.19
2005	0.28	0.24	0.07	**0.08**	0.20
2006	0.27	0.24	0.09	**0.10**	0.17
2007	0.24	0.22	0.03	**0.04**	0.21
2008	0.24	0.22	0.06	**0.07**	0.17
Average	**0.25**	**0.22**	**0.08**	**0.09**	**0.17**

New York Ocean Haul Seine Fall Tagging

Year	Z	A	U	F	M
1988	0.45	0.36	0.02	**0.03**	0.42
1989	-0.12	-0.12	0.03	**0.03**	-0.14
1990	0.41	0.34	0.04	**0.05**	0.37
1991	0.13	0.12	0.07	**0.07**	0.06
1992	-0.06	-0.06	0.05	**0.05**	-0.11
1993	0.63	0.47	0.04	**0.06**	0.57
1994	0.24	0.21	0.03	**0.04**	0.20
1995	0.06	0.06	0.06	**0.06**	0.01
1996	0.09	0.08	0.04	**0.04**	0.04
1997	0.24	0.21	0.05	**0.05**	0.19
1998	0.70	0.50	0.03	**0.04**	0.66
1999	0.24	0.21	0.06	**0.07**	0.17
2000	0.42	0.34	0.03	**0.04**	0.38
2001	0.27	0.24	0.05	**0.06**	0.22
2002	0.36	0.30	0.07	**0.08**	0.28
2003	0.29	0.25	0.06	**0.07**	0.22
2004	0.55	0.42	0.04	**0.06**	0.49
2005	0.79	0.55	0.04	**0.06**	0.73
2006	0.04	0.04	0.04	**0.04**	0.00
2007	0.63	0.47	0.02	**0.03**	0.60
2008	0.57	0.43	0.03	**0.05**	0.52
Average	**0.30**	**0.24**	**0.04**	**0.05**	**0.25**

Table 22 continued.

New Jersey Delaware Bay March-April

Year	Z	A	U	F	M
1988					
1989	0.10	0.09	0.03	**0.03**	0.06
1990	-0.13	-0.14	0.07	**0.06**	-0.19
1991	0.22	0.20	0.03	**0.03**	0.19
1992	0.62	0.46	0.03	**0.04**	0.58
1993	0.43	0.35	0.02	**0.03**	0.40
1994	0.26	0.23	0.03	**0.04**	0.22
1995	0.00	0.00	0.06	**0.06**	-0.07
1996	-0.08	-0.08	0.09	**0.08**	-0.16
1997	0.67	0.49	0.06	**0.09**	0.58
1998	0.16	0.14	0.11	**0.12**	0.03
1999	0.27	0.24	0.05	**0.06**	0.21
2000	0.20	0.18	0.07	**0.08**	0.12
2001	0.10	0.09	0.09	**0.10**	0.00
2002	0.51	0.40	0.06	**0.07**	0.43
2003	0.45	0.36	0.08	**0.09**	0.36
2004	0.25	0.22	0.12	**0.13**	0.12
2005	0.38	0.32	0.09	**0.11**	0.27
2006	0.42	0.34	0.06	**0.08**	0.34
2007	0.26	0.23	0.11	**0.12**	0.14
2008	0.40	0.33	0.09	**0.11**	0.30
Average	**0.27**	**0.22**	**0.06**	**0.07**	**0.19**

North Carolina Winter Trawl Survey

Year	Z	A	U	F	M
1988	-0.09	-0.10	0.03	**0.03**	-0.13
1989	0.39	0.32	0.03	**0.03**	0.35
1990	0.51	0.40	0.06	**0.08**	0.43
1991	0.33	0.28	0.08	**0.10**	0.23
1992	0.12	0.12	0.14	**0.15**	-0.02
1993	0.14	0.13	0.11	**0.11**	0.02
1994	0.63	0.47	0.08	**0.11**	0.52
1995	-0.02	-0.02	0.14	**0.13**	-0.15
1996	0.51	0.40	0.11	**0.13**	0.38
1997	0.61	0.46	0.15	**0.21**	0.41
1998	0.30	0.26	0.14	**0.16**	0.14
1999	0.01	0.01	0.22	**0.22**	-0.21
2000	1.11	0.67	0.08	**0.13**	0.98
2001	0.45	0.36	0.11	**0.14**	0.31
2002	0.54	0.42	0.12	**0.15**	0.38
2003	0.41	0.33	0.11	**0.13**	0.28
2004	0.01	0.01	0.12	**0.12**	-0.11
2005	1.30	0.73	0.06	**0.10**	1.20
2006	0.93	0.61	0.10	**0.16**	0.77
2007	0.50	0.40	0.16	**0.20**	0.30
2008	0.56	0.43	0.18	**0.24**	0.32
Average	**0.43**	**0.31**	**0.10**	**0.13**	**0.30**

Table 22 continued.

Producer Area Programs

Hudson River Spring Spawning Stock Survey						Delaware River - DE/PA Spring Spawning Stock					
Year	**Z**	**A**	**U**	**F**	**M**	**Year**	**Z**	**A**	**U**	**F**	**M**
1987						1987					
1988	0.19	0.17	0.05	**0.05**	0.14	1988					
1989	0.14	0.13	0.05	**0.05**	0.09	1989					
1990	0.24	0.22	0.07	**0.08**	0.17	1990					
1991	0.29	0.25	0.07	**0.08**	0.21	1991					
1992	0.28	0.24	0.09	**0.10**	0.18	1992					
1993	0.30	0.26	0.10	**0.12**	0.18	1993	0.29	0.25	0.13	**0.15**	0.14
1994	0.31	0.26	0.09	**0.10**	0.21	1994	0.24	0.21	0.12	**0.14**	0.10
1995	0.31	0.26	0.12	**0.14**	0.16	1995	0.32	0.27	0.12	**0.15**	0.17
1996	0.31	0.26	0.15	**0.18**	0.13	1996	0.33	0.28	0.18	**0.21**	0.12
1997	0.28	0.25	0.24	**0.27**	0.01	1997	0.38	0.31	0.11	**0.13**	0.24
1998	0.32	0.27	0.18	**0.21**	0.11	1998	0.36	0.31	0.14	**0.16**	0.20
1999	0.31	0.27	0.14	**0.17**	0.15	1999	0.37	0.31	0.10	**0.12**	0.25
2000	0.29	0.25	0.10	**0.11**	0.17	2000	0.39	0.33	0.15	**0.18**	0.21
2001	0.32	0.27	0.09	**0.11**	0.22	2001	0.40	0.33	0.15	**0.18**	0.21
2002	0.30	0.26	0.08	**0.10**	0.21	2002	0.40	0.33	0.14	**0.17**	0.24
2003	0.36	0.31	0.10	**0.12**	0.25	2003	0.58	0.44	0.15	**0.19**	0.39
2004	0.38	0.32	0.13	**0.16**	0.22	2004	0.63	0.47	0.15	**0.20**	0.42
2005	0.38	0.32	0.09	**0.11**	0.28	2005	0.57	0.43	0.10	**0.13**	0.44
2006	0.38	0.32	0.10	**0.13**	0.25	2006	0.59	0.44	0.11	**0.15**	0.44
2007	0.37	0.31	0.10	**0.12**	0.25	2007	0.60	0.45	0.08	**0.10**	0.50
2008	0.37	0.31	0.09	**0.10**	0.27	2008	0.57	0.44	0.08	**0.11**	0.46
Average	**0.31**	**0.26**	**0.11**	**0.12**	**0.18**	**Average**	**0.44**	**0.35**	**0.13**	**0.15**	**0.28**

Table 22 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**	0.20
1995	0.44	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	0.46	0.37	0.22	**0.28**	0.19
1999	0.49	0.39	0.17	**0.22**	0.28
2000	0.59	0.45	0.17	**0.22**	0.37
2001	0.62	0.46	0.12	**0.16**	0.46
2002	0.63	0.47	0.12	**0.16**	0.47
2003	0.56	0.43	0.13	**0.17**	0.39
2004	0.58	0.44	0.10	**0.14**	0.44
2005	0.58	0.44	0.11	**0.14**	0.43
2006	0.56	0.43	0.14	**0.18**	0.38
2007	0.58	0.44	0.09	**0.12**	0.46
2008	0.58	0.44	0.11	**0.15**	0.43
Average	**0.42**	**0.33**	**0.12**	**0.15**	**0.27**

Virginia Rappahanock River Spring Spawning Stock Survey

Year	Z	A	U	F	M
1987					
1988					
1989					
1990	0.05	0.05	0.17	**0.18**	-0.13
1991	1.20	0.70	0.14	**0.24**	0.96
1992	0.06	0.06	0.31	**0.32**	-0.25
1993	0.39	0.32	0.23	**0.28**	0.12
1994	0.47	0.38	0.25	**0.31**	0.16
1995	0.32	0.28	0.19	**0.22**	0.10
1996	0.41	0.33	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	0.94	0.61	0.13	**0.20**	0.74
2000	0.77	0.54	0.14	**0.19**	0.58
2001	0.70	0.50	0.18	**0.25**	0.45
2002	0.40	0.33	0.19	**0.23**	0.17
2003	0.17	0.15	0.18	**0.20**	-0.03
2004	1.00	0.63	0.12	**0.19**	0.81
2005	0.77	0.53	0.13	**0.19**	0.57
2006	0.81	0.55	0.13	**0.19**	0.61
2007	0.77	0.54	0.12	**0.17**	0.60
2008	0.71	0.51	0.08	**0.11**	0.60
Average	**0.58**	**0.41**	**0.18**	**0.23**	**0.35**

Table 23. 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	NJDEL	NCCOOP	Unweighted average	lower 95% CI	upper 95% CI
1988		0.06		0.07	**0.06**	0.04	0.08
1989		0.04	0.02	0.05	**0.03**	0.02	0.05
1990		0.08	0.04	0.10	**0.07**	0.04	0.10
1991		0.18	0.17	0.08	**0.13**	0.10	0.16
1992	0.06	0.12	0.02	0.14	**0.07**	0.05	0.10
1993	0.08	0.18	0.10	0.13	**0.12**	0.07	0.17
1994	0.05	0.10	0.05	0.09	**0.07**	0.04	0.10
1995	0.06	0.24	0.12	0.17	**0.11**	0.08	0.15
1996	0.11	0.15	0.22	0.14	**0.15**	0.11	0.20
1997	0.20	0.32	0.21	0.22	**0.21**	0.14	0.28
1998	0.12	0.25	0.41	0.24	**0.20**	0.13	0.28
1999	0.15	0.43	0.09	0.28	**0.24**	0.14	0.33
2000	0.15	0.14	0.15	0.07	**0.12**	0.08	0.17
2001	0.10	0.12	0.17	0.17	**0.14**	0.09	0.19
2002	0.09	0.24	0.12	0.14	**0.12**	0.08	0.15
2003	0.13	0.20	0.18	0.14	**0.16**	0.10	0.22
2004	0.11	0.22	0.18	0.15	**0.17**	0.11	0.22
2005	0.08	0.33	0.18	0.09	**0.17**	0.08	0.26
2006	0.11	0.13	0.17	0.15	**0.15**	0.10	0.19
2007	0.04	0.02	0.16	0.25	**0.15**	0.10	0.20
2008	0.08	0.09	0.17	0.26	**0.15**	0.10	0.20

Values in red excluded from averages.

Table 23 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	Weighted average*	lower 95% CI	upper 95% CI
1987							
1988	0.11		0.08		**0.11**		
1989	0.08		0.04		**0.08**		
1990	0.12		0.10	0.30	**0.16**	0.06	0.25
1991	0.12		0.13	0.43	**0.13**	0.05	0.21
1992	0.14		0.14	0.42	**0.14**	0.06	0.22
1993	0.19	0.14	0.14	0.44	**0.15**	0.07	0.24
1994	0.14	0.13	0.13	0.31	**0.18**	0.07	0.29
1995	0.18	0.17	0.25	0.51	**0.22**	0.11	0.34
1996	0.26	0.39	0.20	0.23	**0.23**	0.10	0.37
1997	0.36	0.33	0.28	0.48	**0.35**	0.19	0.50
1998	0.26	0.35	0.27	0.56	**0.28**	0.14	0.42
1999	0.25	0.19	0.26	0.35	**0.27**	0.11	0.44
2000	0.17	0.36	0.21	0.33	**0.22**	0.11	0.34
2001	0.16	0.33	0.13	0.28	**0.19**	0.09	0.29
2002	0.22	0.29	0.12	0.41	**0.16**	0.06	0.25
2003	0.17	0.21	0.13	0.35	**0.20**	0.09	0.31
2004	0.25	0.30	0.10	0.20	**0.16**	0.07	0.26
2005	0.20	0.19	0.14	0.28	**0.19**	0.08	0.30
2006	0.18	0.26	0.17	0.29	**0.21**	0.09	0.33
2007	0.20	0.24	0.11	0.20	**0.16**	0.06	0.26
2008	0.18	0.14	0.13	0.20	**0.16**	0.03	0.28

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

Values in red excluded from averages.

Table 24. 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	NJDEL	NCCOOP	**Unweighted average**	lower 95% CI	upper 95% CI
1987							
1988		0.03		0.03	**0.03**		
1989		0.03	0.03	0.03	**0.03**	0.03	0.04
1990		0.05	0.06	0.08	**0.06**	0.05	0.08
1991		0.07	0.03	0.10	**0.07**	0.05	0.08
1992	0.06	0.05	0.04	0.15	**0.05**	0.04	0.06
1993	0.06	0.06	0.03	0.11	**0.07**	0.04	0.09
1994	0.05	0.04	0.04	0.11	**0.06**	0.04	0.08
1995	0.04	0.06	0.06	0.13	**0.05**	0.04	0.06
1996	0.08	0.04	0.08	0.13	**0.08**	0.06	0.11
1997	0.13	0.05	0.09	0.21	**0.12**	0.08	0.16
1998	0.12	0.04	0.12	0.16	**0.11**	0.07	0.15
1999	0.10	0.07	0.06	0.22	**0.08**	0.05	0.11
2000	0.11	0.04	0.08	0.13	**0.08**	0.05	0.10
2001	0.07	0.06	0.10	0.14	**0.09**	0.07	0.11
2002	0.10	0.08	0.07	0.15	**0.10**	0.07	0.13
2003	0.09	0.07	0.09	0.13	**0.10**	0.07	0.13
2004	0.10	0.06	0.13	0.12	**0.10**	0.07	0.12
2005	0.08	0.06	0.11	0.10	**0.08**	0.06	0.10
2006	0.10	0.04	0.08	0.16	**0.09**	0.06	0.12
2007	0.04	0.03	0.12	0.20	**0.10**	0.06	0.14
2008	0.07	0.05	0.11	0.24	**0.11**	0.08	0.15

Table 24 continued.

Producer Area Programs*

Year	HUDSON	DE/PA	MDCB	VARAP	**Average**	lower 95% CI	upper 95% CI
1987			0.01				
1988	0.05		0.01		**0.02**	0.01	0.03
1989	0.05		0.01		**0.01**	0.01	0.02
1990	0.08		0.08	0.18	**0.08**	0.05	0.11
1991	0.08		0.12	0.24	**0.11**	0.07	0.16
1992	0.10		0.15	0.32	**0.14**	0.09	0.20
1993	0.12	0.15	0.13	0.28	**0.17**	0.10	0.24
1994	0.10	0.14	0.15	0.31	**0.18**	0.09	0.27
1995	0.14	0.15	0.23	0.22	**0.21**	0.11	0.31
1996	0.18	0.21	0.21	0.18	**0.20**	0.11	0.29
1997	0.27	0.13	0.26	0.25	**0.25**	0.14	0.36
1998	0.21	0.16	0.28	0.22	**0.24**	0.13	0.36
1999	0.17	0.12	0.22	0.20	**0.20**	0.10	0.29
2000	0.11	0.18	0.22	0.19	**0.20**	0.11	0.29
2001	0.11	0.18	0.16	0.25	**0.18**	0.10	0.26
2002	0.10	0.17	0.16	0.23	**0.17**	0.09	0.25
2003	0.12	0.19	0.17	0.20	**0.16**	0.10	0.23
2004	0.16	0.20	0.14	0.19	**0.15**	0.09	0.21
2005	0.11	0.13	0.14	0.19	**0.15**	0.08	0.22
2006	0.13	0.15	0.18	0.19	**0.17**	0.09	0.26
2007	0.12	0.10	0.12	0.17	**0.13**	0.06	0.20
2008	0.10	0.11	0.15	0.11	**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).

Values in red excluded in averages.

Table 25. 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	NJDEL	NCCOOP	**Unweighted average**	lower 95% CI	upper 95% CI
1987							
1988		0.04		0.05	**0.04**	0.03	0.05
1989		0.04	0.00	0.04	**0.04**	0.03	0.05
1990		0.15	0.11	0.11	**0.12**	0.08	0.16
1991		0.15	0.37	0.11	**0.21**	0.13	0.29
1992	0.08	0.15	0.00	0.11	**0.11**	0.10	0.13
1993	0.08	0.15	0.10	0.11	**0.11**	0.08	0.14
1994	0.08	0.15	0.05	0.11	**0.10**	0.08	0.11
1995	0.18	0.28	0.10	0.19	**0.19**	0.17	0.21
1996	0.19	0.28	0.21	0.19	**0.22**	0.20	0.24
1997	0.19	0.28	0.19	0.19	**0.21**	0.19	0.24
1998	0.19	0.29	0.32	0.19	**0.25**	0.22	0.27
1999	0.19	0.28	0.20	0.19	**0.21**	0.19	0.24
2000	0.13	0.22	0.16	0.14	**0.16**	0.14	0.19
2001	0.13	0.22	0.19	0.15	**0.17**	0.15	0.20
2002	0.13	0.22	0.17	0.14	**0.17**	0.14	0.19
2003	0.10	0.22	0.21	0.14	**0.17**	0.14	0.19
2004	0.10	0.21	0.19	0.14	**0.16**	0.14	0.18
2005	0.10	0.21	0.20	0.14	**0.16**	0.14	0.19
2006	0.10	0.21	0.13	0.14	**0.15**	0.12	0.17
2007	0.08	0.13	0.15	0.14	**0.12**	0.10	0.14
2008	0.08	0.13	0.17	0.15	**0.13**	0.11	0.15

Values in red excluded from averages.

Table 25 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	**Weighted average***	lower 95% CI	upper 95% CI
1987			0.02		**0.02**	0.01	0.03
1988	0.09		0.03		**0.03**	0.01	0.05
1989	0.09		0.03		**0.03**	0.02	0.05
1990	0.15		0.13	0.14	**0.13**	0.11	0.16
1991	0.15		0.13	0.14	**0.14**	0.11	0.16
1992	0.15	0.08	0.13	0.14	**0.13**	0.11	0.16
1993	0.15	0.08	0.13	0.14	**0.13**	0.11	0.16
1994	0.15	0.08	0.13	0.15	**0.13**	0.11	0.16
1995	0.26	0.18	0.26	0.23	**0.25**	0.22	0.28
1996	0.26	0.19	0.25	0.23	**0.24**	0.21	0.27
1997	0.26	0.19	0.26	0.23	**0.25**	0.22	0.27
1998	0.26	0.19	0.27	0.23	**0.25**	0.21	0.28
1999	0.26	0.19	0.27	0.23	**0.25**	0.21	0.29
2000	0.18	0.13	0.15	0.12	**0.15**	0.12	0.17
2001	0.18	0.13	0.15	0.12	**0.15**	0.12	0.17
2002	0.18	0.13	0.14	0.12	**0.14**	0.12	0.16
2003	0.18	0.10	0.11	0.12	**0.12**	0.10	0.15
2004	0.18	0.10	0.11	0.11	**0.12**	0.10	0.14
2005	0.18	0.10	0.11	0.11	**0.12**	0.10	0.14
2006	0.18	0.10	0.11	0.11	**0.12**	0.10	0.14
2007	0.18	0.08	0.08	0.11	**0.10**	0.08	0.12
2008	0.18	0.08	0.08	0.11	**0.10**	0.08	0.12

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

Table 26. 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	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	0.02	0.02	**0.02**	0.01	0.03
1990		0.06	0.05	0.10	**0.07**	0.06	0.09
1991		0.06	0.07	0.10	**0.08**	0.06	0.10
1992	0.06	0.06	0.03	0.11	**0.07**	0.05	0.08
1993	0.07	0.06	0.03	0.11	**0.07**	0.06	0.08
1994	0.07	0.06	0.03	0.10	**0.06**	0.06	0.07
1995	0.14	0.10	0.08	0.17	**0.12**	0.11	0.14
1996	0.14	0.10	0.13	0.17	**0.13**	0.12	0.15
1997	0.15	0.10	0.15	0.17	**0.14**	0.13	0.16
1998	0.15	0.10	0.18	0.17	**0.15**	0.13	0.17
1999	0.15	0.10	0.12	0.17	**0.13**	0.12	0.15
2000	0.11	0.07	0.12	0.11	**0.11**	0.09	0.12
2001	0.11	0.07	0.14	0.11	**0.11**	0.10	0.12
2002	0.11	0.07	0.12	0.11	**0.10**	0.09	0.12
2003	0.10	0.07	0.14	0.10	**0.10**	0.09	0.11
2004	0.10	0.07	0.14	0.10	**0.10**	0.09	0.11
2005	0.10	0.07	0.15	0.10	**0.10**	0.09	0.11
2006	0.10	0.07	0.10	0.10	**0.09**	0.08	0.10
2007	0.07	0.05	0.12	0.10	**0.09**	0.07	0.10
2008	0.07	0.05	0.12	0.10	**0.09**	0.07	0.10

Table 26 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		**0.04**		
1990	0.10		0.07	0.06	**0.07**	0.06	0.08
1991	0.10		0.12	0.08	**0.11**	0.10	0.12
1992	0.10		0.19	0.11	**0.15**	0.14	0.16
1993	0.10	0.15	0.17	0.10	**0.14**	0.13	0.15
1994	0.10	0.15	0.16	0.12	**0.14**	0.13	0.16
1995	0.19	0.16	0.24	0.14	**0.20**	0.19	0.22
1996	0.20	0.16	0.22	0.11	**0.18**	0.17	0.20
1997	0.20	0.16	0.29	0.13	**0.22**	0.20	0.25
1998	0.20	0.16	0.34	0.13	**0.25**	0.23	0.27
1999	0.20	0.16	0.28	0.14	**0.22**	0.20	0.25
2000	0.13	0.17	0.21	0.08	**0.16**	0.14	0.18
2001	0.13	0.17	0.16	0.09	**0.14**	0.12	0.16
2002	0.13	0.17	0.12	0.09	**0.12**	0.10	0.13
2003	0.12	0.15	0.15	0.10	**0.13**	0.12	0.15
2004	0.12	0.15	0.11	0.11	**0.11**	0.10	0.13
2005	0.12	0.15	0.09	0.09	**0.10**	0.09	0.11
2006	0.12	0.15	0.10	0.10	**0.11**	0.09	0.12
2007	0.12	0.11	0.06	0.09	**0.08**	0.07	0.09
2008	0.12	0.10	0.07	0.09	**0.08**	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 27. 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 age3+ and 7+ obtained via "Kill = F * Stock Size".

Year	Fishing Mortality	Age 3+ Kill includes discards	Total Stock Size Thousands
1988	0.17	411.4	2,432
1989	0.24	443.2	1,866
1990	0.25	873	3,443
1991	0.15	913.8	5,969
1992	0.20	938.2	4,673
1993	0.24	1,367.1	5,686
1994	0.20	1,715.5	8,690
1995	0.17	2,562.1	15,035
1996	0.24	3,276.2	13,752
1997	0.30	4,285.3	14,453
1998	0.29	3,908.5	13,439
1999	0.27	3,587.6	13,350
2000	0.39	4,684.9	11,934
2001	0.31	4,156	13,462
2002	0.31	3,667.4	11,746
2003	0.25	4,561.2	18,353
2004	0.36	5,031.7	13,805
2005	0.39	5,126.2	13,088
2006	0.42	5,834.9	13,806
2007	0.36	5,674.5	15,953
2008	0.36	4,249.8	11,674

Table 27 continued.

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Year	Fishing Mortality	Age 7+ Kill includes discards	Total Stock Size Thousands
1988	0.05	101.4	1,877
1989	0.09	95	1,002
1990	0.13	222.3	1,670
1991	0.16	296.4	1,880
1992	0.09	262.7	2,934
1993	0.17	380.6	2,307
1994	0.13	475.9	3,770
1995	0.17	740	4,347
1996	0.21	965.1	4,594
1997	0.22	1,371.1	6,282
1998	0.28	1,080.5	3,802
1999	0.22	1,146.8	5,129
2000	0.18	1,481.1	8,231
2001	0.18	1,591.8	9,095
2002	0.17	2,085.4	12,035
2003	0.26	2,169.2	8,232
2004	0.36	2,440.4	6,852
2005	0.27	2,131	7,947
2006	0.26	2,218.2	8,595
2007	0.27	2,121.5	7,932
2008	0.30	1,962.3	6,531

Table 28. 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
1988	0.02	411.4	17,202
1989	0.02	443.2	17,936
1990	0.07	873.0	12,309
1991	0.09	913.8	10,363
1992	0.10	938.2	9,854
1993	0.12	1,367.1	11,596
1994	0.12	1,715.5	14,351
1995	0.13	2,562.1	19,468
1996	0.14	3,276.2	23,171
1997	0.18	4,285.3	23,358
1998	0.18	3,908.5	22,008
1999	0.14	3,587.6	26,317
2000	0.14	4,684.9	34,162
2001	0.13	4,156.0	30,794
2002	0.13	3,667.4	27,203
2003	0.13	4,561.2	34,960
2004	0.12	5,031.7	41,067
2005	0.12	5,126.2	44,216
2006	0.13	5,834.9	43,826
2007	0.11	5,674.5	49,911
2008	0.12	4,249.8	34,847

Table 28 continued.

Year	Fishing Mortality	Age 7+ Kill includes discards	Total Stock Size Thousands
1988	0.09	101.4	1,186
1989	0.06	95	1,669
1990	0.12	222.3	1,929
1991	0.13	296.4	2,262
1992	0.11	262.7	2,480
1993	0.14	380.6	2,775
1994	0.13	475.9	3,758
1995	0.17	740	4,370
1996	0.19	965.1	4,978
1997	0.28	1,371.1	4,943
1998	0.24	1,080.5	4,460
1999	0.26	1,146.8	4,495
2000	0.17	1,481.1	8,545
2001	0.17	1,591.8	9,569
2002	0.14	2,085.4	15,228
2003	0.18	2,169.2	12,040
2004	0.17	2,440.4	14,774
2005	0.18	2,131	11,885
2006	0.18	2,218.2	12,470
2007	0.15	2,121.5	13,878
2008	0.15	1,962.3	12,686

Table 29. 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
1988	0.02	411.4	25,623
1989	0.03	443.2	15,758
1990	0.07	873	11,970
1991	0.09	913.8	9,978
1992	0.11	938.2	8,749
1993	0.10	1367.1	13,322
1994	0.10	1715.5	16,626
1995	0.16	2562.1	15,735
1996	0.16	3276.2	20,602
1997	0.18	4285.3	23,415
1998	0.20	3908.5	19,628
1999	0.18	3587.6	20,136
2000	0.13	4684.9	34,952
2001	0.12	4156	33,489
2002	0.11	3667.4	33,323
2003	0.12	4561.2	38,929
2004	0.11	5031.7	46,617
2005	0.10	5126.2	50,967
2006	0.10	5834.9	58,758
2007	0.08	5674.5	67,888
2008	0.09	4249.8	49,853

Table 29 continued.

Instantaneous Rates Method

Year	Fishing Mortality	Age 7+ Kill includes discards	Total Stock Size Thousands
1988	0.04	101.4	2,709
1989	0.04	95	2,556
1990	0.13	222.3	1,733
1991	0.17	296.4	1,709
1992	0.13	262.7	2,096
1993	0.12	380.6	3,114
1994	0.12	475.9	4,123
1995	0.22	740	3,395
1996	0.23	965.1	4,235
1997	0.23	1371.1	5,979
1998	0.25	1080.5	4,359
1999	0.23	1146.8	4,949
2000	0.15	1481.1	9,593
2001	0.16	1591.8	10,037
2002	0.15	2085.4	13,603
2003	0.14	2169.2	14,973
2004	0.14	2440.4	17,387
2005	0.14	2131	15,161
2006	0.13	2218.2	16,769
2007	0.11	2121.5	18,794
2008	0.12	1962.3	16,823

Table 30. 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
{S(d)r(p)}	0
{S(v)r(p)}	0
{S(t)r(p)}	0
{S(t)r(t)}	**1**

IRCR (1M)

Model	CB 18-28"
{F(t)F'(t)M(.)}	**1**
{F(p)F'(t)M(.)}	0
{F(.)F'(t)M(.)}	0
{F(t)F'(p)M(.)}	0
{F(t)F'(.)M(.)}	0
{F(p)F'(p)M(.)}	0
{F(.)F'(.)M(.)}	0
{F(d)F'(d)M(.)}	0
{F(v)F'(v)M(.)}	0

IRCR (2M)

Model	CB 18-28"
{F(t)F'(t)M(.)}	0
{F(p)F'(t)M(.)}	0
{F(.)F'(t)M(.)}	0
{F(t)F'(p)M(.)}	0
{F(t)F'(.)M(.)}	0
{F(p)F'(p)M(.)}	0
{F(.)F'(.)M(.)}	0
{F(d)F'(d)M(.)}	0
{F(v)F'(v)M(.)}	0
{F(t)F'(t)M(p)}	**0.635**
{F(p)F'(t)M(p)}	0
{F(.)F'(t)M(p)}	0
{F(t)F'(p)M(p)}	**0.365**
{F(t)F'(.)M(p)}	0
{F(p)F'(p)M(p)}	0
{F(.)F'(.)M(p)}	0
{F(d)F'(d)M(p)}	0
{F(v)F'(v)M(p)}	0

Table 31. 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	0.85	0.01	0.07	0.94	-0.10	**0.94**	**-0.09**	-0.19	0.14
1988	0.76	0.13	0.04	0.86	-0.05	**0.80**	**0.08**	-0.02	0.22
1989	0.97	-0.12	0.03	0.93	-0.04	**1.01**	**-0.16**	-0.17	-0.15
1990	0.58	0.39	0.05	0.56	-0.04	**0.61**	**0.35**	0.23	0.50
1991	0.71	0.20	0.07	0.42	-0.05	**0.74**	**0.15**	0.02	0.33
1992	0.61	0.34	0.10	0.40	-0.07	**0.65**	**0.28**	0.14	0.45
1993	0.54	0.47	0.08	0.32	-0.04	**0.56**	**0.43**	0.29	0.59
1994	0.63	0.32	0.10	0.41	-0.06	**0.67**	**0.25**	0.11	0.44
1995	0.50	0.55	0.11	0.38	-0.07	**0.53**	**0.48**	0.31	0.67
1996	0.70	0.20	0.10	0.38	-0.06	**0.75**	**0.14**	-0.03	0.40
1997	0.47	0.60	0.09	0.34	-0.05	**0.49**	**0.55**	0.35	0.81
1998	0.35	0.91	0.09	0.32	-0.05	**0.36**	**0.86**	0.62	1.13
1999	0.39	0.79	0.08	0.29	-0.04	**0.40**	**0.76**	0.53	1.02
2000	0.29	1.07	0.09	0.40	-0.06	**0.31**	**1.01**	0.78	1.27
2001	0.38	0.82	0.09	0.37	-0.05	**0.40**	**0.77**	0.52	1.06
2002	0.51	0.52	0.07	0.34	-0.04	**0.53**	**0.48**	0.24	0.79
2003	0.60	0.37	0.07	0.26	-0.03	**0.62**	**0.34**	0.09	0.73
2004	0.24	1.27	0.06	0.27	-0.02	**0.25**	**1.25**	0.90	1.64
2005	0.33	0.95	0.05	0.31	-0.03	**0.34**	**0.92**	0.60	1.31
2006	0.29	1.08	0.08	0.33	-0.04	**0.30**	**1.04**	0.64	1.52
2007	0.27	1.17	0.06	0.38	-0.03	**0.28**	**1.13**	0.68	1.67
2008	0.43	0.69	0.06	0.31	-0.03	**0.44**	**0.66**	0.31	1.15

Table 32. R/M estimates of exploitation (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	0.06
1988	0.01	0.06
1989	0.00	0.05
1990	0.04	0.09
1991	0.06	0.11
1992	0.09	0.17
1993	0.07	0.11
1994	0.08	0.14
1995	0.11	0.19
1996	0.10	0.18
1997	0.09	0.16
1998	0.09	0.15
1999	0.07	0.12
2000	0.07	0.13
2001	0.09	0.15
2002	0.07	0.12
2003	0.08	0.11
2004	0.06	0.09
2005	0.07	0.10
2006	0.07	0.13
2007	0.06	0.09
2008	0.05	0.08

Table 33. 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 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	0.16	0.15	0.01	**0.01**	0.15
1988	0.28	0.24	0.01	**0.01**	0.27
1989	0.03	0.03	0.00	**0.00**	0.03
1990	0.54	0.42	0.04	**0.05**	0.49
1991	0.35	0.29	0.06	**0.07**	0.28
1992	0.49	0.39	0.09	**0.12**	0.38
1993	0.62	0.46	0.07	**0.10**	0.52
1994	0.47	0.37	0.08	**0.10**	0.37
1995	0.70	0.50	0.11	**0.15**	0.55
1996	0.35	0.30	0.10	**0.11**	0.24
1997	0.75	0.53	0.09	**0.13**	0.62
1998	1.06	0.65	0.09	**0.15**	0.91
1999	0.94	0.61	0.07	**0.11**	0.83
2000	1.22	0.71	0.07	**0.12**	1.11
2001	0.97	0.62	0.09	**0.14**	0.83
2002	0.67	0.49	0.07	**0.10**	0.56
2003	0.52	0.40	0.08	**0.11**	0.41
2004	1.42	0.76	0.06	**0.12**	1.30
2005	1.10	0.67	0.07	**0.12**	0.98
2006	1.23	0.71	0.07	**0.12**	1.11
2007	1.32	0.73	0.06	**0.11**	1.21
2008	0.84	0.57	0.05	**0.08**	0.76
Average	**0.69**	**0.47**	**0.07**	**0.10**	**0.60**

Table 34. 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 the Instantaneous Rates model and a tag reporting rate of 0.64.

Year	F	M	S	F'
1987	0.00	0.37	0.69	0.04
1988	0.01	0.37	0.69	0.01
1989	0.00	0.37	0.69	0.04
1990	0.05	0.37	0.66	0.05
1991	0.09	0.37	0.63	0.06
1992	0.15	0.37	0.59	0.08
1993	0.12	0.37	0.61	0.05
1994	0.12	0.37	0.61	0.07
1995	0.14	0.37	0.60	0.07
1996	0.11	0.37	0.62	0.07
1997	0.13	0.37	0.61	0.05
1998	0.12	0.37	0.61	0.05
1999	0.07	0.37	0.64	0.03
2000	0.07	0.37	0.65	0.04
2001	0.05	0.37	0.66	0.03
2002	0.05	0.37	0.66	0.02
2003	0.05	0.37	0.65	0.02
2004	0.05	0.37	0.66	0.02
2005	0.04	0.37	0.67	0.02
2006	0.04	0.37	0.66	0.02
2007	0.03	0.37	0.67	0.02
2008	0.03	0.37	0.67	0.01

Table 35. 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 two-natural mortality period (1987-1996 and 1997-2008) Instantaneous Rates model and a tag reporting rate of 0.64.

Year	F	M	S	F'
1987	0.00	0.27	0.76	0.03
1988	0.01	0.27	0.76	0.02
1989	0.00	0.27	0.76	0.03
1990	0.05	0.27	0.73	0.05
1991	0.07	0.27	0.71	0.05
1992	0.13	0.27	0.67	0.06
1993	0.10	0.27	0.69	0.05
1994	0.09	0.27	0.69	0.06
1995	0.11	0.27	0.68	0.06
1996	0.08	0.27	0.70	0.05
1997	0.11	0.80	0.40	0.05
1998	0.15	0.80	0.38	0.06
1999	0.12	0.80	0.40	0.05
2000	0.10	0.80	0.40	0.06
2001	0.10	0.80	0.41	0.05
2002	0.10	0.80	0.40	0.05
2003	0.12	0.80	0.40	0.04
2004	0.11	0.80	0.40	0.04
2005	0.08	0.80	0.41	0.03
2006	0.10	0.80	0.40	0.04
2007	0.06	0.80	0.42	0.04
2008	0.07	0.80	0.42	0.03

Figure 1. Retrospective analysis of catch equation results for fish >28”. Data shown are from the previous stock assessment in 2004 and in 2006.

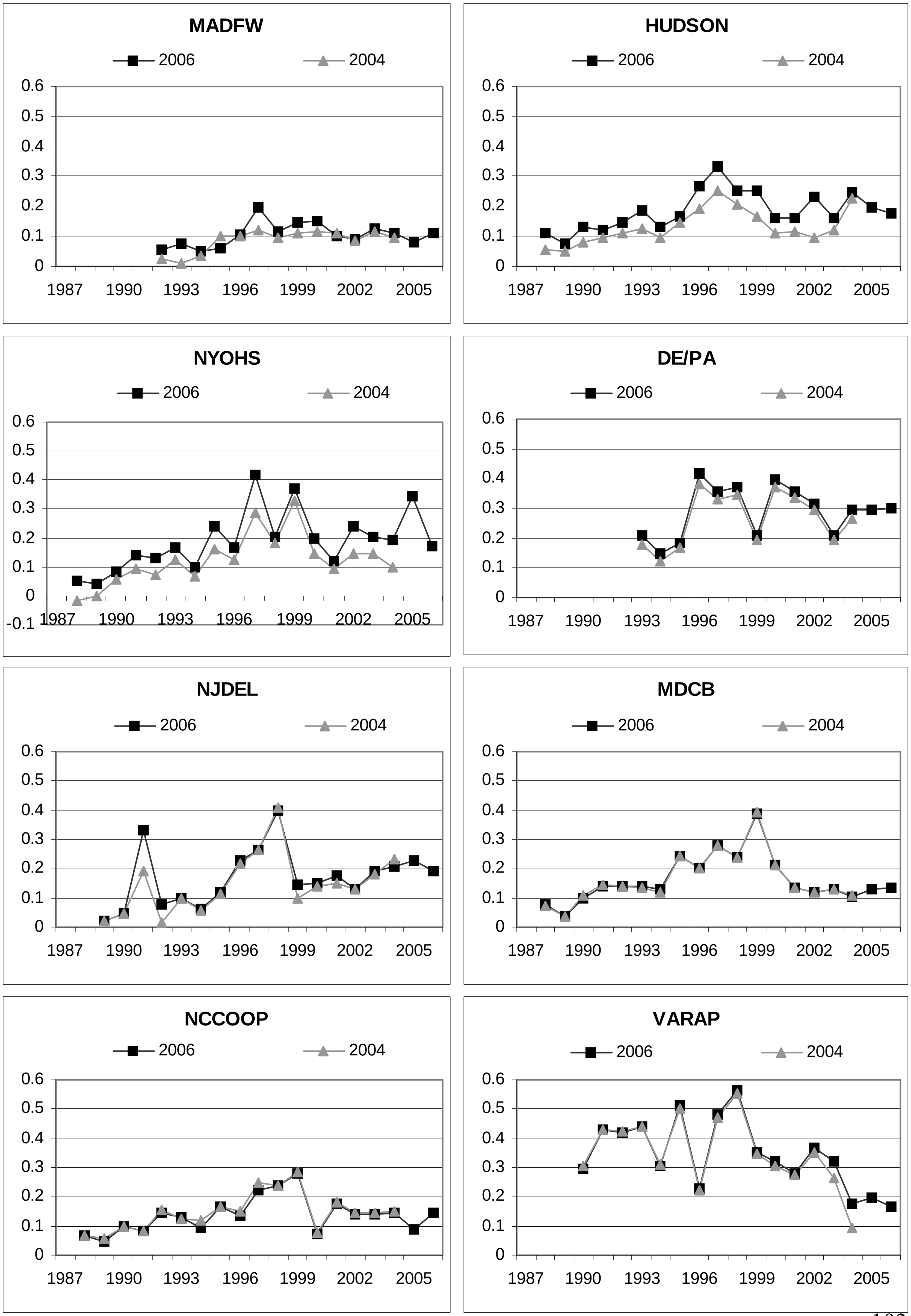


Figure 2. Retrospective analysis of catch equation results for fish >18". Data shown are from the previous stock assessment in 2004 and in 2006.

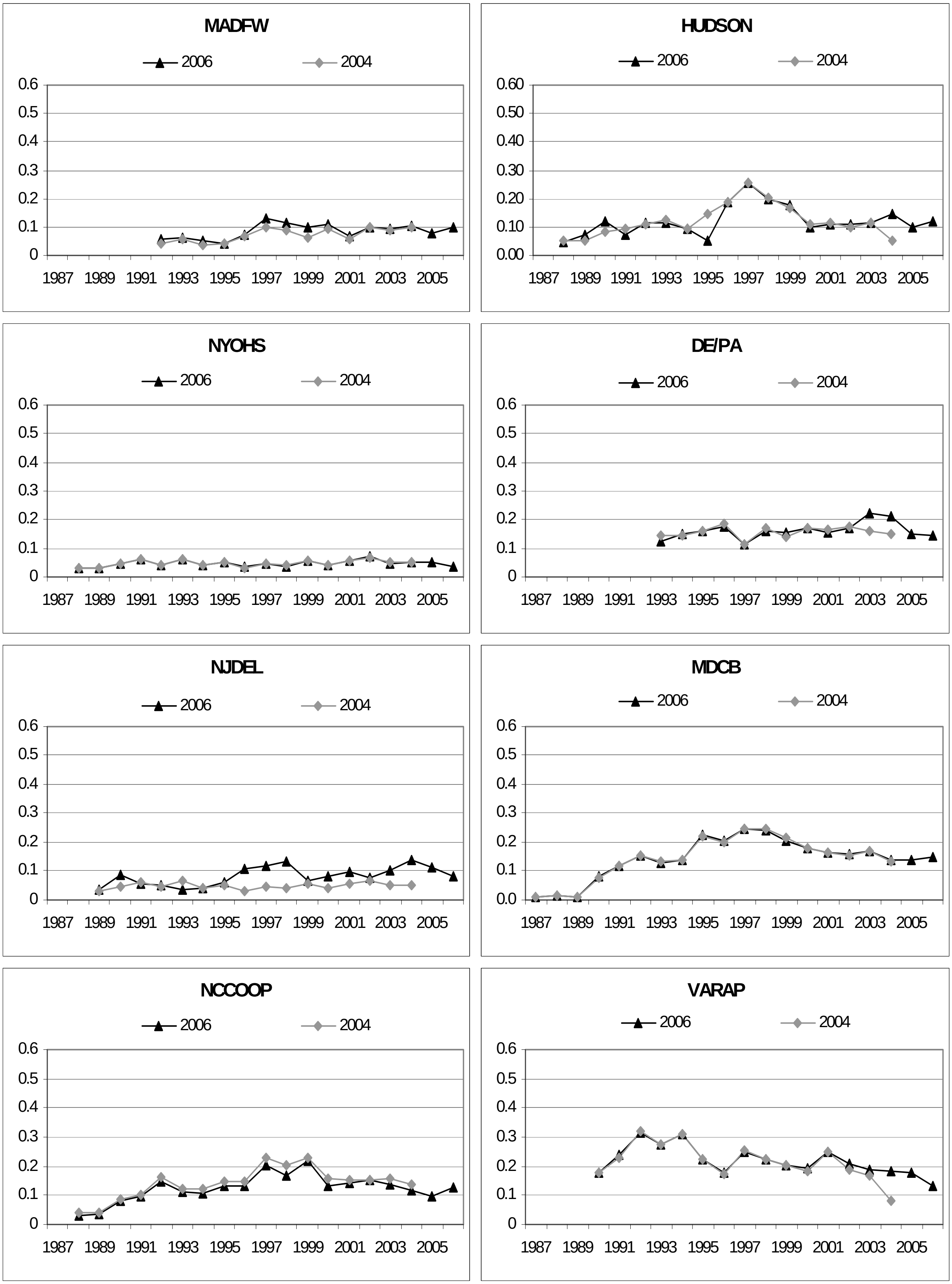
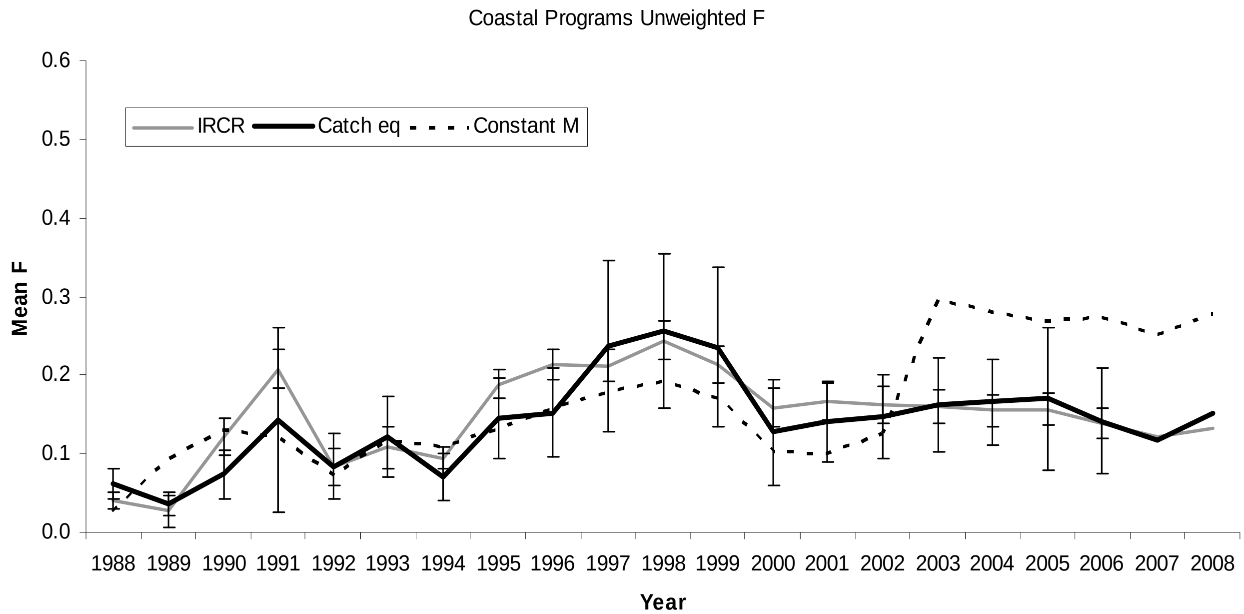


Figure 3. Comparison of coast program and producer area mean fishing mortality estimates from the three methods, for fish ≥ 28 inches. 95% confidence intervals are shown for the catch equation and IRCR methods.



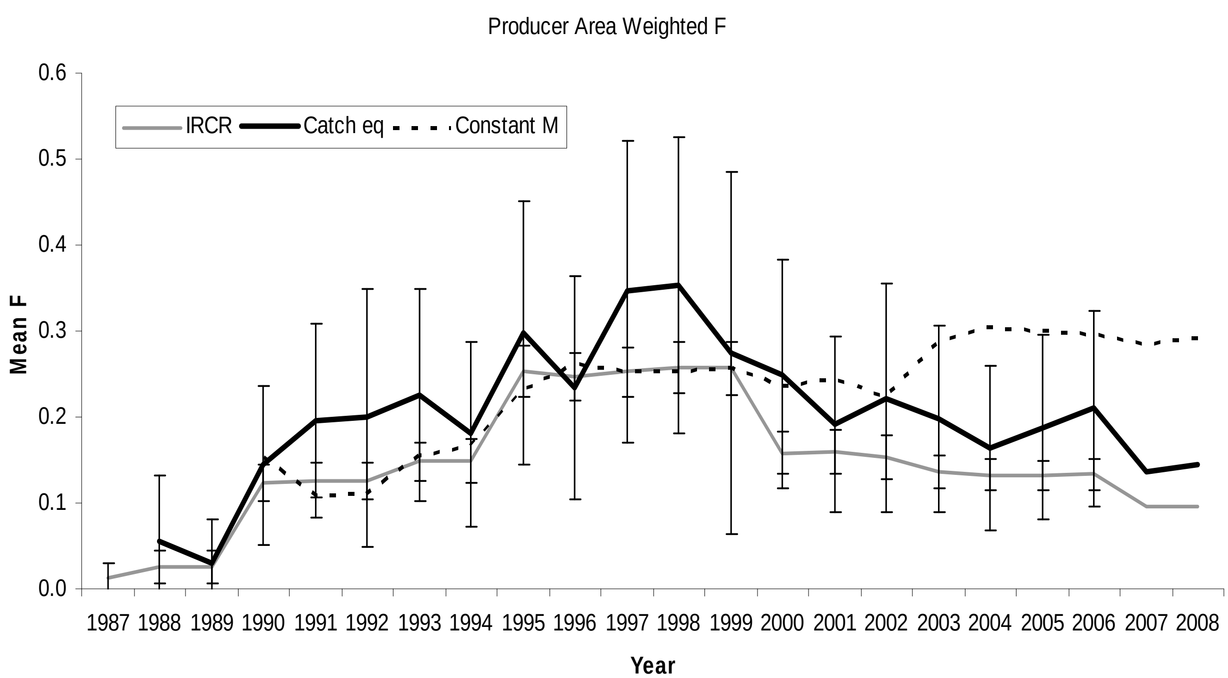
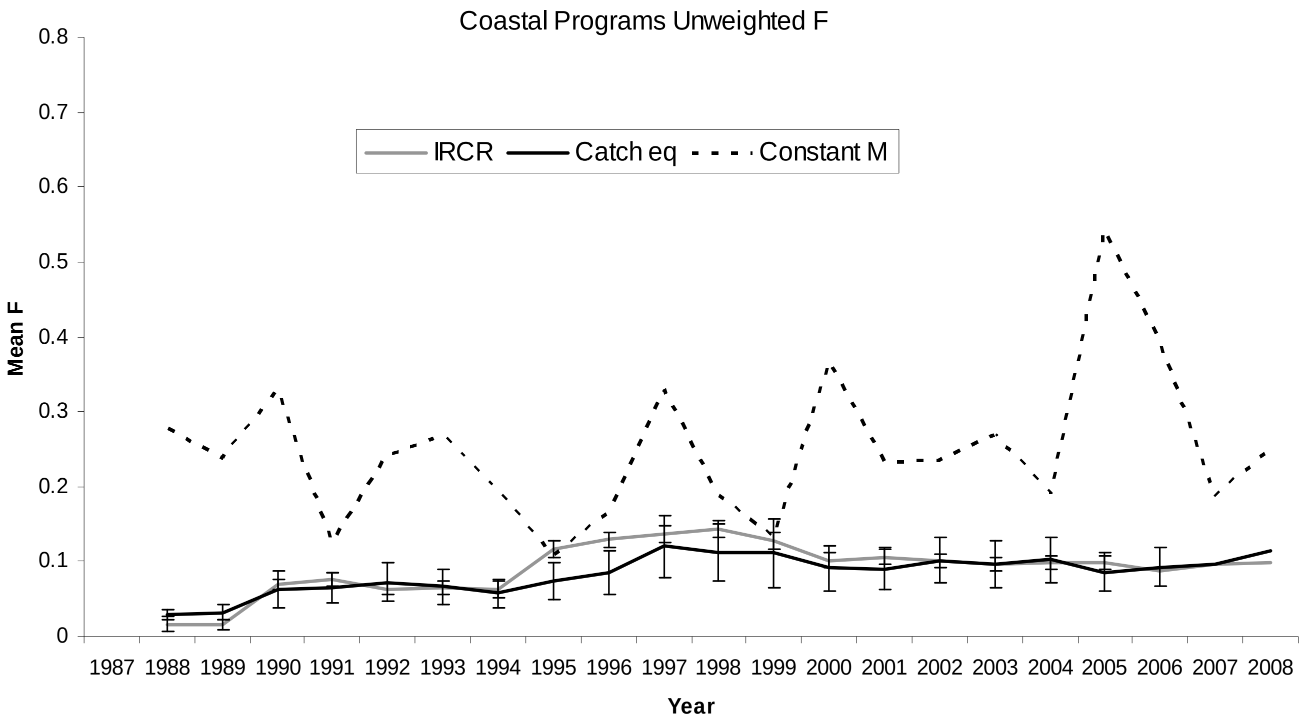


Figure 4. Comparison of coast program and producer area mean fishing mortality estimates from the three methods, for fish ≥ 18 inches. 95% confidence intervals are shown for the catch equation and IRCR methods.



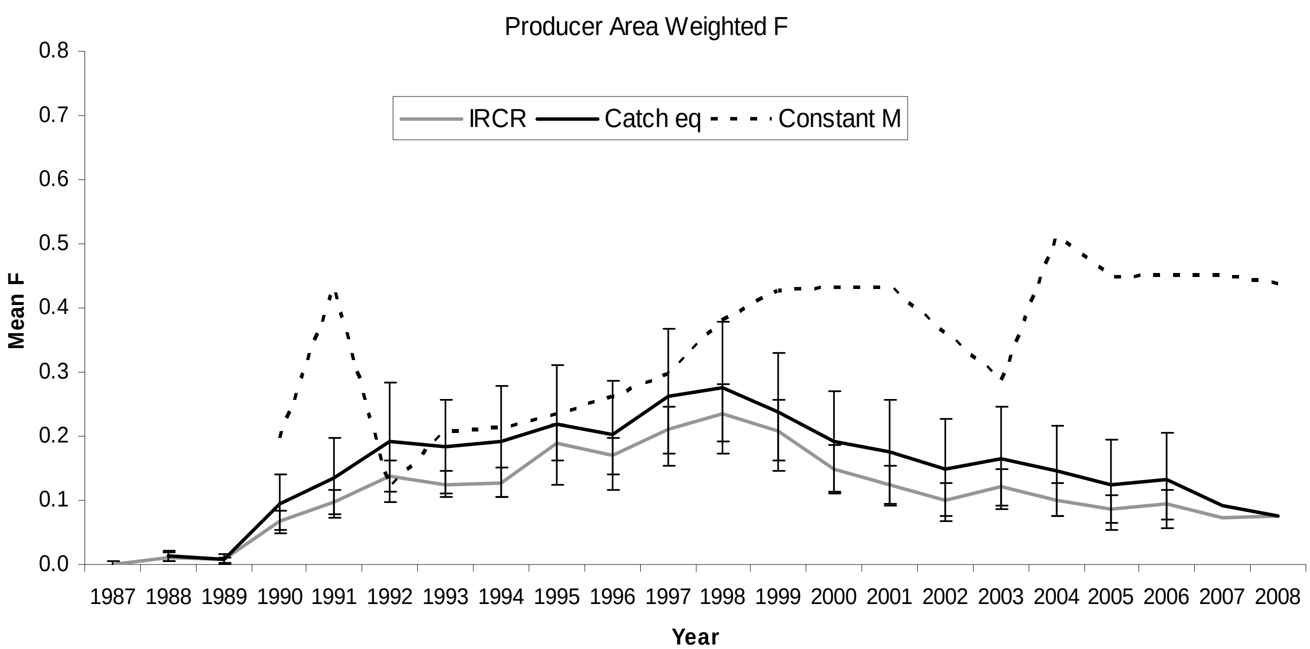


Figure 5. Comparison of stock size estimates from the three methods, for fish age seven and older (comparable to fish ≥ 28 inches). Stock size obtained via "Kill = F * Stock Size".

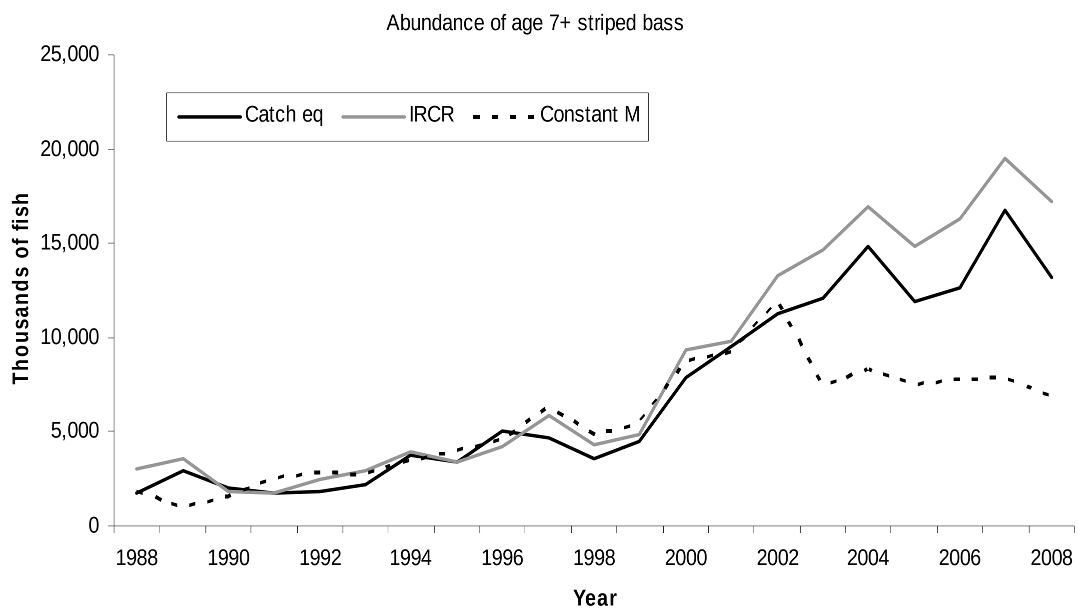
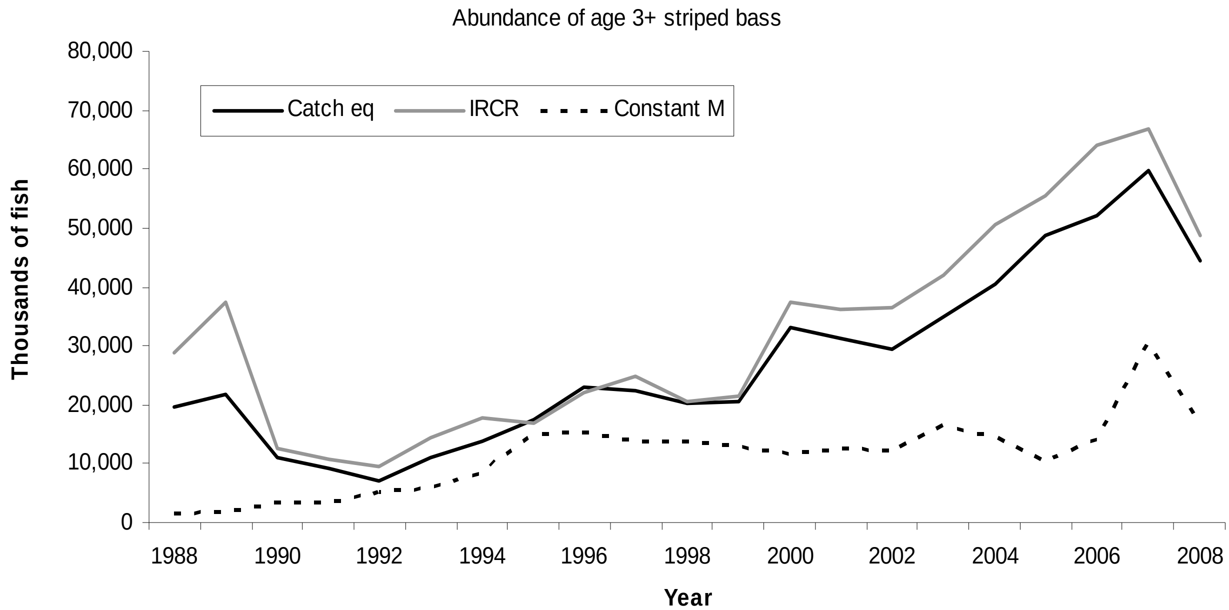


Figure 6. Comparison of stock size estimates from the three methods, for fish age three and older (comparable to fish ≥ 18 inches). Stock size obtained via "Kill = F * Stock Size".



APPENDIX A

Input Tagging Matrices for Program MARK/Catch Equation Method and Instantaneous Rates - Catch and Release Model, by Tagging Program.

Table 1. Program MARK input matrices for the coastal tagging programs, for fish ≥ 28".

Massachusetts

Release		recapture year																
Number	Year	92	93	94	95	96	97	98	99	"00"	01	02	03	04	05	06	07	08
329	1992	21	22	12	12	8	4	0	4	3	1	0	0	0	0	0	0	0
611	1993		35	32	26	29	17	17	11	2	2	2	2	1	0	0	0	0
462	1994			21	28	27	19	17	7	2	1	2	2	0	1	0	0	1
218	1995				15	12	10	4	5	3	1	1	1	0	0	1	0	1
274	1996					22	15	13	11	9	1	3	1	1	1	0	0	0
118	1997						17	6	3	3	1	2	0	1	0	1	1	0
219	1998							16	16	9	8	2	4	1	1	0	0	0
59	1999								6	3	1	1	0	0	0	0	0	0
163	2000									10	6	7	3	4	0	1	1	0
411	2001										21	23	16	9	11	3	2	2
353	2002											23	13	14	9	8	4	2
172	2003												9	3	6	6	0	0
615	2004													31	24	13	15	7
542	2005														25	25	11	13
510	2006															33	15	14
480	2007																10	20
385	2008																	17

New York – Ocean Haul Seine

Release		recapture year																				
Number	Year	88	89	90	91	92	93	94	95	96	97	98	99	"00"	01	02	03	04	05	06	07	08
209	1988	25	12	14	9	5	6	2	2	1	0	0	2	0	0	0	0	0	0	0	0	0
339	1989		35	28	25	13	13	7	4	1	1	2	0	0	2	0	0	0	0	0	0	0
244	1990			23	17	10	6	3	0	2	1	2	0	0	0	0	0	0	0	0	0	0
281	1991				32	23	10	6	5	2	6	3	0	1	1	0	0	0	0	0	0	0
287	1992					41	24	14	17	6	3	6	0	1	1	0	0	1	0	1	0	0
235	1993						28	13	13	7	6	0	1	0	0	0	0	0	0	0	0	0
252	1994							25	18	20	20	6	5	1	3	2	1	0	0	0	0	0
349	1995								53	37	22	18	6	4	3	1	4	3	0	0	0	0
110	1996									15	5	14	5	1	0	0	1	1	1	0	0	0
69	1997										12	5	4	0	2	2	1	1	1	1	0	0
82	1998											6	4	3	1	1	1	0	0	0	0	0
83	1999												13	7	3	1	1	4	1	0	0	0
56	2000													8	6	2	4	2	0	0	0	0
90	2001														8	6	5	7	1	0	0	0
176	2002															29	11	5	0	3	0	3
144	2003																13	5	7	1	0	1
153	2004																	17	4	3	1	1
63	2005																		9	3	1	4
56	2006																			5	5	5
24	2007																				3	0
142	2008																					8

New Jersey – Delaware Bay

Release		recapture year																			
Number	Year	89	90	91	92	93	94	95	96	97	98	99	"00"	01	02	03	04	05	06	07	08
38	1989	4	3	7	2	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
9	1990		2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1991			3	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
76	1992				7	6	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0
91	1993					8	4	5	2	3	0	1	0	0	1	0	0	0	0	0	0
308	1994						27	24	17	16	11	4	3	2	1	2	0	0	0	0	0
552	1995							55	51	32	27	14	5	6	3	4	3	1	2	1	1
589	1996								82	35	45	13	9	6	4	5	6	2	0	1	0
68	1997									12	2	1	1	0	3	0	0	0	0	0	0
126	1998										21	10	6	3	0	4	1	1	0	0	0
101	1999											9	6	6	5	2	1	3	1	0	0
233	2000												22	18	12	12	7	5	0	1	1
522	2001													52	38	24	16	8	5	2	4
359	2002														27	23	14	11	2	3	2
564	2003															58	28	27	9	8	5
847	2004																94	48	21	19	15
180	2005																	23	10	11	3
225	2006																		25	10	11
434	2007																			38	26
518	2008																				47

North Carolina – Cooperative Trawl Cruise

Release		recapture year																				
Number	Year	88	89	90	91	92	93	94	95	96	97	98	99	"00"	01	02	03	04	05	06	07	08
191	1988	18	11	9	3	10	4	5	0	0	1	0	1	0	0	0	0	0	0	0	0	0
411	1989		24	20	18	14	7	3	2	1	1	0	0	1	1	0	0	0	0	0	0	0
322	1990			25	19	16	8	3	2	2	3	2	1	0	0	0	0	0	0	0	0	0
856	1991				74	39	48	34	18	7	12	8	1	1	1	1	0	0	0	0	0	0
433	1992					46	29	14	14	8	8	10	6	3	0	0	0	0	0	0	0	0
142	1993						17	5	5	3	3	1	0	0	1	0	0	0	0	0	0	0
480	1994							41	25	9	10	6	6	1	3	1	2	2	0	0	0	0
372	1995								43	16	17	14	5	3	2	5	1	1	2	0	0	1
557	1996									35	20	15	6	5	4	4	0	3	1	1	0	0
869	1997										88	44	25	14	13	0	3	4	1	0	1	2
106	1998											12	11	0	2	1	1	0	0	1	0	1
179	1999												21	8	5	2	0	3	2	1	1	1
164	2000													9	6	2	3	3	2	1	0	0
515	2001														46	23	15	5	11	9	1	2
789	2002															51	43	22	18	10	4	2
1578	2003																107	65	38	25	15	7
784	2004																	58	26	26	17	6
557	2005																		25	21	11	7
2113	2006																			153	105	57
305	2007																				31	22
923	2008																					99

Table 2. Program MARK input matrices for the producer area tagging programs, for fish ≥ 28".

New York – Hudson River

Release Number	Year	88	89	90	91	92	93	94	95	96	97	98	99	"00"	01	02	03	04	05	06	07	08
277	1988	25	31	18	11	10	5	4	1	4	1	1	1	0	0	1	0	0	0	0	0	0
387	1989		42	29	17	9	6	9	4	0	0	0	0	1	0	0	1	0	0	0	0	0
445	1990			62	31	27	14	9	4	1	3	1	0	0	1	0	0	0	0	0	0	0
364	1991				38	31	13	10	9	5	5	2	0	1	0	0	1	0	1	1	0	0
699	1992					90	58	35	21	14	13	10	5	2	1	0	0	1	0	0	0	0
536	1993						77	36	24	20	15	7	8	0	1	0	0	0	1	0	0	0
381	1994							44	33	27	10	6	6	5	4	2	0	2	1	0	0	0
461	1995								52	34	30	21	11	4	1	2	1	1	1	0	0	0
681	1996									91	68	33	18	3	9	4	3	4	3	1	1	0
184	1997										29	11	12	6	3	2	2	0	1	1	0	0
530	1998											67	45	18	9	20	6	0	1	2	0	1
503	1999												65	22	27	12	14	7	3	4	1	3
485	2000													46	24	23	18	13	6	3	3	0
576	2001														49	39	14	7	6	10	2	3
196	2002															20	11	9	4	7	4	2
677	2003																64	44	35	17	13	3
649	2004																	76	34	34	18	7
574	2005																		59	44	21	14
707	2006																			62	40	38
399	2007																				35	27
540	2008																					50

Delaware/Pennsylvania – Delaware River

Release Number	Year	93	94	95	96	97	98	99	"00"	01	02	03	04	05	06	07	08
	1993																
	1994																
	1995																
	1996																
	1997																
	1998																
	1999																
	2000																
	2001																
	2002																
	2003																
	2004																
	2005																
	2006																
	2007																
	2008																

Maryland – Chesapeake Bay

Release		recapture year																					
Total	Year	87	88	89	90	91	92	93	94	95	96	97	98	99	"00"	01	02	03	04	05	06	07	08
	1987	1	0	2	0	1	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	1988		6	8	7	14	6	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	1989			9	17	17	6	4	3	5	2	0	0	0	0	0	0	0	0	0	0	0	0
	1990				23	16	12	5	2	4	0	3	1	0	0	0	0	0	0	0	0	0	0
	1991					46	22	20	5	9	3	5	1	0	2	0	0	0	0	0	0	0	0
	1992						45	30	19	17	7	10	6	5	2	1	0	0	0	0	0	0	0
	1993							59	44	42	15	16	8	9	1	3	2	0	0	0	0	0	0
	1994								52	43	26	14	15	10	4	3	0	1	1	1	0	0	0
	1995									63	32	23	16	7	6	2	2	3	0	0	2	0	1
	1996										97	54	44	18	9	7	2	1	1	0	0	0	0
	1997											41	26	18	2	2	1	1	0	1	0	0	0
	1998												29	16	3	5	2	0	0	1	0	1	0
	1999													19	8	8	3	1	2	1	0	1	1
	2000														21	16	4	5	4	1	0	2	1
	2001															31	19	11	6	3	3	0	1
	2002																18	20	6	7	2	3	0
	2003																	22	11	9	8	4	3
	2004																		17	9	11	3	4
	2005																			21	15	7	4
	2006																				17	6	6
	2007																					8	5
	2008																						7

Virginia – Rappahannock River

Release		recapture year																		
Number	Year	90	91	92	93	94	95	96	97	98	99	"00"	01	02	03	04	05	06	07	08
301	1990	26	9	15	2	4	6	1	0	2	1	1	0	0	1	0	0	0	0	0
390	1991		41	24	16	11	3	2	2	1	2	0	0	0	1	0	0	0	0	0
40	1992			4	3	2	2	0	0	0	1	0	0	0	0	0	0	0	0	0
212	1993				22	18	7	4	7	0	0	1	0	0	0	0	0	0	0	0
123	1994					9	7	5	1	2	0	0	0	0	0	0	0	0	0	0
210	1995						29	11	8	3	3	2	3	0	1	0	1	0	0	0
67	1996							1	3	1	0	0	1	0	0	0	0	0	0	0
212	1997								15	13	8	3	0	1	2	1	0	0	0	0
158	1998									24	13	2	3	2	0	0	0	0	0	0
162	1999										17	6	2	3	2	0	0	0	0	0
365	2000											28	19	14	9	4	3	0	1	0
269	2001												19	14	4	6	2	1	1	0
122	2002													10	6	7	1	0	2	1
400	2003														35	24	7	1	3	3
686	2004															39	12	13	5	4
284	2005																16	11	8	1
175	2006																	13	4	4
840	2007																		54	30
76	2008																			6

Table 3. Instantaneous Rates – Catch and Release Model input matrices for the coastal tagging programs, for fish ≥ 28”. The first matrix contains all harvested recaptures and the second matrix contains released fish with their tag removed.

<u>Massachusetts</u>

Release		Harvested recaptures																
Total	Year	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
329	1992	6	10	7	11	8	4	0	3	3	1	0	0	0	0	0	0	0
611	1993		17	18	15	25	16	14	9	1	2	2	2	1	0	0	0	0
462	1994			8	23	23	15	13	7	2	0	2	2	0	1	0	0	1
218	1995				4	8	9	3	3	1	1	1	1	0	0	1	0	1
274	1996					10	10	11	9	7	0	3	1	1	1	0	0	0
118	1997						8	4	2	3	1	1	0	1	0	1	1	0
219	1998							9	11	6	6	2	3	1	0	0	0	0
59	1999								3	3	1	1	0	0	0	0	0	0
163	2000									9	4	4	3	3	0	1	1	0
411	2001										15	18	10	7	10	3	0	1
353	2002											11	11	11	5	5	3	2
172	2003												8	2	5	4	0	0
615	2004													25	17	9	12	6
542	2005														16	20	9	12
510	2006															20	11	13
480	2007																7	16
385	2008																	12

Release		Released with tag removed																
Total	Year	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
329	1992	15	12	5	1	0	0	0	1	0	0	0	0	0	0	0	0	0
611	1993		18	14	11	4	1	3	2	1	0	0	0	0	0	0	0	0
462	1994			13	5	4	4	4	0	0	1	0	0	0	0	0	0	0
218	1995				11	4	1	1	2	2	0	0	0	0	0	0	0	0
274	1996					12	5	2	2	2	1	0	0	0	0	0	0	0
118	1997						9	2	1	0	0	1	0	0	0	0	0	0
219	1998							7	5	3	2	0	1	0	1	0	0	0
59	1999								3	0	0	0	0	0	0	0	0	0
163	2000									1	2	3	0	1	0	0	0	0
411	2001										6	5	6	2	2	0	2	1
353	2002											12	2	3	3	3	1	0
172	2003												1	1	1	2	0	0
615	2004													6	7	4	3	1
542	2005														9	5	2	1
510	2006															13	4	1
480	2007																3	4
385	2008																	5

New York – Ocean Haul Seine

Release		Harvested recaptures																				
Total	Year	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
209	1988	3	3	5	7	3	3	1	1	1	0	0	2	0	0	0	0	0	0	0	0	0
339	1989		4	10	10	8	10	3	4	1	1	2	0	0	2	0	0	0	0	0	0	0
244	1990			6	8	6	3	3		1	1	2	0	0	0	0	0	0	0	0	0	0
281	1991				14	11	6	3	4	1	4	2	0	1	1	0	0	0	0	0	0	0
287	1992					12	12	6	13	4	3	4	0	1	1	0	0	1	0	1	0	0
235	1993						13	9	10	5	5	0	1	0	0	0	0	0	0	0	0	0
252	1994							9	12	17	15	5	4	1	3	1	1	0	0	0	0	0
349	1995								30	26	16	16	5	4	3	1	4	1	0	0	0	0
110	1996									6	5	7	5	1	0	0	0	1	1	0	0	0
69	1997										9	5	4	0	2	1	1	0	1	1	0	0
82	1998											6	4	3	0	0	1	0	0	0	0	0
83	1999												11	6	2	1	0	4	1	0	0	0
56	2000													4	5	2	3	1	0	0	0	0
90	2001														4	5	4	5	1	0	0	0
176	2002															16	10	3	0	3	0	3
144	2003																9	4	7	1	0	1
153	2004																	9	2	2	1	1
63	2005																		7	3	1	4
56	2006																			3	0	0
24	2007																				5	5
142	2008																					4

Release		Released with tag removed																				
Total	Year	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
209	1988	22	9	9	2	2	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
339	1989		30	17	15	5	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
244	1990			16	9	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
281	1991				17	12	4	3	1	1	2	1	0	0	0	0	0	0	0	0	0	0
287	1992					27	11	8	4	2	0	2	0	0	0	0	0	0	0	0	0	0
235	1993						15	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0
252	1994							16	6	3	5	1	1	0	0	1	0	0	0	0	0	0
349	1995								22	11	6	2	1	0	0	0	0	2	0	0	0	0
110	1996									9	0	6	0	0	0	0	1	0	0	0	0	0
69	1997										3	0	0	0	0	1	0	1	0	0	0	0
82	1998											0	0	0	1	1	0	0	0	0	0	0
83	1999												2	1	1	0	1	0	0	0	0	0
56	2000													4	1	0	1	1	0	0	0	0
90	2001														4	1	1	2	0	0	0	0
176	2002															13	1	2	0	0	0	0
144	2003																4	1	0	0	0	0
153	2004																	8	2	1	0	0
63	2005																		2	0	0	0
56	2006																			2	0	0
24	2007																				3	0
142	2008																					4

New Jersey – Delaware Bay

Release		Harvested recaptures																			
Total	Year	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
38	1989	0	2	4	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1990		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1991			1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
76	1992				0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
91	1993					3	1	2	2	3	0	1	0	0	0	0	0	0	0	0	0
308	1994						5	9	10	11	8	4	3	2	1	1	0	0	0	0	0
552	1995							22	30	18	16	10	5	3	3	4	2	1	2	1	1
589	1996								47	18	30	12	6	5	3	3	6	2	0	1	0
68	1997									7	2	1	1	0	3	0	0	0	0	0	0
126	1998										19	5	5	2	0	4	1	1	0	0	0
101	1999											3	3	5	1	0	1	3	1	0	0
233	2000												13	15	8	9	6	4	0	1	1
522	2001													32	26	21	14	6	5	1	4
359	2002														16	12	11	9	2	3	2
564	2003															34	13	19	5	7	4
847	2004																52	30	17	17	15
180	2005																	12	5	6	3
225	2006																		13	7	9
434	2007																			23	22
518	2008																				30

Release		Released with tag removed																			
Total	Year	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
38	1989	3	1	3	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
9	1990		2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1991			2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	1992				7	5	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0
91	1993					5	3	3	0	0	0	0	0	0	1	0	0	0	0	0	0
308	1994						22	15	7	5	2	0	0	0	0	1	0	0	0	0	0
552	1995							29	21	13	11	4	0	2	0	0	1	0	0	0	0
589	1996								33	17	15	1	3	1	1	2	0	0	0	0	0
68	1997									5	0	0	0	0	0	0	0	0	0	0	0
126	1998										2	5	1	1	0	0	0	0	0	0	0
101	1999											5	3	1	4	2	0	0	0	0	0
233	2000												9	3	3	2	1	1	0	0	0
522	2001													19	9	2	2	2	0	1	0
359	2002														9	10	3	2	0	0	0
564	2003															23	12	5	4	1	0
847	2004																40	17	4	2	0
180	2005																	10	5	4	0
225	2006																		11	3	2
434	2007																			15	3
518	2008																				16

North Carolina – Cooperative Trawl Cruise

Release		Harvested recaptures																				
Total	Year	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
191	1988	4	3	4	0	6	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
411	1989		6	7	7	11	4	2	2	1	1	0	0	1	0	0	0	0	0	0	0	0
322	1990			11	6	11	5	1	2	2	2	2	1	0	0	0	0	0	0	0	0	0
856	1991				23	19	23	20	16	5	11	7	1	1	1	1	0	0	0	0	0	0
433	1992					22	11	7	10	7	6	7	5	2	0	0	0	0	0	0	0	0
142	1993						6	3	5	3	2	1	0	0	1	0	0	0	0	0	0	0
480	1994							14	16	7	6	5	6	1	3	1	2	2	0	0	0	0
372	1995								21	13	16	11	5	2	2	5	1	1	2	0	0	1
557	1996									26	17	12	3	3	3	4	0	3	1	1	0	0
869	1997										67	31	16	9	11	0	3	3	1	0	1	0
106	1998											9	7	0	2	1	1	0	0	0	0	1
179	1999												18	5	5	2	0	2	2	1	1	0
164	2000													4	6	1	2	3	2	1	0	0
515	2001														32	18	11	3	9	6	1	0
789	2002															39	31	20	13	7	3	1
1578	2003																75	53	29	16	12	7
784	2004																	40	18	15	11	5
557	2005																		17	16	9	5
2113	2006																			107	80	46
305	2007																				24	20
923	2008																					73

Release		Released with tag removed																				
Total	Year	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
191	1988	0	8	5	2	3	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0
411	1989		17	13	11	3	3	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
322	1990			14	11	5	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
856	1991				45	18	23	14	2	2	1	1	0	0	0	0	0	0	0	0	0	0
433	1992					23	17	7	4	1	2	3	0	1	0	0	0	0	0	0	0	0
142	1993						8	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
480	1994							26	8	1	4	1	0	0	0	0	0	0	0	0	0	0
372	1995								22	2	1	3	0	1	0	0	0	0	0	0	0	0
557	1996									8	3	3	2	2	1	0	0	0	0	0	0	0
869	1997										18	13	9	5	1	0	0	1	0	0	0	2
106	1998											3	4	0	0	0	0	0	0	1	0	0
179	1999												3	3	0	0	0	1	0	0	0	1
164	2000													4	0	1	1	0	0	0	0	0
515	2001														11	3	4	1	2	2	0	2
789	2002															12	11	1	5	3	1	1
1578	2003																27	12	8	9	3	0
784	2004																	17	8	10	5	1
557	2005																		8	5	1	2
2113	2006																			44	23	11
305	2007																				7	2
923	2008																					23

Table 4. Instantaneous Rates – Catch and Release Model input matrices for the producer area tagging programs, for fish ≥ 28”.

Delaware/Pennsylvania – Delaware River

Release		Harvested recaptures															
Total	Year	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	1993																
	1994																
	1995																
	1996																
	1997																
	1998																
	1999																
	2000																
	2001																
	2002																
	2003																
	2004																
	2005																
	2006																
	2007																
	2008																

Release		Harvested recaptures															
Total	Year	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	1993																
	1994																
	1995																
	1996																
	1997																
	1998																
	1999																
	2000																
	2001																
	2002																
	2003																
	2004																
	2005																
	2006																
	2007																
	2008																

New York – Hudson River

Release Total	Release Year	Harvested recaptures 88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
826	1988	11	9	7	9	6	3	2	1	4	0	1	1	0	0	0	0	0	0	0	0	0
669	1989		9	13	9	4	5	7	4	0	0	0	0	1	0	0	1	0	0	0	0	0
783	1990			17	14	11	8	4	4	1	3	1	0	0	0	0	0	0	0	0	0	0
546	1991				14	14	8	5	9	5	2	1	0	0	0	0	1	0	1	1	0	0
1135	1992					34	27	16	11	12	10	7	3	2	1	0	0	1	0	0	0	0
940	1993						34	16	11	16	10	5	5	0	1	0	0	0	1	0	0	0
643	1994							18	24	21	8	6	4	4	4	2	0	2	0	0	0	0
628	1995								27	23	20	18	10	1	1	1	1	1	1	0	0	0
1069	1996									63	44	27	12	2	7	2	3	3	1	1	0	0
241	1997										22	7	8	5	3	2	1	0	1	1	0	0
698	1998											47	29	13	7	13	5	0	1	2	0	1
798	1999												43	13	21	9	12	4	2	3	1	3
846	2000													28	17	13	8	8	6	3	3	0
1069	2001														32	23	12	6	5	8	1	3
597	2002															16	8	7	2	5	3	1
1379	2003																39	35	25	10	11	3
1273	2004																	56	25	24	14	5
1325	2005																		40	29	16	8
1130	2006																			44	30	28
755	2007																				26	20
1236	2008																					34

Release Total	Release Year	released with tag removed 88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	1988	0	21	11	1	4	2	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	1989		30	14	7	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1990			43	15	14	4	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	1991				22	16	5	3	0	0	3	0	0	1	0	0	0	0	0	0	0	0
	1992					48	30	19	10	2	3	3	2	0	0	0	0	0	0	0	0	0
	1993						35	20	12	2	5	2	2	0	0	0	0	0	0	0	0	0
	1994							24	8	5	2	0	2	1	0	0	0	0	0	0	0	0
	1995								21	8	10	3	1	3	0	1	0	0	0	0	0	0
	1996									23	24	5	5	1	2	2	0	1	2	0	1	0
	1997										7	3	4	1	0	0	1	0	0	0	0	0
	1998											17	13	2	2	7	1	0	0	0	0	0
	1999												20	8	6	3	1	3	0	1	0	0
	2000													17	6	8	9	2	0	0	0	0
	2001														14	11	2	1	1	2	1	0
	2002															3	3	1	1	0	1	1
	2003																22	6	9	4	1	0
	2004																	18	8	9	4	1
	2005																		18	13	4	6
	2006																			12	9	6
	2007																				6	5
	2008																					13

Maryland – Chesapeake Bay

Release		Harvested recaptures																					
Total	Year	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	1987	0	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	1988		2	1	3	7	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	1989			3	7	3	3	2	1	5	2	0	0	0	0	0	0	0	0	0	0	0	0
	1990				10	8	5	3	1	3	0	3	1	0	0	0	0	0	0	0	0	0	0
	1991					18	10	13	3	7	3	4	1	0	2	0	0	0	0	0	0	0	0
	1992						21	15	11	14	4	8	6	3	2	1	0	0	0	0	0	0	0
	1993							31	25	30	13	14	7	8	1	3	2	0	0	0	0	0	0
	1994								25	27	20	14	10	8	4	2	0	0	1	0	0	0	0
	1995									45	24	17	12	4	5	2	2	3	0	0	2	0	1
	1996										60	35	36	14	6	7	2	1	1	0	0	0	0
	1997											33	19	15	1	2	1	1	0	0	0	0	0
	1998												23	13	2	3	2	0	0	1	0	1	0
	1999													16	5	6	2	1	2	1	0	1	1
	2000														18	12	0	4	4	1	0	2	1
	2001															21	10	10	5	2	3	0	1
	2002																13	18	5	6	0	3	0
	2003																	14	9	8	6	2	3
	2004																		13	7	9	2	3
	2005																			16	11	6	4
	2006																				14	4	4
	2007																					6	4
	2008																						6

Release		Released with tag removed																					
Total	Year	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	1987	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1988		0	7	4	5	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1989			5	9	13	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1990				13	7	6	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	1991					25	9	7	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0
	1992						22	12	6	2	3	2	0	2	0	0	0	0	0	0	0	0	0
	1993							24	16	9	2	2	1	1	0	0	0	0	0	0	0	0	0
	1994								25	15	4	0	4	1	0	1	0	0	0	1	0	0	0
	1995									18	6	6	3	3	1	0	0	0	0	0	0	0	0
	1996										33	19	7	3	2	0	0	0	0	0	0	0	0
	1997											7	7	2	1	0	0	0	0	1	0	0	0
	1998												6	3	0	2	0	0	0	0	0	0	0
	1999													3	3	2	1	0	0	0	0	0	0
	2000														3	4	4	1	0	0	0	0	0
	2001															8	9	1	1	1	0	0	0
	2002																5	1	1	1	2	0	0
	2003																	6	1	1	2	2	0
	2004																		4	2	1	1	1
	2005																			4	4	1	0
	2006																				2	2	2
	2007																					2	1
	2008																						1

Virginia – Rappahannock River

Release		Harvested recaptures																		
Total	Year	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
297	1990	10	1	6	1	3	5	1	0	0	1	1	0	0	1	0	0	0	0	0
386	1991		19	10	12	9	2	1	2	0	2	0	0	0	1	0	0	0	0	0
40	1992			2	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0
209	1993				11	11	5	2	3	0	0	0	0	0	0	0	0	0	0	0
123	1994					4	4	4	1	0	0	0	0	0	0	0	0	0	0	0
205	1995						18	6	5	2	1	1	2	0	1	0	0	0	0	0
67	1996							0	3	1	0	0	1	0	0	0	0	0	0	0
210	1997								11	12	6	2	0	1	1	1	0	0	0	0
156	1998									16	9	1	3	1	0	0	0	0	0	0
159	1999										13	2	1	2	1	0	0	0	0	0
362	2000											13	11	6	5	3	3	0	1	0
268	2001												9	8	2	6	1	0	0	0
122	2002													7	3	5	1	0	1	1
392	2003														23	13	3	1	2	2
680	2004															21	8	8	3	3
281	2005																12	7	5	1
175	2006																	10	3	3
836	2007																		32	22
76	2008																			5

Release		Released with tag removed																		
Total	Year	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
297	1990	14	6	7	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
386	1991		19	10	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
40	1992			2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
209	1993				10	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
123	1994					4	1	0	0	1	0	0	0	0	0	0	0	0	0	0
205	1995						5	2	2	1	0	0	0	0	0	0	0	0	0	0
67	1996							1	0	0	0	0	0	0	0	0	0	0	0	0
210	1997								2	1	1	0	0	0	0	0	0	0	0	0
156	1998									6	3	0	0	1	0	0	0	0	0	0
159	1999										2	1	0	1	0	0	0	0	0	0
362	2000											9	6	4	2	0	0	0	0	0
268	2001												7	4	2	0	0	0	1	0
122	2002													2	2	0	0	0	1	0
392	2003														8	6	2	0	0	0
680	2004															11	2	5	1	0
281	2005																3	4	1	0
175	2006																	2	1	1
836	2007																		11	5
76	2008																			0

APPENDIX B

AD Model Builder Code for the Instantaneous Rates Catch/Release Model (IRCR)

```
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--
><>--
//
//
//  Jiang et. al (2007) Age-independent instantaneous rates model for catch and release
//
//
//
//  Gary Nelson
//
//  Massachusetts Division of Marine Fisheries
//
//  Gloucester, MA 01930
//
//  gary.nelson@state.ma.us
//
//  Version 1.2
//
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><><>--><>--
><>//

DATA_SECTION

// Starting and ending year of the release year
 init_int styrR;
 init_int endyrR;

//Starting and ending year of recovery years
 init_int styr;
 init_int endyr;

 //Total Releases by Year
 init_vector N(styrR,endyrR);

//Recapture Matrix for harvest fish
 init_imatrix rh(styrR,endyrR,styr,endyr);

//Recapture Matrix for releases fish
 init_imatrix rr(styrR,endyrR,styr,endyr);

//---Reporting Rate for harvested fish----------
 init_number lh;

 //---Initial probability of tag shedding and tag-induced mortality for harvested fish--
 init_number phih;

 //---Reporting Rate for released fish----------
 init_number lr;

 //---Initial probability of tag shedding and tag-induced mortality for released fish--
 init_number phir;

//Hooking Mortality
 init_number h;

//Number of Natural Mortality Periods and Beginnng Years
 init_int mp;
 init_ivector mp_int(1,mp);
 int pp;

//Number of Fishing  Mortality Periods and Beginning Years
 init_int fp;
 init_ivector fp_int(1,fp);
 int qq;

//Number of Tag Mortality Periods
 init_int fap;
 init_ivector fap_int(1,fap);
 int ss;
 int tp;
```

```
 LOCAL_CALCS
  pp=mp+1;
  qq=fp+1;
  ss=fap+1;
  tp=mp+fp+fap+(4*(endyr-styr+1));
 END_CALCS
 matrix sigma(1,tp,1,tp+1);
 !! set_covariance_matrix(sigma);
 //looping variables
 int y;
 int t;
 int a;
 int d;
 int cnt;
 int total;
 int Ntags;
 int looper;
 int df_r;
 int df_h;
 int hless;
 int rless;

PARAMETER_SECTION
 number dodo;
 number dodo1;
 number probs;
 number AIC;
 number AICc;
 number K;
 number up_df;
 number up_count;
 number up_chi;
 number up_chat;
 number p_chi;
 number p_df;
 number p_chat;

 //------------F estimates------------------------------
 init_bounded_vector e_F(1,fp,-30.,1.6,1);
 vector F(styr,endyr);
 vector fp_yr(1,qq);

  //------------M estimates------------------------------
 init_bounded_vector e_M(1,mp,-30,1.6,1);
 vector M(styr,endyr);
 vector mp_yr(1,pp);

 //--------------Tag Mortality----------------------------
 init_bounded_vector e_FA(1,fap,-30.,1.6,1);
 vector FA(styr,endyr);
 vector fap_yr(1,ss);

 //------------------Tag Number of Tags-------------------
 vector tags(styrR,endyrR);

 //----------------Mortality Calculations------------
 matrix s(styrR,endyrR,styr,endyr);
 matrix u_h(styrR,endyrR,styr,endyr);
 matrix u_r(styrR,endyrR,styr,endyr);
 vector S_fish(styr,endyr);

 //---------Predicted Cell recoveries-------------
 vector sum_prob_h(styrR,endyrR);
 vector sum_prob_r(styrR,endyrR);
 matrix s_prob(styrR,endyrR,styr,endyr);
 matrix exp_prob_h(styrR,endyrR,styr,endyr);
 matrix ll_h(styrR,endyrR,styr,endyr);
 matrix exp_prob_r(styrR,endyrR,styr,endyr);
 matrix ll_r(styrR,endyrR,styr,endyr);
 vector ll_ns(styrR,endyrR);
 matrix exp_r_h(styrR,endyrR,styr,endyr);
```

```
 matrix exp_r_r(styrR,endyrR,styr,endyr);
 matrix pool_r(styrR,endyrR,styr,endyr);
 matrix pool_h(styrR,endyrR,styr,endyr);
 matrix pool_r_e(styrR,endyrR,styr,endyr);
 matrix pool_h_e(styrR,endyrR,styr,endyr);
 matrix chi_r(styrR,endyrR,styr,endyr);
 matrix chi_h(styrR,endyrR,styr,endyr);
 matrix p_chi_r(styrR,endyrR,styr,endyr);
 matrix p_chi_h(styrR,endyrR,styr,endyr);
 matrix pear_r(styrR,endyrR,styr,endyr);
 matrix pear_h(styrR,endyrR,styr,endyr);
 vector exp_ns(styrR,endyrR);
 vector chi_ns(styrR,endyrR);
 vector pear_ns(styrR,endyrR);
 sdreport_vector S(styr,endyr);
 sdreport_vector FM(styr,endyr);
 sdreport_vector FT(styr,endyr);
 sdreport_vector NM(styr,endyr);

 //----------Likelihood Values------------------------------------------
 number f_tag;
 objective_function_value f;

INITIALIZATION_SECTION
 e_F -1.6;
 e_FA -1.6;
 e_M -1.6;

RUNTIME_SECTION
 maximum_function_evaluations 100, 500, 5000;
 convergence_criteria 1e-5, 1e-7, 1e-16;

PRELIMINARY_CALCS_SECTION
 F.initialize();
 FA.initialize();
 M.initialize();
PROCEDURE_SECTION
 calc_number_tags();
 calc_M_vector();
 calc_F_vector();
 calc_FA_vector();
 calc_fish_surv();
 calc_s();
 calc_s_prob();
 calc_u_h();
 calc_u_r();
 calc_exp_prob_h();
 calc_exp_prob_r();
 calc_LL();
 calc_Chisquare();
 calc_pooled_cells();
 evaluate_the_objective_function();

FUNCTION calc_number_tags
  cnt=0;
  for(t=styrR;t<=endyrR;t++){
    Ntags=0;
    for(y=styr+cnt;y<=endyr;y++){
      Ntags+=rh(t,y)+rr(t,y);
      }
      tags(t)=Ntags;
      cnt+=1;
   }

FUNCTION calc_M_vector
 for(t=1;t<=mp;t++){
       mp_yr(t)=mp_int(t);
   }
   mp_yr(pp)=endyr+1;

 for(t=styr;t<=endyr;t++){
```

```
     for(d=1;d<=mp;d++){
         if(t>=mp_yr(d) && t<mp_yr(d+1)){
           M(t)=mfexp(e_M(d));
           NM(t)=M(t);
          }
      }
   }

FUNCTION calc_F_vector
 for(t=1;t<=fp;t++){
   fp_yr(t)=fp_int(t);
   }
   fp_yr(qq)=endyr+1;

 for(t=styr;t<=endyr;t++){
     for(d=1;d<=fp;d++){
         if(t>=fp_yr(d) && t<fp_yr(d+1)){
           F(t)=mfexp(e_F(d));
           FM(t)=F(t);
          }
       }
   }

FUNCTION calc_FA_vector
  for(t=1;t<=fap;t++){
    fap_yr(t)=fap_int(t);
   }
    fap_yr(ss)=endyr+1;

 for(t=styr;t<=endyr;t++){
   for(d=1;d<=fap;d++){
     if(t>=fap_yr(d) && t<fap_yr(d+1)){
       FA(t)=mfexp(e_FA(d));
       FT(t)=FA(t);
      }
    }
  }

FUNCTION calc_fish_surv
  for (t=styr;t<=endyr;t++){
     S_fish(t)=mfexp(-1*(F(t)+h*FA(t)+M(t)));
     S(t)=S_fish(t);
   }

FUNCTION calc_s
 cnt=0;
 for(t=styrR;t<=endyrR;t++){
    for(y=styr+cnt;y<=endyr;y++) {
       if(t==y){s(t,y)=1;}
       if(t!=y){s(t,y)=mfexp(-F(y-1)-FA(y-1)-M(y-1));}
      }
      cnt+=1;
   }

FUNCTION calc_u_h
  cnt=0;
  for(t=styrR;t<=endyrR;t++){
    for(y=styr+cnt;y<=endyr;y++) {
       u_h(t,y)=(F(y)/(F(y)+FA(y)+M(y)))*(1-mfexp(-F(y)-FA(y)-M(y)));
      }
      cnt+=1;
   }

FUNCTION calc_u_r
 cnt=0;
 for (t=styrR;t<=endyrR;t++){
    for (y=styr+cnt;y<=endyr;y++) {
       u_r(t,y)=(FA(y)/(F(y)+FA(y)+M(y)))*(1-mfexp(-F(y)-FA(y)-M(y)));
      }
      cnt+=1;
   }
```

```
FUNCTION calc_s_prob
 cnt=0;
 for(t=styrR;t<=endyrR;t++){
    looper=0;
    for(y=styr+cnt;y<=endyr;y++){
        probs=1;
        for(a=y-looper;a<=y;a++){
            probs=probs*s(t,a);
         }
         s_prob(t,y)=probs;
         looper+=1;
     }
     cnt+=1;
   }

FUNCTION calc_exp_prob_h
 cnt=0;
 for(t=styrR;t<=endyrR;t++){
    dodo=0;
    for(y=styr+cnt;y<=endyr;y++){
       exp_prob_h(t,y)=lh*phih*s_prob(t,y)*u_h(t,y);
         dodo+=exp_prob_h(t,y);
      }
    sum_prob_h(t)=dodo;
    cnt+=1;
  }

FUNCTION calc_exp_prob_r
 cnt=0;
 for(t=styrR;t<=endyrR;t++){
    dodo=0;
    for(y=styr+cnt;y<=endyr;y++) {
      exp_prob_r(t,y)=lr*phir*s_prob(t,y)*u_r(t,y);
        dodo+=exp_prob_r(t,y);
      }
    sum_prob_r(t)=dodo;
    cnt+=1;
  }

FUNCTION calc_LL
 cnt=0;
 for(t=styrR;t<=endyrR;t++){
   for(y=styr+cnt;y<=endyr;y++) {
      ll_h(t,y)=0;
      ll_r(t,y)=0;
      if(rh(t,y)!=0){
        ll_h(t,y)=rh(t,y)*log(exp_prob_h(t,y));
       }
      if(rr(t,y)!=0){
        ll_r(t,y)=rr(t,y)*log(exp_prob_r(t,y));
       }
    }
    cnt+=1;
  }
 for (t=styrR;t<=endyrR;t++){
     ll_ns(t)=(N(t)-tags(t))*log(1-(sum_prob_h(t)+sum_prob_r(t)));
   }

FUNCTION evaluate_the_objective_function
 f_tag=0;
 cnt=0;
 for(t=styrR;t<=endyrR;t++){
    for(y=styr+cnt;y<=endyr;y++){
       f_tag+=ll_h(t,y)+ll_r(t,y);
      }
      cnt+=1;
   }

   for(t=styrR;t<=endyrR;t++){
      f_tag+=ll_ns(t);
```

```
      }
    f=f_tag*-1.;

FUNCTION calc_Chisquare
 cnt=0;
 up_count=0;
 for(t=styrR;t<=endyrR;t++){
    for(y=styr+cnt;y<=endyr;y++){
       up_count+=1;
      }
      cnt+=1;
   }

 cnt=0;
 for(t=styrR;t<=endyrR;t++) {
    for(y=styr+cnt;y<=endyr;y++) {
       exp_r_r(t,y)=exp_prob_r(t,y)*N(t);
       exp_r_h(t,y)=exp_prob_h(t,y)*N(t);
      }
    cnt+=1;
   }

  cnt=0;
  for(t=styrR;t<=endyrR;t++) {
    for(y=styr+cnt;y<=endyr;y++){
        chi_r(t,y)=square(rr(t,y)-exp_r_r(t,y))/exp_r_r(t,y);
        chi_h(t,y)=square(rh(t,y)-exp_r_h(t,y))/exp_r_h(t,y);
        pear_r(t,y)=(rr(t,y)-exp_r_r(t,y))/sqrt(exp_r_r(t,y));
        pear_h(t,y)=(rh(t,y)-exp_r_h(t,y))/sqrt(exp_r_h(t,y));
      }
      cnt+=1;
    }
  for (t=styrR;t<=endyrR;t++){
        exp_ns(t)=N(t)*(1-(sum_prob_h(t)+sum_prob_r(t)));
   }

  //Not seen chi
  for(t=styrR;t<=endyrR;t++){
      chi_ns(t)=0;
      chi_ns(t)=square((N(t)-tags(t))-exp_ns(t))/exp_ns(t);
      pear_ns(t)=((N(t)-tags(t))-exp_ns(t))/sqrt(exp_ns(t));
   }

 //total chi square
 up_chi=sum(chi_r)+sum(chi_h)+sum(chi_ns);
 K=fap+mp+fp;
 up_df=up_count*2-K;
 up_chat=up_chi/up_df;
 AIC=-1.*2*f_tag+2*K;
 AICc=AIC+(2*K*(K+1))/(sum(N)-K-1);

FUNCTION calc_pooled_cells
// Pool harvested cells
  cnt=0;
  for(t=styrR;t<=endyrR;t++){
     for(y=styr+cnt;y<=endyr;y++) {
       pool_h_e(t,y)=0;
       pool_h(t,y)=0;
       pool_h_e(t,y)=exp_r_h(t,y);
       pool_h(t,y)=rh(t,y);
       }
      cnt+=1;
   }
  cnt=0;
  hless=0;
  for(t=styrR;t<=endyrR;t++){
    for(y=endyr;y>=styr+cnt;y--){
          if(pool_h_e(t,y)>=1){
             pool_h(t,y)=pool_h(t,y);
             pool_h_e(t,y)=pool_h_e(t,y);
            }
```

```
          if(pool_h_e(t,y)>=0 && pool_h_e(t,y)<1){
             if(y!=styr+cnt)
               {
                hless+=1;
                pool_h_e(t,y-1)=pool_h_e(t,y-1)+pool_h_e(t,y);
                pool_h(t,y-1)=pool_h(t,y-1)+pool_h(t,y);
                pool_h(t,y)=0;
                pool_h_e(t,y)=0;
               }
               if (y==styr+cnt) break;
            }
         }//for
         cnt+=1;
     }//for

// Pool released cells
  cnt=0;
  for(t=styrR;t<=endyrR;t++){
      for(y=styr+cnt;y<=endyr;y++){
            pool_r_e(t,y)=0;
            pool_r(t,y)=0;
            pool_r_e(t,y)=exp_r_r(t,y);
            pool_r(t,y)=rr(t,y);
        }
      cnt+=1;
   }
  cnt=0;
  rless=0;
  for(t=styrR;t<=endyrR;t++){
    for(y=endyr;y>=styr+cnt;y--){
          if(pool_r_e(t,y)>=1){
             pool_r(t,y)=pool_r(t,y);
             pool_r_e(t,y)=pool_r_e(t,y);
            }
          if(pool_r_e(t,y)>=0 && pool_r_e(t,y)<1){
            if (y!=styr+cnt){
                rless+=1;
                pool_r_e(t,y-1)=pool_r_e(t,y-1)+pool_r_e(t,y);
                pool_r(t,y-1)=pool_r(t,y-1)+pool_r(t,y);
                pool_r(t,y)=0;
                pool_r_e(t,y)=0;
               }
               if (y==styr+cnt) break;
            }
         }//for
         cnt+=1;
     }//for
  p_df=up_count*2-hless-rless-K;

 //Pooled Chi-square
  cnt=0;
  for(t=styrR;t<=endyrR;t++) {
    for(y=styr+cnt;y<=endyr;y++) {
        p_chi_h(t,y)=0;
        p_chi_r(t,y)=0;
        if(pool_h_e(t,y)!=0){
          p_chi_h(t,y)=square(pool_h(t,y)-pool_h_e(t,y))/pool_h_e(t,y);
         }
        if(pool_r_e(t,y)!=0){
          p_chi_r(t,y)=square(pool_r(t,y)-pool_r_e(t,y))/pool_r_e(t,y);
         }
      }
      cnt+=1;
   }
  p_chi=sum(p_chi_h)+sum(p_chi_r)+sum(chi_ns);
  p_chat=p_chi/p_df;

REPORT_SECTION
 report<<"Log-L"<<"  "<<"\t"<<"K"<<"\t"<<"AIC"<<"         "<<"AICc"<<"       "<<"Eff. Sample
Size"<<endl;
 report<<f_tag<<"   "<<"\t"<<K<<"\t"<<AIC<<"\t"<<AICc<<"\t"<<sum(N)<<endl;
```

```
 report<<" "<<endl;
 report<<" "<<endl;
 report<<"*******Model Statistics*******************"<<endl;
 report<<"Unpooled Chi-square     "<<"  "<<up_chi<<endl;
 report<<"Upooled df              "<<"  "<<up_df<<endl;
 report<<"Unpooled c-hat          "<<"  "<<up_chat<<endl;
 report<<"Pooled Chi-square       "<<"  "<<p_chi<<endl;
 report<<"Pooled df               "<<"  "<<p_df<<endl;
 report<<"Pooled c-hat            "<<"  "<<p_chat<<endl;
 report <<"*****************************************"<<endl;
 report<<"  "<<endl;
 report<<"  "<<endl;
 report << "S for fish" << endl;
 report << S_fish << endl;
 report<<" "<<endl;
 report<<"******************Observed and Calculated
Data************************************"<<endl;
 report << "Obs Recoveries of harvest fish "<< endl;
 report<<rh<<endl;
 report <<" "<<endl;
 report << "Obs Recoveries of release fish "<< endl;
 report<<rr<<endl;
 report <<" "<<endl;

 report << "Total Released "<< endl;
 report<<N<<endl;
 report <<" "<<endl;

 report <<"Total Recovered Tags"<<endl;
 report <<tags<<endl;
 report<<" "<<endl;

 report << "s matrix" << endl;
 report <<s<<endl;
 report<<" "<<endl;

 report << "S_prob matrix" << endl;
 report <<s_prob<<endl;
 report<<" "<<endl;

 report << "Exploitation Rate of harvested fish" << endl;
 report <<u_h<<endl;
 report<<" "<<endl;

 report << "Exploitation Rate of released fish" << endl;
 report <<u_r<<endl;
 report<<" "<<endl;

 report <<"Expected Probability of harvested fish"<<endl;
 report<<exp_prob_h<<endl;
 report <<" "<<endl;

 report <<"Expected Probability of released fish"<<endl;
 report<<exp_prob_r<<endl;
 report <<" "<<endl;

 report<<"Not Seen Probability"<<endl;
 report<<1-(sum_prob_h+sum_prob_r)<<endl;
 report<<" "<<endl;

 report <<"Expected Number of harvested fish"<<endl;
 report<<exp_r_h<<endl;
 report <<" "<<endl;

 report <<"Expected Number of released fish"<<endl;
 report<<exp_r_r<<endl;
 report <<" "<<endl;

 report <<"Expected Number of not seen"<<endl;
 report<<exp_ns<<endl;
 report <<" "<<endl;
```

```
 report <<"Cell Likelihoods of harvested fish"<<endl;
 report<<ll_h<<endl;
 report <<" "<<endl;

 report <<"Cell Likelihoods of released fish"<<endl;
 report<<ll_r<<endl;
 report <<" "<<endl;

 report <<"Cell Likelihoods of unseen"<<endl;
 report<<ll_ns<<endl;
 report <<" "<<endl;

 report <<"Unpooled Chi-squares of Harvested Fish"<<endl;
 report<<chi_h<<endl;
 report <<" "<<endl;

 report <<"Unpooled Chi-squares of Released Fish"<<endl;
 report<<chi_r<<endl;
 report <<" "<<endl;

 report <<"Chi-squares of Not Seen"<<endl;
 report<<chi_ns<<endl;
 report <<" "<<endl;

 report <<"Pooled Cells of Harvested Fish"<<endl;
 report<<pool_h<<endl;
 report <<" "<<endl;

 report <<"Pooled Expected Cells of Harvested Fish"<<endl;
 report<<pool_h_e<<endl;
 report <<" "<<endl;

 report <<"Pooled Cells of Released Fish"<<endl;
 report<<pool_r<<endl;
 report <<" "<<endl;
 report <<"Pooled Expected Cells of Harvested Fish"<<endl;
 report<<pool_r_e<<endl;
 report <<" "<<endl;

 report <<"Pooled Chi-squares of Harvested Fish"<<endl;
 report<<p_chi_h<<endl;
 report <<" "<<endl;

 report <<"Pooled Chi-squares of Released Fish"<<endl;
 report<<p_chi_r<<endl;
 report <<" "<<endl;
 report <<"Pearson Residuals for released fish"<<endl;
 report<<pear_r<<endl;
 report <<" "<<endl;

 report <<"Pearson Residuals for harvested fish"<<endl;
 report<<pear_h<<endl;
 report <<" "<<endl;

 report <<"Pearson Residuals for not seen"<<endl;
 report<<pear_ns<<endl;
 report <<" "<<endl;

FINAL_SECTION
 //Ouput F and sd
  ofstream ofs1("F.std");
   d=mp+fp+fap+(endyr-styr+1);
   for(y=styr;y<=endyr;y++){
        d+=1;
      ofs1<<FM(y)<<"\t"<<sigma(d,1)<<endl;
     }
 //Output FA and sd
   ofstream ofs2("FA.std");
   for(y=styr;y<=endyr;y++){
        d+=1;
```

```
      ofs2<<FT(y)<<"\t"<<sigma(d,1)<<endl;
    }

//Output M and Sd
 ofstream ofs3("M.std");
for(y=styr;y<=endyr;y++){
       d+=1;
      ofs3<<NM(y)<<"\t"<<sigma(d,1)<<endl;
    }
```

APPENDIX C

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

Abstract

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, Jang 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.

The tagging Subcommittee 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. 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 estimated 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 found to give superior results.

A four year retrospective analysis of the two-M instantaneous rates model found that the results were very consistent for the analyses of fish greater than 18 inches and only slightly more variable for fish greater than 28 inches.

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.

Mycobacteriosis in fish is a chronic disease caused by various species of bacteria in the genus *Mycobacterium*. Mycobacterial disease occurs in a wide range of species of fish worldwide and is an important problem in aquacultural operations. The disease appears as grey granulomatous nodules in internal organs, especially the spleen and kidney, and can also manifest itself as ulcerous skin lesions. Fish with ulcerous dermal lesions in the wild sometimes have an extremely emaciated appearance.

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 (classified as condition 0, clean; condition 1, light infection; condition 2, moderate infection; and condition 3, heavy 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

If mycobacteriosis has no impact on the fate of fish, and if tag return rate is not affected by the presence of lesions, then we would expect to recover equal proportions of tags from fish with and without external lesions. In contrast, if externally ulcerous fish have higher mortality, we might expect to see a lower tag return rate in this group. (We discuss the necessary assumptions below.) Thus, we may estimate the impact of the condition associated with lesions in terms of the relative survival (or relative risk) or in terms of the odds ratio. The results of the tagging experiment can be displayed in a 2x2 contingency table, as follows:

	recovered	not recovered
lesions	*a*	*b*
no lesions	*c*	*d*

The relative survival (with lesions : without lesions) is computed as

$$relative\ survival = \frac{a/(a+b)}{c/(c+d)} = \frac{a(c+d)}{c(a+b)}$$

Thus, if 8% of the tags are recovered from fish with lesions while 16% are recovered from fish without external lesions, the relative survival is 0.5, i.e., fish with external lesions survive half as well as fish without. The odds ratio is computed as

$$odds\ ratio = ad/(bc)$$

(Rosner 1990). The odds of obtaining a tag return from a fish with lesions is a/b; the odds ratio is simply the ratio of the odds for the two groups (fish with and without external lesions). Thus, odds ratio = $(a/b)/(c/d) = ad/bc$. The odds ratio can take on values between 0 and infinity. In the above example, the odds ratio would be 0.46. A value less than one indicates that fish with lesions have lower survival than fish without lesions.

It is of interest to examine whether the ratio of survival changes over time. If the ratio of survival is constant over time, then a plot of log(ratio of recaptures in a time interval) versus time at liberty will reveal a linear function of time with slope equal to the difference in instantaneous mortality rates (i.e., exp(slope) estimates the ratio of survival rates). Note, for this analysis to be valid, it is necessary to assume that the *ratio* of tag reporting rates for the two groups remains constant over time but *not* that the reporting rates for the two groups are equal nor that the rates are unchanging. Departures from a linear relationship indicate that the ratio of survival rates or the ratio of reporting rates is changing over time (or both are changing). This model is a logistic model; consequently, standard methods are available for fitting and examining the model (Hoenig et al. 1990, Hueter *et al*. 2006).

Here, we develop a logistic model of relative survival as a linear model because this approach is intuitive and provides a graphical means to see how the model performs. Better estimates can be obtained using the method of maximum likelihood (e.g., by fitting a generalized linear model).

Suppose the survival rate of "clean" fish is S_o and the survival rate of fish in disease condition x is S_x. We tag and release some fish in each category and the ratio of fish in condition x to condition 0 is R in the releases. We then obtain recaptures at time t, for $t = 1$, 2, … Under the assumption of the model, the ratio among the recaptures at time t, R_t, should be

$$R_t = R\left(\frac{S_x}{S_o}\right)^t$$

Taking natural logarithms of both sides leads to the linear model

$$\log_e(R_t) = \log_e(R) + t \cdot \log_e\left(\frac{S_x}{S_o}\right)$$

where $\log_e(R)$ is the y-axis intercept and $\log_e(S_x/S_o)$ is the slope. Thus, exponentiating the estimated slope provides an estimate of the relative survival (ratio of survival rates). Also, letting the survival rate of fish in disease category *x* be expressed as $S_x = \exp(-Z_x)$ and $S_o = \exp(-Z_o)$, we have

$$\text{slope} = \log_e\left(\frac{\exp(-Z_x)}{\exp(-Z_o)}\right) = Z_o - Z_x$$

which is the difference in the instantaneous total mortality rates. Assuming both groups of fish experience the same fishing mortality, we have

$$\text{slope} = M_o - M_x$$

where M_o is the natural mortality rate of "clean" fish and M_x is the natural mortality rate of fish in disease condition *x*. That is, the slope estimates how much additional natural mortality is caused by mycobacteriosis.

In theory, the intercept of the linear regression line can estimate the initial ratio of fish in the two condition categories. However, if there is differential stress or mortality associated with the tagging process then an artificial situation can be created where the ratio changes substantially over the first few days after release and then stabilizes and is then subject to just differential mortality associated with the disease (and not the tagging process). Thus, it may be necessary to disregard the initial ratio at the time of tagging and the recaptures over the first few days of recapture.

It should be noted that the odds ratio approach is a special case of the logistic regression described above in which observations are obtained at just two points in time. That is, the data for intermediate time steps is not used. Consequently, the results presented are only the results for the logistic regression.

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. Unlike the fishing regulatory periods that were consistent among all the programs, there is no evidence, or reason, to suspect that changes in Natural Mortality occur simultaneously and to the same degree among all the evaluated coastal and producer stocks. Thus the 18 models were:

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 2003-2008, 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.

Since myco has been linked to increased natural mortality in Virginia, a re-examination of the MARK modeling was investigated to determine if the use of myco-based mortality periods rather than the fishery regulation-based would produce superior results. All years up to 1997 were considered the pre-myco period and 1998-2008 were considered the myco period.

Results

Instantaneous rates analyses:

The results from the rate of return of tags from diseased fish were clearly lower than that for "clean" fish (showing no overt signs of disease). If the rate of return were equal for the two groups, a plot of the ratio of returns (or the log of the ratio) versus time would be a horizontal line. But, it can be seen in Figures 1A-D that the slope is negative indicating that diseased fish are not surviving as well as clean fish or that diseased fish are less catchable than clean fish. The slope of the regression lines in Figures 1A-D provide estimates of the difference in instantaneous natural mortality rates, i.e., of the additional mortality caused by mycobacteriosis (Table 1). Estimates of the ratio of annual survival rates can be obtained by exponentiating the slope of the regression line. In computing the linear regression lines, the initial tagging ratio and the recaptures during the first seven days at liberty have not been used because of concerns that they represent an artificial situation associated with the stress of tagging (see methods section for an explanation).

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 2). For fish greater than 28 inches, the temporal and spatial patters 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 for both the greater than 18" (Table 3) and the greater than 28" analyses (Table 4), although Massachusetts used the vic 1M model as a component of analysis for both the 18 and the 28 inch fish..

The coastal programs all showed a decrease in survival and an increase in natural mortality with time for striped bass greater than 18" (Table 5). The New York, New Jersey and North Carolina programs estimated that natural mortality doubled from the first to the second period. 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 estimates of natural mortality exceeded the estimates of fishing mortality for all programs and for most years.

When the analyses are restricted to striped bass greater than 28", the pattern of decreasing survival and increasing natural mortality remains consistent among the coastal and the producer programs (Table 6) but with higher estimates of survival and lower estimates of natural mortality. However, there was no temporal pattern between the estimates of natural and fishing mortality among the coastal or the producer programs.

The Massachusetts and New York programs consistently had lower annual estimate of fishing mortality than the New Jersey coastal programs (Table 7) for striped bass greater than 18". The averaged annual estimates of fishing mortality among the coastal programs varied from only 0.10-0.13 from 1995-2008. The Virginia program consistently had the lowest annual estimate of fishing mortality among the producer programs (Table 7). The weighted average annual fishing mortality estimate among the producer programs peaked at 0.21 in 1998 but decreased and has been 0.11-0.14 from 2004-2008.

The Massachusetts program consistently had the lowest annual estimate of fishing mortality among the coastal programs (Table 8) for striped bass greater than 28". The average estimate of fishing mortality from the coastal programs peaked at 0.24 in 1998 but has varied from 0.15-0.17 from 2000-2008. 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 8). From 2001-2008 the two Chesapeake Bay programs had similar, lower fishing mortality estimates than the Hudson River program. The weighted average of fishing mortality from the producer programs peaked at 0.25 from 1995-1999, but has varied from 0.13-0.16 from 2000-2008 (the weighting is described in Table 8).

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 be higher in the most recent years for both the greater than 18” (Table 9) and the greater than 28” (Table 10) striped bass.

Myco-based period MARK models in Virginia:

The results from program MARK for striped bass greater than 18” in Virginia have been problematic, often producing results that were rejected as unreliable. An examination of the annual MARK estimates of survival showed erratic estimates from 1990-1992 (Fig. 2). The result of this variation is for MARK to default to the S(t)r(t) fully parameterized model for 100% of the weighting with a poor goodness of fit (< 0.10). In the 2007 Tagging Subcommittee workshop it was demonstrated that eliminating these years resulted in a drastically different hiarchy and weighting of the suite of models, with the fishery-based period models becoming prevalent (Table 11) and the goodness of fit increasing to a moderate 0.15.

There was also a one year spike in the survival estimate in 2003 (Fig 2). Hurricane Isabelle wrecked havoc in Virginia in 2003, less than two weeks prior to the recreational fishing season. Most marinas, boat tamps and private docks were damaged and many did not reopen during the fall striped bass season. Commercial watermen were negatively impacted as well, thus the catch of striped bass was greatly reduced for that year and the high survival estimate resulted.

Based on the many analyses that indicated that myco-induced increases in natural mortality have occurred and could be confounding analyses where natural mortality was assumed to be constant, the MARK analyses were redone with a second suite of models with myco-based periods (pre-myco 1993-1997 and myco 1998-2008) replacing the fishery regulation-based periods. However, noting the effect that the erratic 1990-1992 results had on program MARK, the myco period was refined to pre-Isabelle myco (1998-2002, Isabelle (2003) and post Isabelle myco (2004-2008). The Vic and Des variants for the terminal years were also included. The myco period-based models were all ranked higher than the original suite of fishery regulation-based models (Table 11).

The estimates of survival are slightly lower from the myco-based periods than from either of the fishery-based period analyses in the most recent years (Fig. 3). It should also be noted that the myco period analysis indicates that there is a downward trend in the final two years which could be an indication that the effects of myco on the Virginia striped bass stocks is continuing to increase.

Retrospective analyses

The sequential results of the 2M instantaneous rates analyses from 2005-2008 for each program is illustrated in Figures 4 (18 inch fish) and 5 (28 inch fish) for each program. The annual estimates of fishing mortality of 18 inch fish for North Carolina had the most variation among the four different time ranges (Figure 4). The 1988-2005 analysis had more temporal amplitude and generally higher F estimates than the other runs. The other coastal and producer programs had very consistent results among the four time ranges.

When the analyses are restricted to fish greater than 28 inches, the results are somewhat different. The temporal patterns among both the coastal and producer programs are somewhat more variable, most notably for North Carolina and Virginia (Figure 5). However, the 1988-2005 analysis produced consistently higher (though often small) annual estimates of F than the 1988-2008 analysis among the coastal programs but consistently lower annual estimates of F among the producer programs. The differences were small for the Hudson River and Maryland programs, but seem to be increasingly divergent in the Virginia analysis.

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. Estimates of mortality associated with mycobacterial disease and estimated relative survival rates. The slope of the regression line of log(ratio of recaptures) versus time estimates the difference in natural mortality rate (M for clean fish - M for diseased fish). The exponentiated slope estimates the ratio of finite (annual) survival rates (S for diseased fish/ S for clean fish).

Comparison	slope	SE	p-value	exp-slope	adjusted R^2
heavy vs clean	-1.31	0.69	0.10	0.27	0.22
moderate vs clean	-1.49	0.47	0.01	0.23	0.45
light vs clean	-0.71	0.44	0.14	0.49	0.14
moderate+ heavy vs clean	-1.46	0.46	0.01	0.23	0.45

Table 2. 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	1999-2008
New York Ocean Haul Seine	1988-1997	1998-2008
New Jersey/ Delaware	1989-2001	2002-2008
North Carolina	1988-1999	2000-2008
Producer programs		
Hudson River	1988-2001	2002-2008
Delaware River		
Maryland Chesapeake Bay	1987-1998	1999-2008
Virginia Rappahannock River	1990-1997	1998-2008

striped bass ≥ 28"

Coast programs	M1	M2
Massachusetts	1992-1998	1999-2008
New York Ocean Haul Seine	1988-2003	2004-2008
New Jersey/ Delaware	1989-2002	2003-2008
North Carolina	1988-1999	2000-2008
Producer programs		
Hudson River	1988-2000	2001-2008
Delaware River		
Maryland Chesapeake Bay	1987-2000	2001-2008
Virginia Rappahannock River	1990-2003	2004-2008

Table 3. Resultant model weighting of the Instantaneous rates model analyses by program for striped bass greater than 18 inches total length.

Coastal Programs

model number	model	MADFW	NYOHS	NJ/DEL	NCCOOP
1	F(t), Ft(t), M(.)	0	0	0	0
2	F((5p), Ft(t), M(.)	0	0	0	0
3	F(.), Ft(t), M(.)	0	0	0	0
4	F(t), Ft(5p), M(.)	0.009	0	0	0
5	F(t), Ft(.), M(.)	0	0	0	0
6	F(5p), Ft(5p), M(.)	0	0	0	0
7	F(.). Ft(.), M(,)	0	0	0	0
8	F(des), Ft(des), M(,)	0	0	0	0
9	F(vic), Ft(vic), M(.)	**0.150**	0	0	0
10	F(t), Ft(t), M(2p)	0	0	0.033	**0.149**
11	F(5p), Ft(t), M(2p)	0	0	0.025	**0.777**
12	F(.), Ft(t), M(2p)	0	0	0	0
13	F(t), Ft(5p), M(2p)	0.017	0	**0.376**	0.003
14	F(t), Ft(.), M(2p)	0	0	0	0
15	F(5p), Ft(5p), M(2p)	**0.107**	**0.252**	**0.234**	0.011
16	F(.), Ft(.), M(2p)	0	0	0	0
17	F(d), Ft(d), M(2p)	0.036	**0.182**	**0.148**	0.022
18	F(v), Ft(v), M(2p)	**0.675**	**0.566**	**0.183**	0.039

Producer Programs

model number	model	HUDSON	DE/PA	MDCB	VARAP
1	F(t), Ft(t), M(.)	0		0	0
2	F((5p), Ft(t), M(.)	0		0	0
3	F(.), Ft(t), M(.)	0		0	0
4	F(t), Ft(5p), M(.)	0		0	0
5	F(t), Ft(.), M(.)	0		0	0
6	F(5p), Ft(5p), M(.)	0		0	0
7	F(.). Ft(.), M(,)	0		0	0
8	F(des), Ft(des), M(,)	0		0	0
9	F(vic), Ft(vic), M(.)	0		0	0
10	F(t), Ft(t), M(2p)	0.002		**1.000**	0
11	F(5p), Ft(t), M(2p)	**0.998**		0	0
12	F(.), Ft(t), M(2p)	0		0	0
13	F(t), Ft(5p), M(2p)	0		0	**0.294**
14	F(t), Ft(.), M(2p)	0		0	0
15	F(5p), Ft(5p), M(2p)	0		0	**0.421**
16	F(.), Ft(.), M(2p)	0		0	0
17	F(d), Ft(d), M(2p)	0		0	**0.208**
18	F(v), Ft(v), M(2p)	0		0	0.077

Table 4. Resultant model weighting of the Instantaneous rates model analyses by program for striped bass greater than 28 inches total length.

Coastal Programs

model number	model	MADFW	NYOHS	NJ/DEL	NCCOOP
1	F(t), Ft(t), M(.)	0	0	0	0
2	F((5p), Ft(t), M(.)	0	0	0	0
3	F(.), Ft(t), M(.)	0	0	0	0
4	F(t), Ft(5p), M(.)	0	0	0	0
5	F(t), Ft(.), M(.)	0	0	0	0
6	F(5p), Ft(5p), M(.)	0	0	0	0
7	F(.). Ft(.), M(,)	0	0	0	0
8	F(des), Ft(des), M(,)	0	0	0	0
9	F(vic), Ft(vic), M(.)	**0.306**	0	0	0
10	F(t), Ft(t), M(2p)	0	0	0.001	**0.623**
11	F(5p), Ft(t), M(2p)	0	0.002	0	0.035
12	F(.), Ft(t), M(2p)	0	0	0	0
13	F(t), Ft(5p), M(2p)	0.004	0	**0.999**	**0.076**
14	F(t), Ft(.), M(2p)	0	0	0	0
15	F(5p), Ft(5p), M(2p)	0.030	**0.531**	0	0.006
16	F(.), Ft(.), M(2p)	0	0	0	0
17	F(d), Ft(d), M(2p)	0.019	**0.271**	0	**0.199**
18	F(v), Ft(v), M(2p)	**0.633**	**0.196**	0	**0.060**

Producer Programs

model number	model	HUDSON	DE/PA	MDCB	VARAP
1	F(t), Ft(t), M(.)	0		0	0
2	F((5p), Ft(t), M(.)	0.001		0	0
3	F(.), Ft(t), M(.)	0		0	0
4	F(t), Ft(5p), M(.)	0		0	0
5	F(t), Ft(.), M(.)	0		0	0
6	F(5p), Ft(5p), M(.)	0		0	0
7	F(.). Ft(.), M(,)	0		0	0
8	F(des), Ft(des), M(,)	0		0	0
9	F(vic), Ft(vic), M(.)	0		0	0
10	F(t), Ft(t), M(2p)	0.001		0	0
11	F(5p), Ft(t), M(2p)	**0.999**		**0.149**	0
12	F(.), Ft(t), M(2p)	0		0	0
13	F(t), Ft(5p), M(2p)	0		0.002	0.006
14	F(t), Ft(.), M(2p)	0		0	0
15	F(5p), Ft(5p), M(2p)	0		**0.454**	**0.405**
16	F(.), Ft(.), M(2p)	0		0	0
17	F(d), Ft(d), M(2p)	0		**0.172**	**0.488**
18	F(v), Ft(v), M(2p)	0		**0.223**	**0.101**

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

Year	S	F	M
1987			
1988			
1989			
1990			
1991			
1992	0.83	0.07	0.11
1993	0.83	0.07	0.11
1994	0.83	0.07	0.11
1995	0.78	0.14	0.11
1996	0.77	0.14	0.11
1997	0.77	0.14	0.11
1998	0.77	0.14	0.11
1999	0.73	0.14	0.16
2000	0.76	0.11	0.16
2001	0.76	0.11	0.16
2002	0.76	0.11	0.16
2003	0.76	0.10	0.16
2004	0.77	0.10	0.16
2005	0.77	0.10	0.16
2006	0.77	0.10	0.16
2007	0.78	0.08	0.16
2008	0.78	0.08	0.16

New York Ocean Haul Seine

Year	S	F	M
1987			
1988	0.83	0.01	0.15
1989	0.83	0.01	0.15
1990	0.80	0.06	0.15
1991	0.80	0.06	0.15
1992	0.80	0.06	0.15
1993	0.80	0.06	0.15
1994	0.80	0.06	0.15
1995	0.78	0.09	0.15
1996	0.78	0.09	0.15
1997	0.78	0.09	0.15
1998	0.65	0.09	0.33
1999	0.65	0.09	0.33
2000	0.66	0.08	0.33
2001	0.66	0.08	0.33
2002	0.66	0.08	0.33
2003	0.65	0.09	0.33
2004	0.65	0.09	0.33
2005	0.65	0.09	0.33
2006	0.65	0.09	0.33
2007	0.67	0.07	0.33
2008	0.67	0.07	0.33

Table 5 continued.

New Jersey/Delaware

Year	S	F	M
1987			
1988			
1989	0.85	0.02	0.13
1990	0.83	0.04	0.13
1991	0.82	0.05	0.13
1992	0.84	0.03	0.13
1993	0.84	0.03	0.13
1994	0.84	0.03	0.13
1995	0.78	0.10	0.13
1996	0.77	0.12	0.13
1997	0.76	0.13	0.13
1998	0.75	0.14	0.13
1999	0.77	0.12	0.13
2000	0.77	0.12	0.13
2001	0.77	0.12	0.13
2002	0.67	0.12	0.27
2003	0.65	0.15	0.27
2004	0.65	0.15	0.27
2005	0.64	0.16	0.27
2006	0.65	0.14	0.27
2007	0.64	0.16	0.27
2008	0.63	0.17	0.27

North Carolina

Year	S	F	M
1987			
1988	0.79	0.02	0.21
1989	0.79	0.02	0.21
1990	0.73	0.10	0.21
1991	0.72	0.10	0.21
1992	0.72	0.10	0.21
1993	0.72	0.11	0.21
1994	0.72	0.10	0.21
1995	0.69	0.14	0.21
1996	0.70	0.14	0.21
1997	0.69	0.15	0.21
1998	0.69	0.15	0.21
1999	0.70	0.14	0.21
2000	0.56	0.12	0.45
2001	0.56	0.12	0.45
2002	0.56	0.12	0.45
2003	0.55	0.14	0.45
2004	0.55	0.14	0.45
2005	0.56	0.13	0.45
2006	0.56	0.14	0.45
2007	0.55	0.14	0.45
2008	0.55	0.15	0.45

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	0.81	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			
1994	0.77	0.10	0.14	1994			
1995	0.71	0.19	0.14	1995			
1996	0.71	0.19	0.14	1996			
1997	0.71	0.19	0.14	1997			
1998	0.71	0.19	0.14	1998			
1999	0.71	0.19	0.14	1999			
2000	0.76	0.12	0.14	2000			
2001	0.76	0.12	0.14	2001			
2002	0.70	0.12	0.23	2002			
2003	0.68	0.14	0.23	2003			
2004	0.68	0.14	0.23	2004			
2005	0.68	0.14	0.23	2005			
2006	0.69	0.14	0.23	2006			
2007	0.69	0.14	0.23	2007			
2008	0.69	0.14	0.23	2008			

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	0.07	0.40
1991	0.72	0.12	0.20	1991	0.62	0.08	0.40
1992	0.68	0.18	0.20	1992	0.61	0.09	0.40
1993	0.69	0.16	0.20	1993	0.61	0.09	0.40
1994	0.70	0.16	0.20	1994	0.61	0.10	0.40
1995	0.65	0.23	0.20	1995	0.59	0.12	0.40
1996	0.66	0.21	0.20	1996	0.60	0.11	0.40
1997	0.63	0.26	0.20	1997	0.59	0.12	0.40
1998	0.61	0.29	0.20	1998	0.49	0.12	0.59
1999	0.52	0.25	0.40	1999	0.49	0.13	0.59
2000	0.54	0.21	0.40	2000	0.51	0.09	0.59
2001	0.56	0.18	0.40	2001	0.50	0.10	0.59
2002	0.58	0.14	0.40	2002	0.50	0.10	0.59
2003	0.55	0.20	0.40	2003	0.49	0.11	0.59
2004	0.57	0.16	0.40	2004	0.49	0.12	0.59
2005	0.58	0.14	0.40	2005	0.50	0.11	0.59
2006	0.57	0.17	0.40	2006	0.49	0.11	0.59
2007	0.60	0.12	0.40	2007	0.50	0.11	0.59
2008	0.59	0.13	0.40	2008	0.49	0.11	0.59

Table 6. 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	0.83	0.08	0.10
1993	0.83	0.08	0.10
1994	0.83	0.08	0.10
1995	0.75	0.18	0.10
1996	0.75	0.18	0.10
1997	0.75	0.18	0.10
1998	0.75	0.18	0.10
1999	0.72	0.18	0.14
2000	0.76	0.13	0.14
2001	0.76	0.13	0.14
2002	0.76	0.13	0.14
2003	0.78	0.11	0.14
2004	0.78	0.11	0.14
2005	0.78	0.11	0.14
2006	0.78	0.11	0.14
2007	0.80	0.08	0.14
2008	0.80	0.08	0.14

New York Ocean Haul Seine

Year	S	F	M
1987			
1988	0.84	0.03	0.13
1989	0.84	0.03	0.13
1990	0.76	0.13	0.13
1991	0.76	0.13	0.13
1992	0.76	0.13	0.13
1993	0.76	0.13	0.13
1994	0.76	0.13	0.13
1995	0.69	0.24	0.13
1996	0.69	0.24	0.13
1997	0.69	0.24	0.13
1998	0.69	0.24	0.13
1999	0.69	0.24	0.13
2000	0.73	0.17	0.13
2001	0.73	0.17	0.13
2002	0.73	0.17	0.13
2003	0.72	0.19	0.13
2004	0.52	0.19	0.46
2005	0.52	0.19	0.46
2006	0.52	0.19	0.46
2007	0.52	0.19	0.46
2008	0.51	0.21	0.46

Table 6 continued.

New Jersey/Delaware

Year	S	F	M
1987			
1988			
1989	0.92	0.00	0.07
1990	0.82	0.11	0.07
1991	0.63	0.38	0.07
1992	0.92	0.00	0.07
1993	0.83	0.10	0.07
1994	0.88	0.05	0.07
1995	0.83	0.11	0.07
1996	0.75	0.21	0.07
1997	0.76	0.19	0.07
1998	0.67	0.32	0.07
1999	0.76	0.19	0.07
2000	0.80	0.16	0.07
2001	0.78	0.18	0.07
2002	0.80	0.15	0.07
2003	0.65	0.19	0.23
2004	0.65	0.19	0.23
2005	0.63	0.22	0.23
2006	0.67	0.16	0.23
2007	0.64	0.20	0.23
2008	0.61	0.25	0.23

North Carolina

Year	S	F	M
1987			
1988	0.81	0.05	0.15
1989	0.81	0.0	0.15
1990	0.77	0.09	0.15
1991	0.78	0.08	0.15
1992	0.75	0.13	0.15
1993	0.75	0.13	0.15
1994	0.76	0.11	0.15
1995	0.72	0.17	0.15
1996	0.74	0.15	0.15
1997	0.70	0.20	0.15
1998	0.71	0.18	0.15
1999	0.72	0.17	0.15
2000	0.67	0.10	0.29
2001	0.63	0.16	0.29
2002	0.65	0.14	0.29
2003	0.64	0.15	0.29
2004	0.63	0.16	0.29
2005	0.64	0.15	0.29
2006	0.64	0.16	0.29
2007	0.62	0.19	0.29
2008	0.60	0.21	0.29

Table 6 continued.

<u>Producer Area Programs</u>

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			
1994	0.77	0.16	0.09	1994			
1995	0.70	0.25	0.09	1995			
1996	0.70	0.25	0.09	1996			
1997	0.70	0.25	0.09	1997			
1998	0.70	0.25	0.09	1998			
1999	0.70	0.25	0.09	1999			
2000	0.77	0.17	0.09	2000			
2001	0.71	0.17	0.17	2001			
2002	0.71	0.17	0.17	2002			
2003	0.68	0.20	0.17	2003			
2004	0.69	0.20	0.17	2004			
2005	0.68	0.20	0.17	2005			
2006	0.68	0.20	0.17	2006			
2007	0.69	0.20	0.17	2007			
2008	0.69	0.20	0.17	2008			

Table 6 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	0.66	0.14	0.26
1991	0.75	0.13	0.14	1991	0.66	0.14	0.26
1992	0.75	0.13	0.14	1992	0.66	0.14	0.26
1993	0.75	0.13	0.14	1993	0.66	0.14	0.26
1994	0.75	0.13	0.14	1994	0.66	0.14	0.26
1995	0.67	0.25	0.14	1995	0.62	0.22	0.26
1996	0.67	0.25	0.14	1996	0.62	0.22	0.26
1997	0.67	0.25	0.14	1997	0.62	0.22	0.26
1998	0.67	0.25	0.14	1998	0.62	0.22	0.26
1999	0.67	0.25	0.14	1999	0.62	0.22	0.26
2000	0.75	0.14	0.14	2000	0.69	0.12	0.26
2001	0.65	0.14	0.28	2001	0.69	0.12	0.26
2002	0.65	0.14	0.28	2002	0.69	0.12	0.26
2003	0.66	0.14	0.28	2003	0.67	0.13	0.26
2004	0.66	0.14	0.28	2004	0.52	0.13	0.52
2005	0.66	0.14	0.28	2005	0.52	0.13	0.52
2006	0.66	0.14	0.28	2006	0.52	0.13	0.52
2007	0.66	0.13	0.28	2007	0.52	0.14	0.52
2008	0.66	0.13	0.28	2008	0.50	0.17	0.52

Table 7. 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	NYOHS	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	0.02	0.02	**0.02**	0.01	0.03
1990		0.06	0.04	0.10	**0.07**	0.06	0.07
1991		0.06	0.05	0.10	**0.07**	0.06	0.08
1992	0.07	0.06	0.03	0.10	**0.07**	0.06	0.07
1993	0.07	0.06	0.03	0.11	**0.07**	0.06	0.07
1994	0.07	0.06	0.03	0.10	**0.06**	0.06	0.07
1995	0.14	0.09	0.10	0.14	**0.12**	0.11	0.13
1996	0.14	0.09	0.12	0.14	**0.12**	0.11	0.13
1997	0.14	0.09	0.13	0.15	**0.13**	0.12	0.14
1998	0.14	0.09	0.14	0.15	**0.13**	0.12	0.14
1999	0.14	0.09	0.12	0.14	**0.12**	0.11	0.13
2000	0.11	0.08	0.12	0.12	**0.11**	0.10	0.12
2001	0.11	0.08	0.12	0.12	**0.11**	0.10	0.12
2002	0.11	0.08	0.12	0.12	**0.11**	0.10	0.12
2003	0.10	0.09	0.15	0.14	**0.12**	0.11	0.13
2004	0.10	0.09	0.15	0.14	**0.12**	0.11	0.13
2005	0.10	0.09	0.16	0.13	**0.12**	0.11	0.13
2006	0.10	0.09	0.14	0.14	**0.12**	0.11	0.13
2007	0.08	0.07	0.16	0.14	**0.11**		
2008	0.08	0.07	0.17	0.15	**0.12**		

Table 7 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		**0.01**	0.01	0.02
1989	0.04		0.00		**0.01**	0.00	0.01
1990	0.10		0.07	0.07	**0.07**	0.05	0.08
1991	0.10		0.12	0.08	**0.10**	0.08	0.12
1992	0.10		0.18	0.09	**0.13**	0.11	0.16
1993	0.10		0.16	0.09	**0.12**	0.10	0.14
1994	0.10		0.16	0.10	**0.12**	0.10	0.15
1995	0.18		0.23	0.12	**0.18**	0.15	0.21
1996	0.19		0.21	0.11	**0.16**	0.13	0.19
1997	0.20		0.26	0.12	**0.19**	0.15	0.23
1998	0.20		0.29	0.12	**0.21**	0.16	0.25
1999	0.19		0.25	0.13	**0.19**	0.14	0.24
2000	0.13		0.21	0.09	**0.15**	0.11	0.19
2001	0.13		0.18	0.10	**0.13**	0.10	0.17
2002	0.14		0.14	0.10	**0.12**	0.09	0.14
2003	0.17		0.20	0.11	**0.16**	0.13	0.19
2004	0.18		0.16	0.12	**0.14**	0.11	0.16
2005	0.18		0.14	0.11	**0.12**	0.10	0.14
2006	0.18		0.17	0.11	**0.14**	0.12	0.16
2007	0.18		0.12	0.11	**0.11**		
2008	0.17		0.13	0.11	**0.12**		

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

Table 8. 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	NJDEL	NCCOOP	**Unweighted average**	lower 95% CI	upper 95% CI
1987							
1988		0.03		0.05	**0.04**	0.03	0.05
1989		0.03	0.00	0.0	**0.03**	0.00	0.05
1990		0.13	0.11	0.09	**0.11**	0.09	0.13
1991		0.13	0.38	0.08	**0.20**	0.17	0.22
1992	0.08	0.13	0.00	0.13	**0.08**	0.06	0.11
1993	0.08	0.13	0.10	0.13	**0.11**	0.08	0.13
1994	0.08	0.13	0.05	0.11	**0.09**	0.08	0.11
1995	0.18	0.24	0.11	0.17	**0.17**	0.16	0.19
1996	0.18	0.24	0.21	0.15	**0.19**	0.17	0.21
1997	0.18	0.24	0.19	0.20	**0.20**	0.18	0.22
1998	0.18	0.24	0.32	0.18	**0.23**	0.20	0.25
1999	0.18	0.24	0.19	0.17	**0.19**	0.17	0.22
2000	0.13	0.17	0.16	0.10	**0.14**	0.11	0.16
2001	0.13	0.17	0.18	0.16	**0.16**	0.14	0.18
2002	0.13	0.17	0.15	0.14	**0.15**	0.12	0.17
2003	0.11	0.19	0.19	0.15	**0.16**	0.14	0.18
2004	0.11	0.19	0.19	0.16	**0.16**	0.14	0.18
2005	0.11	0.19	0.22	0.15	**0.17**	0.15	0.19
2006	0.11	0.19	0.16	0.16	**0.15**	0.13	0.17
2007	0.08	0.19	0.20	0.19	**0.17**		
2008	0.08	0.21	0.25	0.21	**0.19**		

Table 8 continued.

Producer Area Programs

Year	HUDSON	DE/PA	MDCB	VARAP	**Weighted average***	lower 95% CI	upper 95% CI
1987			0.03		**0.01**	0.00	0.03
1988	0.09		0.03		**0.03**	0.01	0.04
1989	0.09		0.03		**0.03**	0.01	0.04
1990	0.16		0.13	0.14	**0.13**	0.11	0.15
1991	0.16		0.13	0.14	**0.13**	0.11	0.15
1992	0.16		0.13	0.14	**0.13**	0.11	0.15
1993	0.16	0.23	0.13	0.14	**0.15**	0.13	0.17
1994	0.16	0.23	0.13	0.14	**0.15**	0.13	0.17
1995	0.25	0.27	0.25	0.22	**0.25**	0.22	0.27
1996	0.25	0.27	0.25	0.22	**0.25**	0.22	0.27
1997	0.25	0.27	0.25	0.22	**0.25**	0.22	0.27
1998	0.25	0.27	0.25	0.22	**0.25**	0.22	0.27
1999	0.25	0.27	0.25	0.22	**0.25**	0.22	0.27
2000	0.17	0.28	0.14	0.12	**0.15**	0.13	0.18
2001	0.17	0.28	0.14	0.12	**0.15**	0.13	0.18
2002	0.17	0.28	0.14	0.12	**0.15**	0.13	0.18
2003	0.20	0.26	0.14	0.13	**0.16**	0.14	0.17
2004	0.20	0.26	0.14	0.13	**0.16**	0.14	0.17
2005	0.20	0.26	0.14	0.13	**0.16**	0.14	0.17
2006	0.20	0.26	0.14	0.13	**0.16**	0.14	0.17
2007	0.20		0.13	0.14	**0.13**		
2008	0.20		0.13	0.17	**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 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	0.02	0.01	0.02
1989	0.02	0.01	0.03	0.02	0.01	0.03
1990	0.07	0.06	0.08	0.07	0.06	0.07
1991	0.08	0.07	0.08	0.07	0.06	0.08
1992	0.06	0.06	0.07	0.07	0.06	0.07
1993	0.07	0.06	0.07	0.07	0.06	0.07
1994	0.06	0.06	0.07	0.06	0.06	0.07
1995	0.12	0.11	0.13	0.12	0.11	0.13
1996	0.13	0.12	0.14	0.12	0.11	0.13
1997	0.14	0.12	0.15	0.13	0.12	0.14
1998	0.14	0.13	0.15	0.13	0.12	0.14
1999	0.13	0.12	0.14	0.12	0.11	0.13
2000	0.10	0.09	0.11	0.11	0.10	0.12
2001	0.11	0.10	0.12	0.11	0.10	0.12
2002	0.10	0.09	0.11	0.11	0.10	0.12
2003	0.10	0.09	0.11	0.12	0.11	0.13
2004	0.10	0.09	0.11	0.12	0.11	0.13
2005	0.10	0.09	0.11	0.12	0.11	0.13
2006	0.09	0.08	0.10	0.12	0.11	0.13
2007	0.10			0.11		
2008	0.10			0.12		

Table 9 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	0.01	0.01	0.02	0.01	0.01	0.02
1989	0.01	0.00	0.01	0.01	0.00	0.01
1990	0.07	0.05	0.08	0.07	0.05	0.08
1991	0.10	0.08	0.12	0.10	0.08	0.12
1992	0.14	0.11	0.16	0.13	0.11	0.16
1993	0.13	0.10	0.15	0.12	0.10	0.14
1994	0.13	0.10	0.15	0.12	0.10	0.15
1995	0.19	0.16	0.22	0.18	0.15	0.21
1996	0.17	0.14	0.20	0.16	0.13	0.19
1997	0.21	0.17	0.25	0.19	0.15	0.23
1998	0.24	0.19	0.28	0.21	0.16	0.25
1999	0.21	0.16	0.26	0.19	0.14	0.24
2000	0.15	0.11	0.19	0.15	0.11	0.19
2001	0.12	0.09	0.16	0.13	0.10	0.17
2002	0.10	0.07	0.13	0.12	0.09	0.14
2003	0.12	0.09	0.15	0.16	0.13	0.19
2004	0.10	0.08	0.13	0.14	0.11	0.16
2005	0.09	0.06	0.11	0.12	0.10	0.14
2006	0.09	0.07	0.12	0.14	0.12	0.16
2007	0.07			0.11		
2008	0.08			0.12		

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

Table 10. 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		
Year	Unweighted F	lower 95% CI	upper 95% CI	Unweighted F	lower 95% CI	upper 95% CI
1987						
1988	0.04	0.03	0.05	0.04	0.03	0.05
1989	0.03	0.01	0.05	0.03	0.00	0.05
1990	0.12	0.10	0.14	0.11	0.09	0.13
1991	0.21	0.18	0.23	0.20	0.17	0.22
1992	0.08	0.06	0.11	0.08	0.06	0.11
1993	0.11	0.08	0.13	0.11	0.08	0.13
1994	0.09	0.08	0.11	0.09	0.08	0.11
1995	0.19	0.17	0.21	0.17	0.16	0.19
1996	0.21	0.19	0.23	0.19	0.17	0.21
1997	0.21	0.19	0.23	0.20	0.18	0.22
1998	0.24	0.22	0.27	0.23	0.20	0.25
1999	0.21	0.19	0.24	0.19	0.17	0.22
2000	0.16	0.13	0.18	0.14	0.11	0.16
2001	0.17	0.14	0.19	0.16	0.14	0.18
2002	0.16	0.14	0.18	0.15	0.12	0.17
2003	0.16	0.14	0.18	0.16	0.14	0.18
2004	0.15	0.14	0.17	0.16	0.14	0.18
2005	0.16	0.14	0.18	0.17	0.15	0.19
2006	0.14	0.12	0.16	0.15	0.13	0.17
2007	0.12			0.17		
2008	0.13			0.19		

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	0.01	-0.01	0.03	0.01	0.00	0.03
1988	0.03	0.01	0.04	0.03	0.01	0.04
1989	0.03	0.01	0.04	0.03	0.01	0.04
1990	0.12	0.10	0.14	0.13	0.11	0.15
1991	0.13	0.11	0.15	0.13	0.11	0.15
1992	0.13	0.11	0.15	0.13	0.11	0.15
1993	0.15	0.13	0.17	0.15	0.13	0.17
1994	0.15	0.13	0.17	0.15	0.13	0.17
1995	0.25	0.23	0.28	0.25	0.22	0.27
1996	0.25	0.22	0.28	0.25	0.22	0.27
1997	0.25	0.23	0.28	0.25	0.22	0.27
1998	0.26	0.23	0.28	0.25	0.22	0.27
1999	0.26	0.23	0.28	0.25	0.22	0.27
2000	0.16	0.13	0.18	0.15	0.13	0.18
2001	0.16	0.13	0.18	0.15	0.13	0.18
2002	0.15	0.13	0.18	0.15	0.13	0.18
2003	0.14	0.12	0.15	0.16	0.14	0.17
2004	0.13	0.12	0.15	0.16	0.14	0.17
2005	0.13	0.11	0.15	0.16	0.14	0.17
2006	0.13	0.12	0.15	0.16	0.14	0.17
2007	0.10			0.13		
2008	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 11. MARK model weighting results, 1990-2008 fishery period, 1993-2008 fishery period and 1993-2008 myco period, for striped bass greater than 18 inches total length tagged in the Rappahannock River, Virginia.

1990-2008 fishery periods		1993-2008 fishery periods		1993-2008 myco periods plus Isabelle	
{S(t)r(t)}	**1**	**{S(p)r(p)}**	**0.326**	**{S(myco p)r(myco p)}**	**0.524**
{S(p)r(t)}	0	**{S(t)r(t)}**	**0.263**	**{S(d myco p)r(myco p)}**	**0.237**
{S(p)r(p)}	0	**{S(t)r(p)}**	**0.144**	**{S(v myco p)r(myco p)}**	**0.234**
{S(t)r(p)}	0	**{S(d)r(p)}**	**0.138**	{S(t)r(myco p)}	0.004
{S(.)r(t)}	0	**{S(v)r(p)}**	**0.120**	{S(myco p)r(t)}	0.001
{S(d)r(p)}	0	{S(.)r(p)}	0.009	{S(t)r(t)}	0
{S(v)r(p)}	0	{S(p)r(t)}	0.001	{S(p)r(p)}	0
{S(.)r(p)}	0	{S(.)r(t)}	0	{S(t)r(p)}	0
{S(.)r(.)}	0	{S(.)r(.)}	0	{S(d)r(p)}	0
				{S(v)r(p)}	0
				{S(.)r(myco p)}	0
				{S(.)r(p)}	0
				{S(p)r(t)}	0
				{S(.)r(t)}	0
				{S(.)r(.)}	0

Table 12. Retrospective summary of tag-based estimates of annual instantaneous fishing mortality of striped bass ≥18 inches based on the Instantaneous Rates Model, with the unweighted average for coastal programs, the weighted average for producer areas, and 95% confidence intervals for the years 2005-2008.

	Coastal programs				**Producer programs**			
	F				F			
	2005	2006	2007	2008	2005	2006	2007	2008
1987					0.03	0.03	0.03	0.03
1988	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
1989	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
1990	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08
1991	0.07	0.07	0.07	0.08	0.10	0.10	0.11	0.11
1992	0.07	0.07	0.06	0.06	0.15	0.14	0.15	0.15
1993	0.07	0.07	0.07	0.07	0.13	0.13	0.13	0.13
1994	0.06	0.06	0.06	0.06	0.14	0.13	0.13	0.13
1995	0.11	0.11	0.11	0.11	0.20	0.20	0.20	0.20
1996	0.12	0.12	0.12	0.12	0.17	0.17	0.18	0.18
1997	0.14	0.13	0.13	0.13	0.21	0.21	0.21	0.21
1998	0.14	0.14	0.14	0.14	0.23	0.22	0.23	0.23
1999	0.12	0.12	0.12	0.12	0.21	0.21	0.21	0.21
2000	0.10	0.11	0.11	0.11	0.17	0.16	0.17	0.16
2001	0.11	0.11	0.11	0.11	0.15	0.15	0.15	0.15
2002	0.11	0.11	0.11	0.11	0.13	0.12	0.13	0.13
2003	0.12	0.12	0.12	0.12	0.17	0.16	0.17	0.17
2004	0.12	0.12	0.12	0.12	0.15	0.14	0.15	0.14
2005	0.11	0.11	0.11	0.12	0.13	0.13	0.13	0.13
2006		0.10	0.10	0.11		0.15	0.15	0.15
2007			0.10	0.10			0.12	0.12
2008				0.11				0.13

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

Table 13. Retrospective summary of tag-based estimates of annual instantaneous fishing mortality of striped bass ≥28 inches based on the Instantaneous Rates Model, with the unweighted average for coastal programs, the weighted average for producer areas, and 95% confidence intervals for the years 2005-2008.

Coastal programs					**Producer programs**			
	F				F			
	2005	2006	2007	2008	2005	2006	2007	2008
1987					0.03	0.03	0.03	0.03
1988	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1989	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
1990	0.12	0.12	0.12	0.11	0.14	0.14	0.14	0.14
1991	0.20	0.20	0.20	0.19	0.14	0.14	0.14	0.14
1992	0.09	0.09	0.09	0.08	0.14	0.14	0.14	0.14
1993	0.12	0.12	0.12	0.11	0.14	0.14	0.14	0.14
1994	0.10	0.10	0.10	0.09	0.14	0.14	0.14	0.14
1995	0.19	0.19	0.19	0.17	0.24	0.24	0.24	0.24
1996	0.21	0.20	0.20	0.19	0.24	0.24	0.24	0.24
1997	0.22	0.22	0.22	0.20	0.24	0.24	0.24	0.24
1998	0.25	0.24	0.24	0.23	0.24	0.24	0.24	0.24
1999	0.21	0.21	0.21	0.19	0.24	0.24	0.24	0.24
2000	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14
2001	0.17	0.17	0.17	0.16	0.14	0.14	0.14	0.14
2002	0.15	0.16	0.16	0.15	0.14	0.14	0.14	0.14
2003	0.17	0.17	0.18	0.16	0.16	0.15	0.15	0.15
2004	0.16	0.17	0.18	0.16	0.16	0.15	0.15	0.15
2005	0.16	0.17	0.17	0.16	0.16	0.15	0.15	0.15
2006		0.16	0.18	0.14		0.15	0.15	0.15
2007			0.19	0.16			0.14	0.14
2008				0.20				0.15

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

Figure 1. Logarithm of the ratio of returns of fish tagged in disease condition *x* and disease condition 0 (fish in condition 0 are “clean”, showing no signs of the disease) as a function of time at liberty. Numbers next to the data points are the number of tag returns. The slope of the weighted regression estimates the difference in instantaneous total mortality rates, $Z_o - Z_x$, which is equivalent to the difference in instantaneous natural mortality rates (because the F component of Z is assumed to be the same for both groups of fish). A) Condition 3 versus condition 0. Estimated slope = -1.31. The exponentiated slope, which is an estimate of the relative survival rate, is 0.27 indicating that fish in condition 3 have 27% of the survival rate of clean fish. B) Condition 2 versus condition 0. Estimated slope = -1.49. The exponentiated slope, which is an estimate of the relative survival rate, is 0.23. C) Condition 1 versus condition 0. Estimated slope = -0.71. The exponentiated slope, which is an estimate of the relative survival rate, is 0.49. D) Conditions 2 and 3 combined versus condition 0. Estimated slope = -1.46. The exponentiated slope, which is an estimate of the relative survival rate, is 0.23.

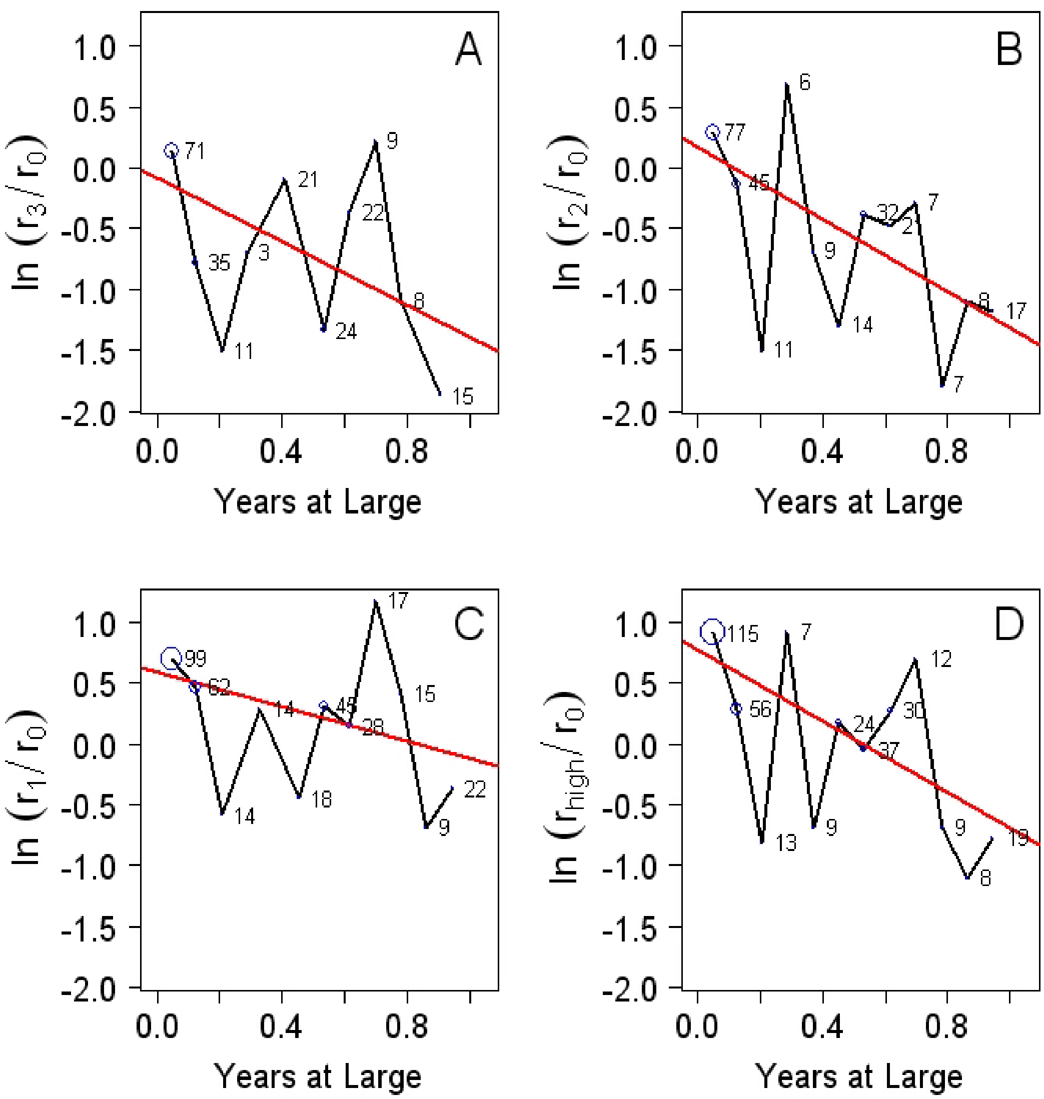


Figure 2. Annual estimates of Survival (S), from program MARK, of striped bass greater than 18" total length tagged in the Rappahannock River, Virginia, 1990-2008.

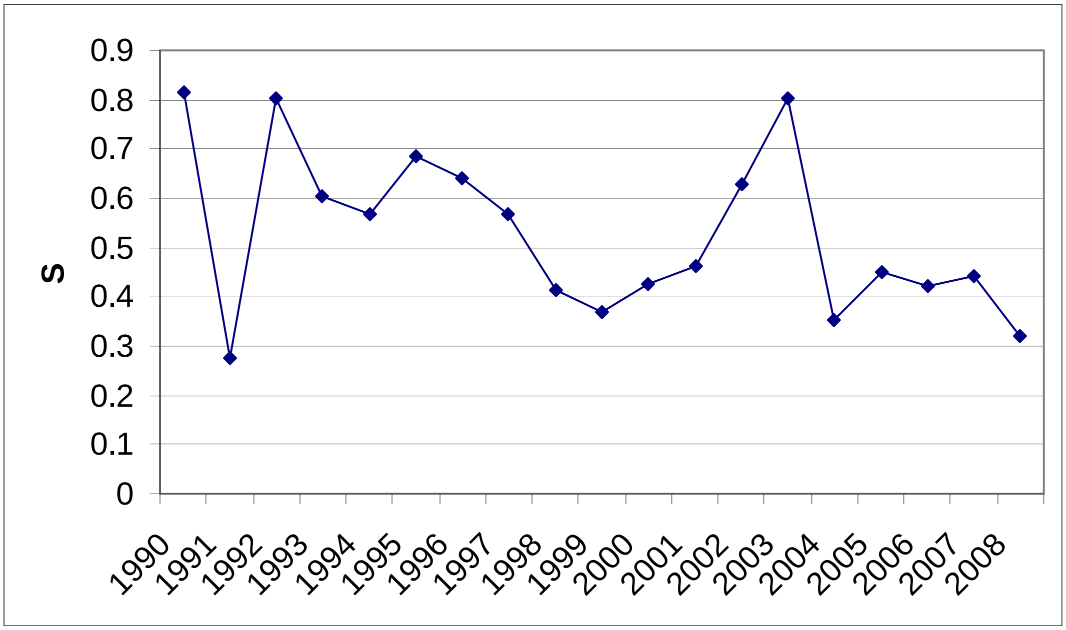


Figure 3. Comparison of the MARK annual adjusted survival (S) estimates for the fishery-based (1990-2008 and 1993-2008) and the myco-based periods (1993-2008).

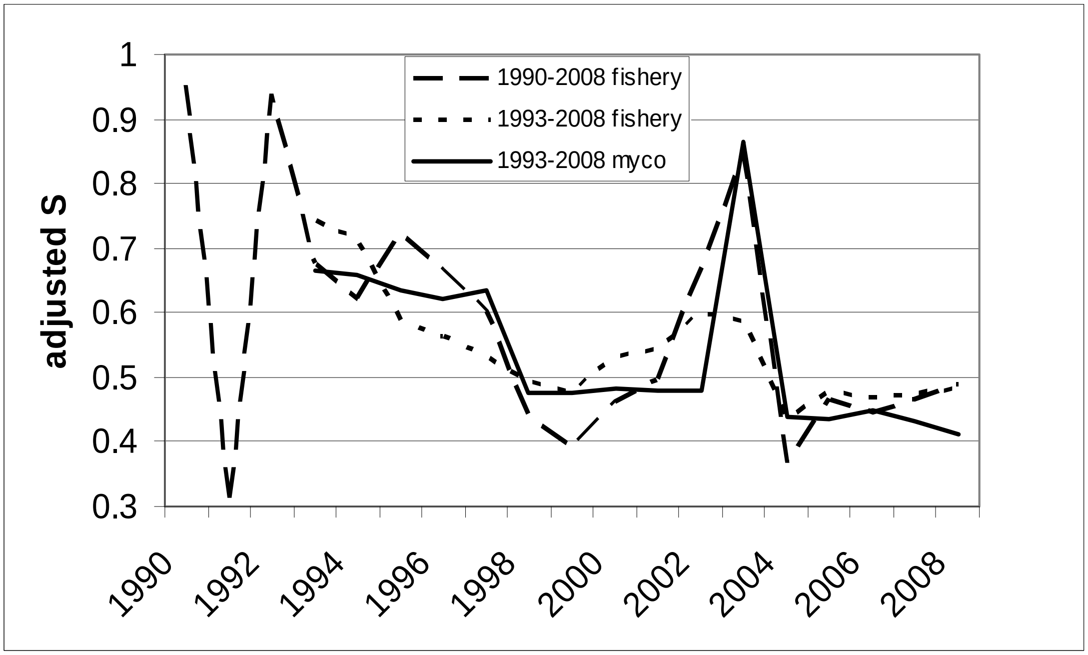
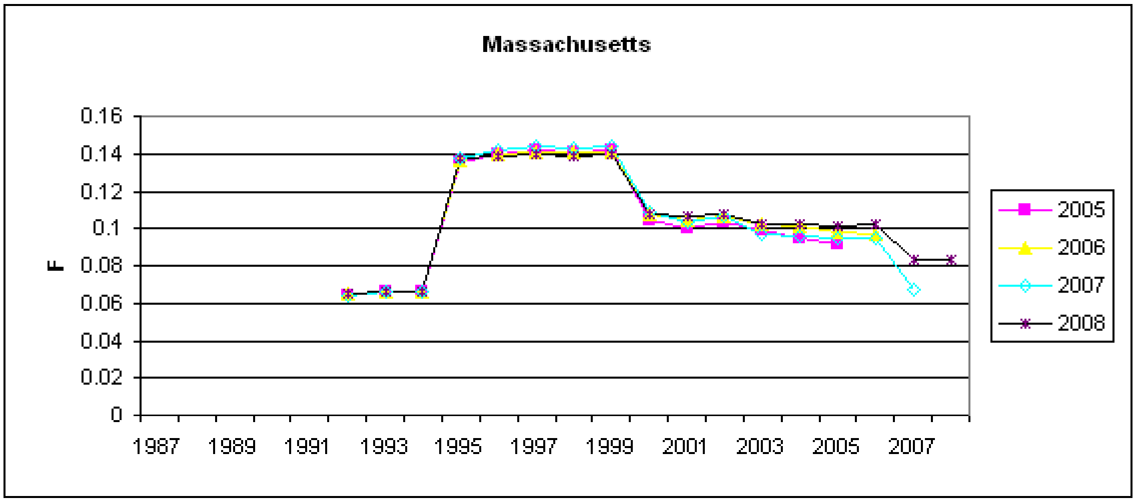
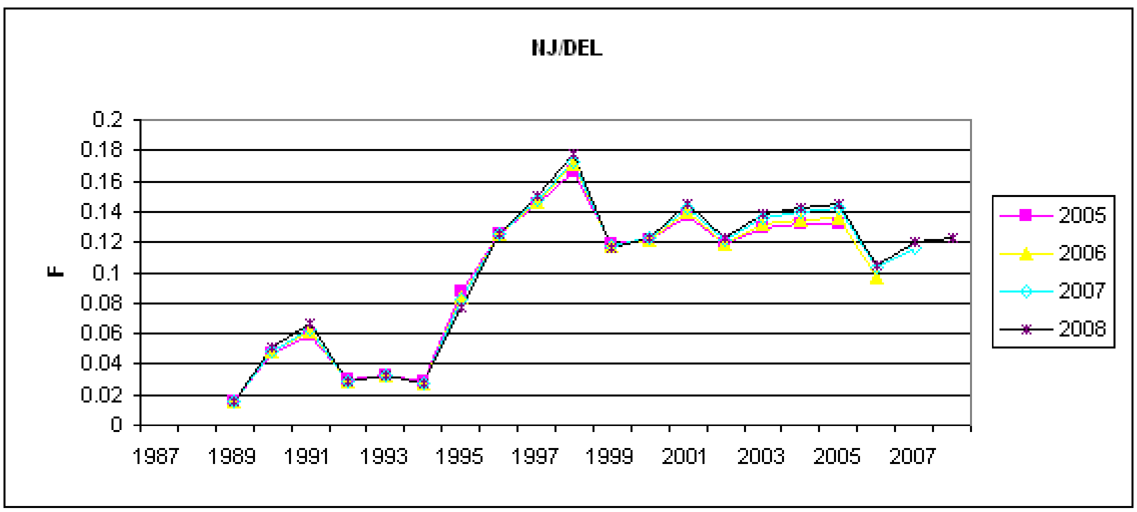


Figure 4. Retrospective comparison in the estimates of fishing mortality (F), by program, for 2005-2008 for striped bass greater than 18 inches.





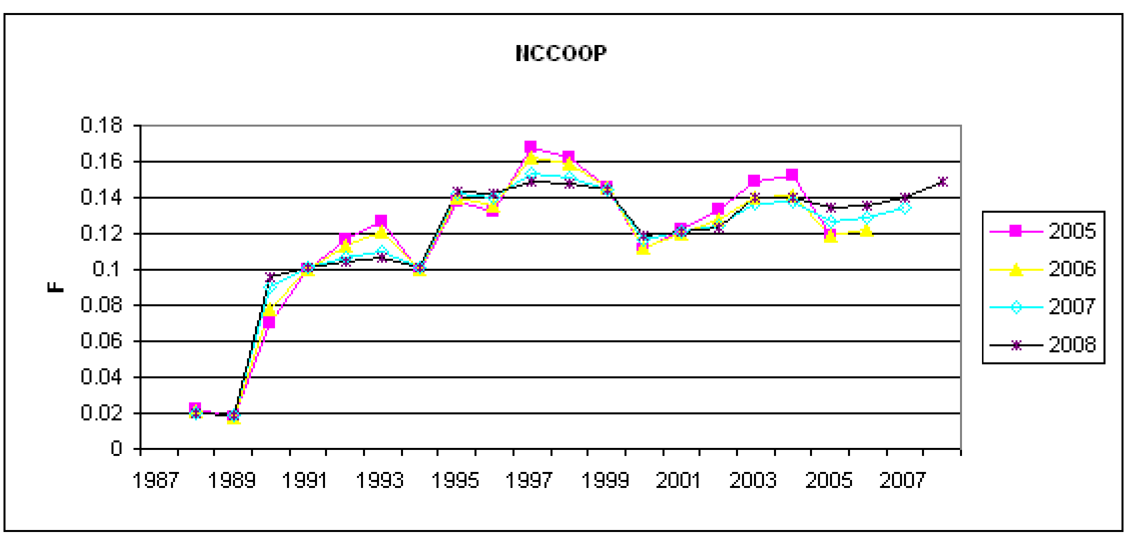
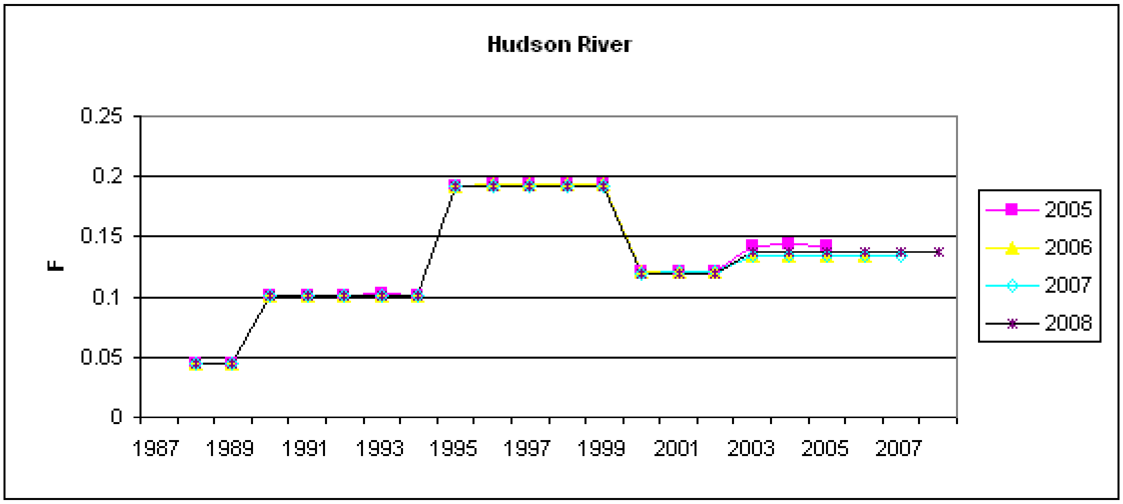
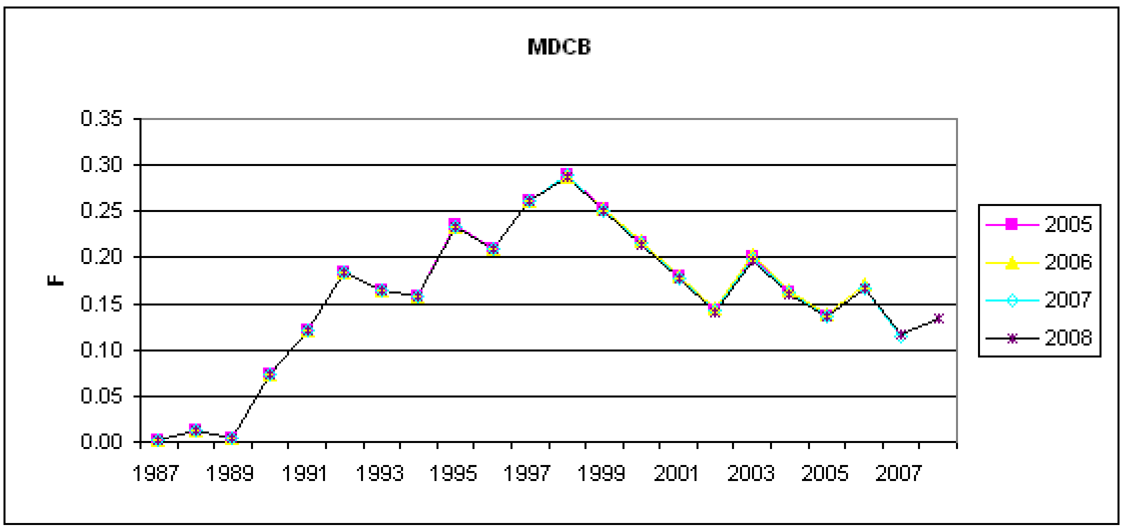


Figure 4 continued.





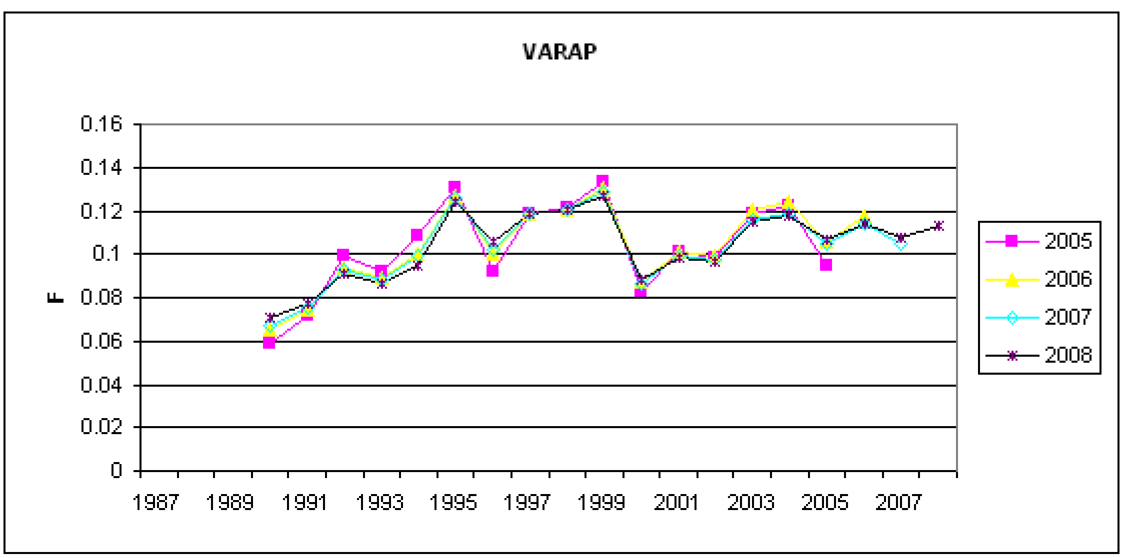
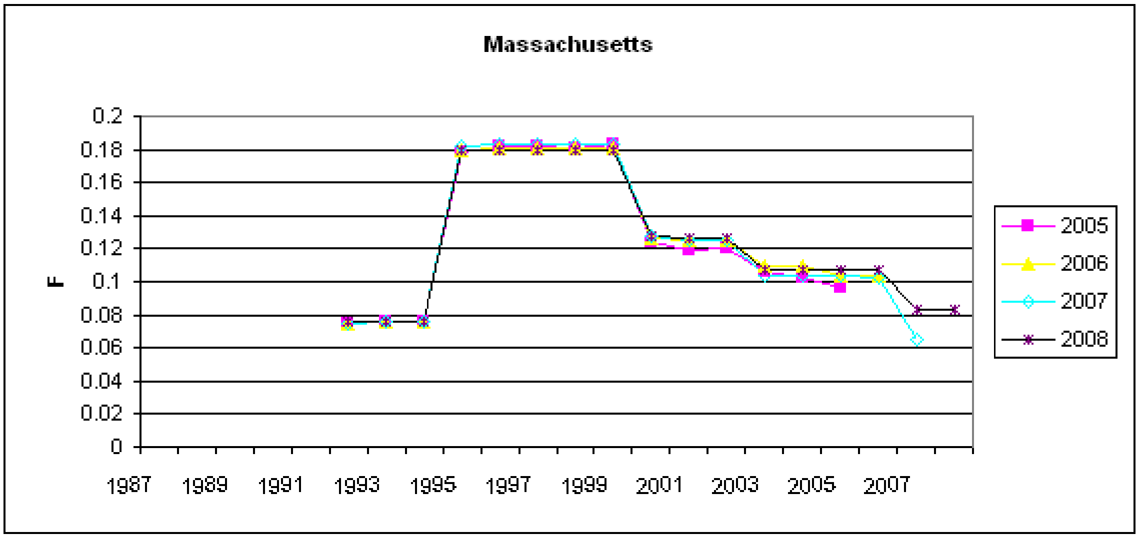
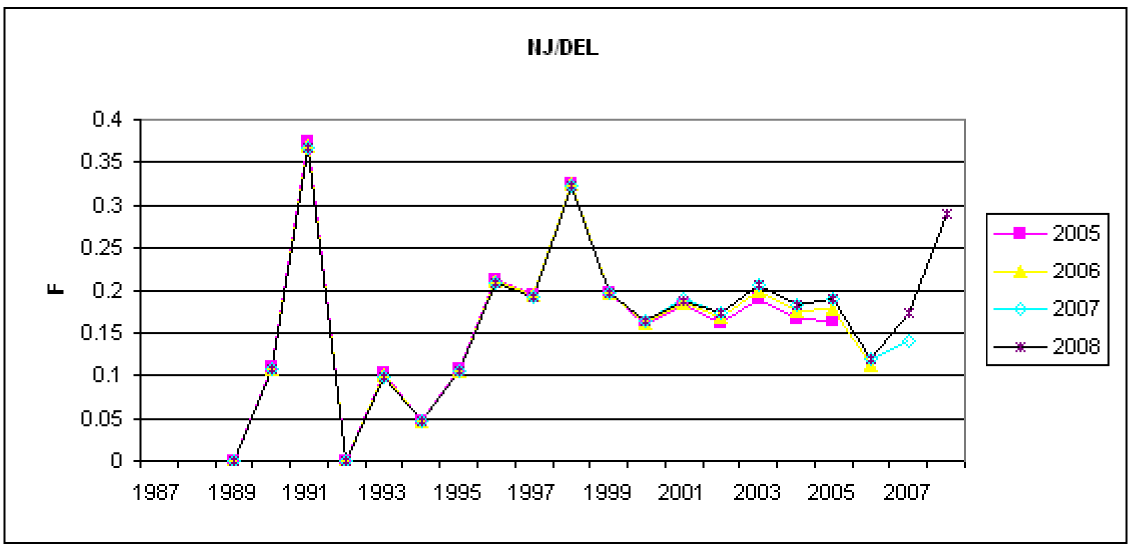


Figure 5. Retrospective comparison in the estimates of fishing mortality (F), by program, for 2005-2008 for striped bass greater than 28 inches.





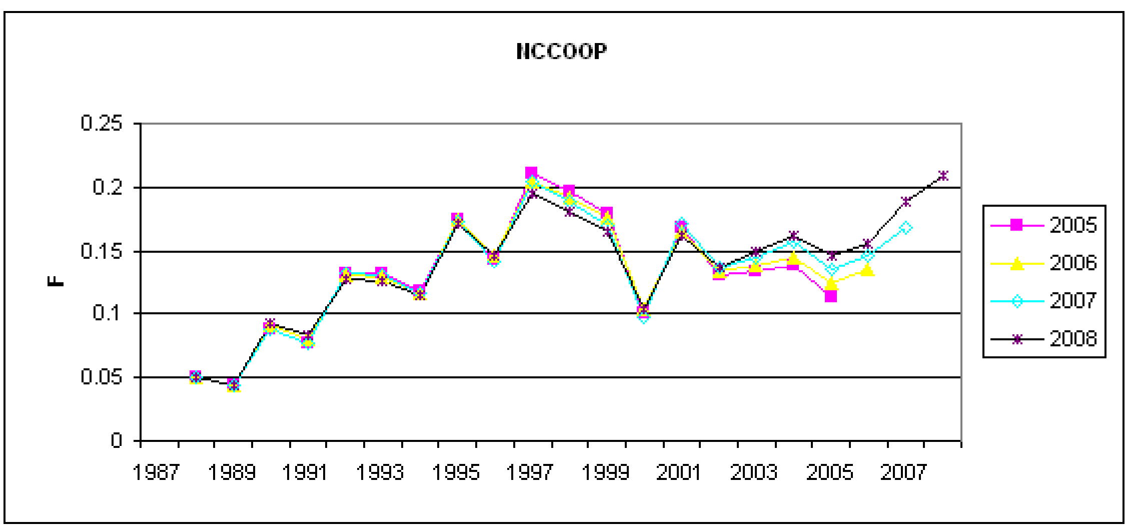
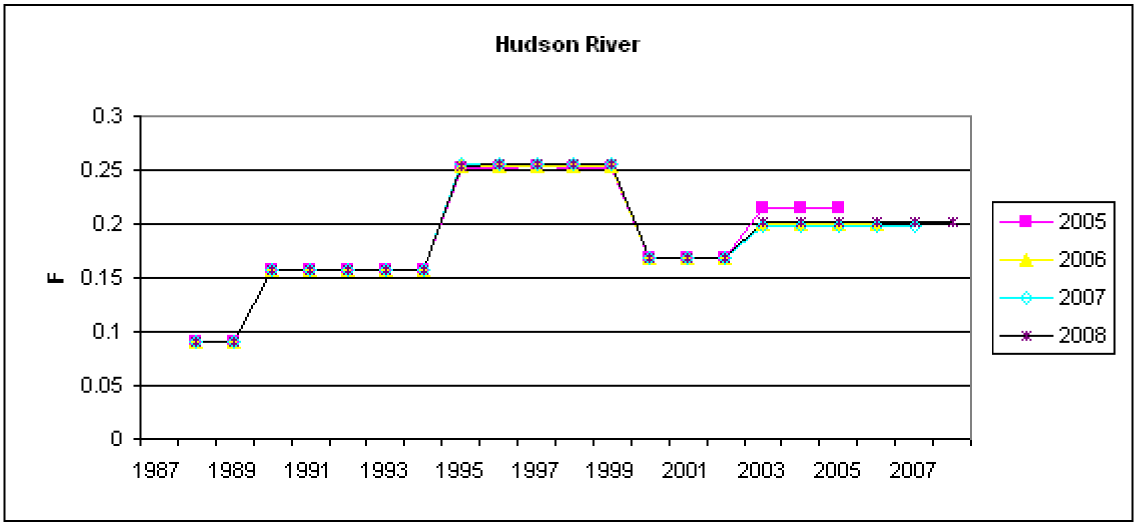
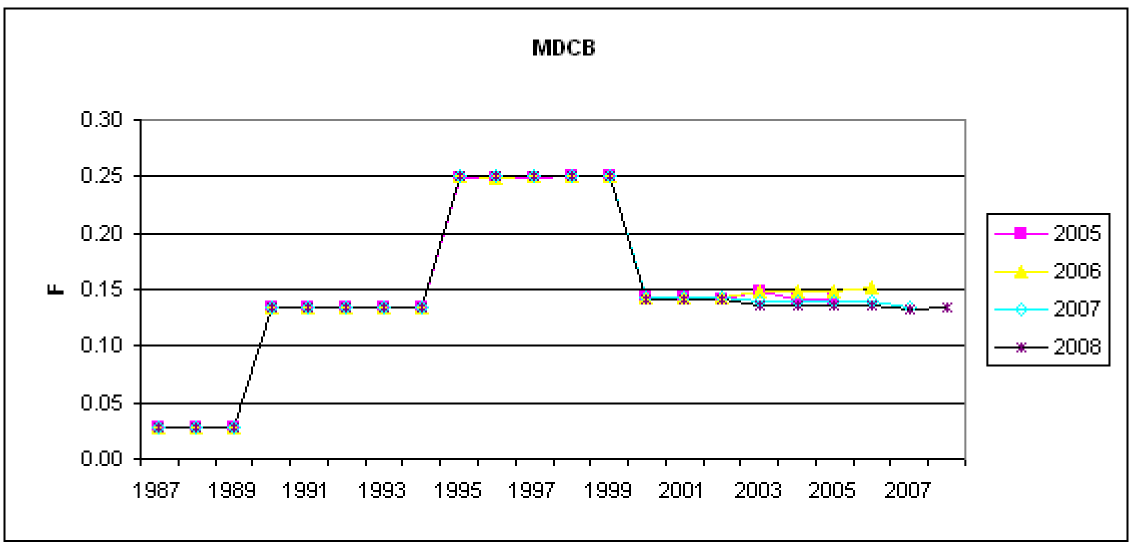
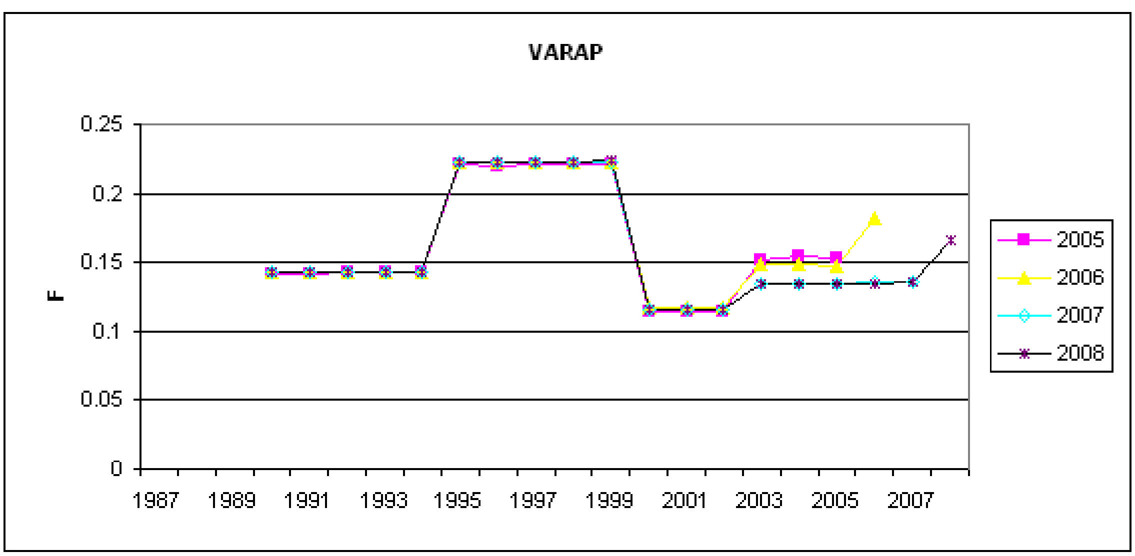


Figure 5 continued.







APPENDIX D

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.

Abstract

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. This model behavior is of concern because many regional managers believe that their tag reporting rate has dropped in recent years while at the same time the tagging models are estimating an increase in natural mortality rate. Determining whether this estimated change in natural mortality rate is real or an artifact of the tagging models is difficult without an updated estimate of tag reporting rate.

A high reward tagging study was conducted in order to determine if the natural mortality rate has indeed risen or if the estimated increase is simply an artifact of the continued use of a constant value (0.43) in the model as the tag reporting rate. This study was conducted by the state agencies in Delaware, Maryland, New York, and Virginia during the 2007 and 2008 tagging seasons. For all the regions combined, 5,943 standard tags were released and 1,245 high reward tags were released. Tags were recaptured for two years resulting in the return of 476 standard tags and 121 high reward tags across all regions. Three separate lines of analysis were conducted in order to explore regional differences in tag reporting rate as well as determine a range of potential overall tag reporting rates.

Commercial fishers appear to have a much lower reporting rate than sport fishers. Estimates for commercial fishers for all states combined (i.e., “overall” estimates) range from 13% to 31% depending on method of analysis. Eliminating the original model from consideration because of concerns about the behavior of the commercial fishery results in a range of estimates from13% to 24%. Recreational anglers appear to have a high reporting rate, with estimates ranging from 77% to 99% for all states combined.

Estimates of overall tag reporting rate (commercial and recreational fishers combined) for all states range from 58% to 82%. Eliminating the original method results in a range of 58% to 71%, a rather narrow range. However, there is some concern that not all high reward tags are reported resulting in a violation of a prime assumption. Thus, the above estimates may be biased high. Because a consensus was not achieved on the reporting rate, the Subcommittee recommended that member states should conduct sensitivity analysis to explore the effects of tag reporting rate decreasing from 0.43 to 0.33 and increasing from 0.43 to 0.53.

Introduction

The purpose of this project is to obtain estimates of the tag reporting rate in the coastal striped bass fishery. Tag reporting rate is defined to be the probability a fisher returns a tag to the US 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 due 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 the standard reward, and those with a special marking and a high value reward. A comparison of the rates of return provides an estimate of the tag reporting rate for the 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), Pollock et al. (1991) 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 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 current study is the first high reward tagging study for striped bass since 2000.

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, α, for high reward tags and that estimates are positively biased if the 100% reporting rate assumption is violated. Therefore, as part of the current study, it was important to explore the sensitivity of the results to violations of the assumption of 100% reporting of high reward tags.

There was some reason to believe that commercial fishers might behave differently than recreational fishers with respect to returning tags to the state agencies. In particular, commercial fishers may have a lower reporting rate of both standard and high reward tags because: 1) in the rush to harvest large numbers of fish for commercial purposes, some tags might 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 conflict between the fishing industry and government agencies. Because the two fishery sectors behave differently, it was decided to explore the use of multi-component fishery tagging models, as described by Pollock et al. (2002).

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. Table 1 summarizes the total regional tagging efforts and Table 2 summarizes the recaptures by region of release. Tables 1 and 2 show total numbers of tags released and recaptured; however these values had to be modified prior to analysis because of deviations from the tagging protocol and special recapture circumstances.

Any fish released less than 457mm total length was removed from the data set because the original proposal called for the tagging of fish greater than or equal to 457mm total length. Any fish released by Virginia that was recaptured within the first week at large was removed from the data set. This was done because Virginia releases fish in close proximity to cooperative commercial fishermen who regularly recapture tagged fish and are believed to report tags at a rate exceeding that of the general commercial population. Finally, recaptures occurring after April 15th 2009 were removed so that the analysis would be conducted on two complete tagging years running from April 15th 2007 to April 14th 2008 and from April 15th 2008 to April 14th 2009. These exclusions resulted in significant changes to the release and recapture matrices (Tables 3 and 4). The modified release and recapture data were used for all analyses. We conducted a chi-square test of independence on the tag recovery rates between the years and between the tag types and found little difference, and thus felt confident pooling years, in order 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 (see 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. Method 1 was brought into question because the regional estimates of tag reporting rate obtained were high, exceeding 100% for New York, and it was believed that the key assumption of 100% high reward tag return rate was being violated. These issues are of legitimate concern because it is theoretically impossible for tag reporting rate to exceed 100% and less than 100% high reward tag return rate can result in a positive bias of the estimate of tag reporting rate.

Method 2: Weighted landings 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 a method was proposed to estimate tag reporting rate which would only require one to assume that the tag reporting rate of recreationally caught high reward tags was 100% and would not require any assumption about the tag reporting rate of commercially caught high reward tags. The basic idea for this method dates to Paulik (1961), Kimura (1976), and Hearn et al. (1999). It is discussed in Pollock et al. (2002). Landings information obtained from the regional striped bass compliance reports and the Marine Recreational Fisheries Statistics Survey (MRFSS) provided estimates of commercial and recreational landings respectively. These values were used to calculate a tag reporting rate for each region as well as an overall rate for all regions combined. A second overall rate was calculated using the same methodology as before with the inclusion of all striped bass landings information rather than just the sum of the study participant regions. Data used in this line of analysis are presented in Table 5.

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% then the expected number of standard tags that should have been recovered and reported by the commercial sector is represented by equation 3. Here L_{rec} refers to the fraction of the total landings obtained from the recreational fishery and L_{comm} refers to the fraction of the total landings obtained from the commercial fishery. L_{rec} and L_{comm} are calculated using landings information obtained from the striped bass compliance reports and MRFSS.

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

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.

Additional questions were raised as to the validity of assuming 100% recreational high reward tag returns. To explore the ramifications of less than 100% recreational high reward tag return rate on Method 2, two runs of the analysis were done using 100% and 90% assumptions of recreational high reward tag return rate.

Method 3: Harvest only model

Uncertainty over what landings information to use for each region led to a modification of the above method. The modifications include only using recaptures obtained from recreationally and commercially harvested striped bass, combining all regions recaptures and releases, and using all available striped bass harvest information not just the harvest data from the regions participating in the high reward tagging study. Method 3 follows the procedure of method 2 using the modified data presented in Table 6.

Results

Original model: Estimated values of the reporting rate ranged from 0.56 in Virginia to 1.12 in New York (Table 7). The estimates for Maryland and Delaware were 0.85 and 1.02, respectively. The New York and Delaware estimates are obviously impossible and likely indicate a violation in the assumption of 100% reporting of the high reward tags. The estimates from all four programs exceeded the presently accepted value of 0.43 for the reporting rate. Fishery specific estimates of tag reporting rate produced using the original model are higher than expected in the commercial fishery for all regions except Virginia (0.18) (Table 8). The estimates of 0.77, 0.63, and 0.67 obtained for Delaware, Maryland and New York respectively, are likely an artifact of the low commercial tag returns rather than the true tag reporting rate. The overall estimate of commercial tag reporting rate obtained using the original method is 0.31. Estimates of the recreational fishery tag reporting rate are 1.03, 0.90, 1.17, and 0.83 for Delaware, Maryland, New York, and Virginia, and 0.99 overall (Table 9). Again the Delaware and New York estimates are impossible and indicate that a violation of the assumption of 100% high reward tag return rate by recreational fisherman is likely. Despite this violation, estimated reporting rates are consistently high by region suggesting that the recreational fisheries participation in the study is high. The disparity between the commercial and recreational results provide evidence in support of the use of the multi component fishery tagging models described by Pollock et al. (2002).

Weighted landings model: This methodology produced estimates that were lower for every program except Virginia (with the Virginia estimate increasing only slightly, by 0.03) (Table 7) and the overall reporting rate dropped from 0.82 to 0.64. Under the assumption of 100% recreational high reward tag return rate regional estimates of 0.33, 0.50, 1.05, and 0.59 were obtained for Delaware, Maryland, New York, and Virginia, respectively. The estimated reporting rate of the Hudson River program was again in excess of 1.00 suggesting that the assumption of 100% recreational high reward tag return rate was being violated. By assuming a reporting rate of 90% of the high reward tags, the estimates of reporting rate ranged dropped to 0.30, 0.45, 0.94, and 0.53 for Delaware, Maryland, New York, and Virginia, and 0.58 overall (Table 7). The use of the weighted landings model produced significant changes in the estimates of commercial tag reporting rate. Assuming 100% reporting rate of recreationally caught high reward tags, estimates of 0.03, 0.13, 0.42, and 0.20 were obtained for Delaware, Maryland, New York, and Virginia, and 0.14 overall (Table 8). These estimates are significantly lower for Delaware and Maryland, lower for New York and slightly higher (0.02) for Virginia. Relaxing the assumption of 100%

recreational high reward tag reporting rate to 90% recreational high reward tag reporting rate slightly reduced all the regional and overall estimates of commercial tag reporting rate to 0.02, 0.12, 0.37, and 0.18 for Delaware, Maryland, New York, and Virginia, and 0.13 overall (Table 8). Under the assumption of 100% recreational high reward tag reporting rate the weighted landings model produces recreational tag reporting rate estimates identical to that of the original model (Table 9). Relaxing the assumption to 90% recreational high reward tag reporting rate produces estimates of 0.93, 0.81, 1.05, 0.74, and 0.89 for Delaware, Maryland, New York, Virginia, and overall, respectively (Table 9).

Weighted landings model (A) differs from the previous method in that it uses all available striped bass landings information rather than just the landings information for the study participant regions. As a result only the overall estimates of 0.71, 0.19, and 0.99 can be generated for the combined, commercial, and recreational fisheries, respectively (Tables 7, 8, and 9). The previous estimates are obtained under the assumption of 100% recreational high reward tag reporting rate and as before the estimates of tag reporting rate declined to 0.64, 0.17, and 0.89 for the combined, commercial, and recreational fisheries when the assumption was relaxed to 90% (Table 7, 8, and 9).

Harvest only model: The harvest only model produced overall estimates of 0.67, 0.24, and 0.86 for the combined, commercial, and recreational fisheries, respectively, when assuming 100% recreational high reward tag reporting rate (Tables 7, 8, and 9). Relaxation of this assumption to 90% recreational high reward tag reporting rate reduced the estimates to 0.60, 0.21, and 0.77 for the combined, commercial, and recreational fisheries, respectively (Tables 7, 8, and 9).

Discussion

The progression of models used in this study developed as a result of questions and concerns raised by the members of the striped bass tagging sub-committee. The original model produced estimates of overall and fishery-specific tag reporting rates that were deemed to be unrealistically high. Multiple estimates of overall and recreational reporting rates in excess of 100% and commercial reporting rates well above what is believed plausible caused the sub-committee to reject the original model results and consider models with less restrictive assumptions about commercial fishery participation. The resulting models, referred to as the weighted landings model, weighted landings model (A), and the harvest only model, are modifications of multi-component fishery tagging models and allow for estimation of standard tag reporting rate without requiring strong assumptions about the commercial fisheries. Switching to this suite of models resulted in significant changes in the estimates for several regions. The Delaware estimates were the most sensitive to the use of landings data to correct for low cooperation in tag reporting by commercial watermen. Delaware landings data are commercial-dominated but had very few returns when compared to the recreational fishers. This inflates the expected number of returns in the weighted landings and harvest-only models and results in a much lower estimate of reporting rate. While this suite of models appears to be a major advancement over the original model, it still requires the assumption of 100% high reward tag reporting rate by recreational fishers.

Again, the sub-committee decided that, while the recreational fishery may be highly cooperative with this study, it is unlikely that 100% of the high reward tags were reported. As a result the suite of multi-component fishery tagging models was modified to assume 90% recreational high reward tag reporting rate. This suite of models produced overall estimates of standard tag reporting rate ranging from 0.58 – 0.64, well above the previously used 0.43, commercial estimates between 0.13 and 0.21, and recreational estimates between 0.77 and 0.89. It is noted that the range of the estimates across tagging programs is rather low. Furthermore, three of the programs produce very similar results, with New York estimates standing out as different from the others. These recreational estimates are higher than what has been found in earlier studies:

source	estimated reporting rate	location
Rugolo et al. (1994)	0.75	Chesapeake
Hornick et al. (2000)	0.64	Chesapeake
Kahn and Shirey (2000)	0.43	coastal fishery

These results suggest, nominally, that the overall tag reporting rate has risen from 0.43 in 2000 to about 0.61 in 2009. However, when one explores the regional estimates and the influence of each region's contribution it becomes clear that the high estimates obtained from New York and the large contribution of New York tags to the overall study act to inflate the overall estimate of tag reporting rate to levels in excess of what is believed to occur in producer regions like the Chesapeake Bay. The high estimates obtained for New York are likely the result of the dominant regional recreational fishery and the high level of tagging study cooperation believed to occur with recreational fishermen. It is of interest to note that the previously estimated reporting rate of 0.43 was generated in the absence of data from New York and may be lower than the current overall estimate of ~0.61 as a result of this omission. If this is the case, it is possible that the difference observed between the 2000 estimate and 2009 estimate is a result of the data used and not a change in tag reporting rate.

As a result, the tagging sub-committee could not recommend the use of any of the overall estimates. Instead, it was proposed to study the effects of different values of tag reporting rate on the estimation of fishing and natural mortality. Member states were asked to evaluate a constant 0.43 tag reporting rate as a baseline and then explore the effects of decreasing tag reporting in the model from 0.43 to 0.33 over time and increasing tag reporting rate from 0.43 to 0.53 over time. This sensitivity analysis was conducted for bass 18 inches and greater (Table 10) and 28 inches and greater (Table 11). The result of a decrease in reporting rate from the currently used value is to increase the relative amount of total mortality attributed to fishing and decrease the estimate of natural mortality. Conversely, increasing the reporting rate reallocates mortality in favor of natural mortality. Thus an underestimation of reporting rate will lead to an overestimation of fishing mortality.

This study suggests that tag reporting rate can vary widely by region and fishery and that a single value of tag reporting rate is inappropriate when better regional and fishing sector information is available. The use of regional tag reporting rates is important to consider given the confounded nature of tag reporting rate with fishing and natural mortality rate estimation and the regional effects of mycobacterial disease on striped bass. Imposing a single tag reporting rate to all regions is sacrificing information pertinent to managing the fishery for convenience and should be revaluated given the findings of this study. Similarly, use of a single number instead of separate values for recreational and commercial fishers is a problem because commercial fishers have a lower reporting rate than recreational fishers and the ratio of landings taken by the two sectors varies over time; thus, the overall reporting rate will vary over time with the overall rate being high in years when the recreational fishery takes a high proportion of the landings. For this reason, use of separate reporting rates for each sector should be considered.

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Table 1. Standard and high reward tags released by region for the striped bass tag reporting rate study conducted in the spring of 2007 and 2008

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 2. Standard and high reward tag recaptures by region and year for the striped bass tag reporting rate study conducted in 2007 and 2008. 2009 recaptures include recaptures occurring before April 15 2009

		2007 recaptures		2008 recaptures		2009 recaptures	
Release year		Standard	High reward	Standard	High reward	Standard	High reward
2007	DE	36	6	13	6	4	0
	MD	32	7	16	1	1	2
	NY	47	13	51	9	3	0
	VA	96	39	40	16	0	3
2008	DE	-	-	41	5	5	0
	MD	-	-	25	6	2	0
	NY	-	-	85	17	5	0
	VA	-	-	21	7	3	1

Table 3. Standard and high reward tag numbers released by region with fish less than 457mm total length, and fish recaptured in Virginia within 7 days of release removed

Year	Tag Type	Delaware/Pennsylvania	Maryland	New York	Virginia
2007	Standard	313	382	756	1950
	High Reward	78	90	186	380
2008	Standard	421	360	1240	521
	High Reward	63	83	262	103

Table 4. Standard and high reward tag recaptures by region and year with fish released less than 457mm total length, fish recaptured in Virginia within 7 days of release, and fish recaptured after April 15, 2009 removed

Release year		2007 recaptures Standard	2007 recaptures High reward	2008 recaptures Standard	2008 recaptures High reward	2009 recaptures Standard	2009 recaptures High reward
2007	DE	24	3	9	6	2	0
	MD	21	7	12	1	1	2
	NY	47	13	50	9	3	0
	VA	87	26	40	16	0	3
2008	DE	-	-	34	5	5	0
	MD	-	-	22	6	2	0
	NY	-	-	89	17	5	0
	VA	-	-	20	6	3	1

Table 5. Regional releases and recaptures of striped bass pooled over year by fishery and tag type. Landings information is supplied by ASMFC compliance reports and MRFSS, and is used as a weighting factor in the analysis. Landings data includes both harvest and catch and release. Overall landings values are for all regions with striped bass fisheries not just for the study participant regions

Region	Releases Standard	Releases High reward	Commercial Recaptures Standard	Commercial Recaptures High reward	Recreational Recaptures Standard	Recreational Recaptures High reward	Landings by Fishery (numbers of fish) Commercial	Landings by Fishery (numbers of fish) Recreational
DE	734	141	4	1	70	13	62,956	27,089
MD	742	173	8	3	50	13	1,193,150	1,121,304
NY	1996	448	12	4	182	35	151,550	818,993
VA	2471	483	19	21	131	31	274,230	452,488
Overall	5943	1245	43	29	433	92	3,561,188	6,874,810

Table 6. Releases and recaptures of striped bass pooled over year and region by fishery and tag type. Landings information is supplied by ASMFC compliance reports and MRFSS and is used as a weighting factor in the analysis. Landings values are for harvested fish only and represent landings from all regions with striped bass fisheries not just for the study participant regions

Releases Standard	Releases High reward	Commercial Recaptures Standard	Commercial Recaptures High reward	Recreational Recaptures Standard	Recreational Recaptures High reward	Landings by Fishery (numbers of fish) Commercial	Landings by Fishery (numbers of fish) Recreational
5943	1245	29	16	238	58	2,026,302	4,559,478

Table 7. Overall and regional results for all lines of analysis. For models where assumptions had to be made about recreational high reward tag return rate, assumed value is provided in brackets following the model name. Weighted landings model A is an overall method 2 estimate of tag reporting rate generated using all striped bass landings information, not just the landings information of the study participant states.

	Regional Estimates of Tag Reporting Rate				
	Delaware	Maryland	New York	Virginia	Overall
Original model	1.02	.85	1.12	.56	.82
Weighted landings model (100%)	.33	.50	1.05	.59	.64
Weighted landings model (90%)	.30	.45	.94	.53	.58
Weighted landings model A (100%)	NA	NA	NA	NA	.71
Weighted landings model A (90%)	NA	NA	NA	NA	.64
Harvest only model (100%)	NA	NA	NA	NA	.67
Harvest only model (90%)	NA	NA	NA	NA	.60

Table 8. Overall and regional results for the commercial fishery utilizing all lines of analysis. For models where assumptions had to be made about recreational high reward tag return rate, assumed value is provided in brackets following the model name. Weighted landings model A is an overall method 2 estimate of tag reporting rate generated using all striped bass landings information, not just the landings information of the study participant states.

	Regional Estimates of Commercial Tag Reporting Rate				
	Delaware	Maryland	New York	Virginia	Overall
Original model	.77	.62	.67	.18	.31
Weighted landings model (100%)	.03	.13	.42	.20	.14
Weighted landings model (90%)	.02	.12	.37	.18	.13
Weighted landings model A (100%)	NA	NA	NA	NA	.19
Weighted landings model A (90%)	NA	NA	NA	NA	.17
Harvest only model (100%)	NA	NA	NA	NA	.24
Harvest only model (90%)	NA	NA	NA	NA	.21

Table 9. Overall and regional results for the recreational fishery utilizing all lines of analysis. For models where assumptions had to be made about recreational high reward tag return rate, assumed value is provided in brackets following the model name. Weighted landings model A is an overall method 2 estimate of tag reporting rate generated using all striped bass landings information, not just the landings information of the study participant states.

Regional Estimates of Recreational Tag Reporting Rate

	Delaware	Maryland	New York	Virginia	Overall
Original model	1.03	.90	1.17	.83	.99
Weighted landings model (100%)	1.03	.90	1.17	.83	.99
Weighted landings model (90%)	.93	.81	1.05	.74	.89
Weighted landings model A (100%)	NA	NA	NA	NA	.99
Weighted landings model A (90%)	NA	NA	NA	NA	.89
Harvest only model (100%)	NA	NA	NA	NA	.86
Harvest only model (90%)	NA	NA	NA	NA	.77

Table 10. Comparison in the effect of three temporal reporting rate scenarios, constant at 0.43, declining from 0.43 to 0.33 and rising from 0.43 to 0.53, on survival (S), fishing mortality (F) and natural mortality (M) for striped bass greater than 18 inches.

Coastal programs

Massachusetts

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988									
1989									
1990									
1991									
1992	0.83	0.07	0.11	0.84	0.06	0.11	0.83	0.07	0.11
1993	0.83	0.07	0.11	0.83	0.07	0.11	0.83	0.07	0.11
1994	0.83	0.07	0.11	0.83	0.07	0.11	0.83	0.07	0.11
1995	0.78	0.14	0.11	0.78	0.13	0.11	0.78	0.13	0.11
1996	0.77	0.14	0.11	0.77	0.14	0.11	0.78	0.14	0.11
1997	0.77	0.14	0.11	0.77	0.15	0.11	0.78	0.14	0.11
1998	0.77	0.14	0.11	0.77	0.14	0.11	0.78	0.14	0.11
1999	0.73	0.14	0.16	0.75	0.16	0.12	0.71	0.14	0.20
2000	0.76	0.11	0.16	0.76	0.15	0.12	0.75	0.09	0.20
2001	0.76	0.11	0.16	0.78	0.13	0.12	0.75	0.09	0.20
2002	0.76	0.11	0.16	0.77	0.14	0.12	0.75	0.09	0.20
2003	0.76	0.10	0.16	0.77	0.14	0.12	0.75	0.08	0.20
2004	0.77	0.10	0.16	0.78	0.13	0.12	0.75	0.08	0.20
2005	0.77	0.10	0.16	0.78	0.13	0.12	0.75	0.08	0.20
2006	0.77	0.10	0.16	0.78	0.13	0.12	0.75	0.08	0.20
2007	0.78	0.08	0.16	0.80	0.10	0.12	0.77	0.07	0.20
2008	0.78	0.08	0.16	0.80	0.11	0.12	0.77	0.07	0.20

Table 10 continued.

New Jersey

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988									
1989	0.85	0.02	0.13	0.85	0.02	0.13	0.85	0.02	0.13
1990	0.83	0.04	0.13	0.82	0.05	0.13	0.82	0.05	0.13
1991	0.82	0.05	0.13	0.81	0.06	0.13	0.81	0.06	0.13
1992	0.84	0.03	0.13	0.84	0.03	0.13	0.84	0.03	0.13
1993	0.84	0.03	0.13	0.84	0.03	0.13	0.84	0.03	0.13
1994	0.84	0.03	0.13	0.84	0.03	0.13	0.84	0.03	0.13
1995	0.78	0.10	0.13	0.80	0.08	0.13	0.79	0.09	0.13
1996	0.77	0.12	0.13	0.76	0.12	0.13	0.76	0.12	0.13
1997	0.76	0.13	0.13	0.75	0.14	0.13	0.75	0.14	0.13
1998	0.75	0.14	0.13	0.73	0.17	0.13	0.74	0.16	0.13
1999	0.77	0.12	0.13	0.77	0.11	0.13	0.78	0.11	0.13
2000	0.77	0.12	0.13	0.77	0.12	0.13	0.78	0.11	0.13
2001	0.77	0.12	0.13	0.76	0.13	0.13	0.77	0.12	0.13
2002	0.67	0.12	0.27	0.70	0.14	0.20	0.66	0.10	0.32
2003	0.65	0.15	0.27	0.68	0.18	0.20	0.64	0.12	0.32
2004	0.65	0.15	0.27	0.66	0.20	0.20	0.64	0.13	0.32
2005	0.64	0.16	0.27	0.65	0.22	0.20	0.63	0.14	0.32
2006	0.65	0.14	0.27	0.68	0.18	0.20	0.65	0.11	0.32
2007	0.64	0.16	0.27	0.65	0.22	0.20	0.64	0.13	0.32
2008	0.63	0.17	0.27	0.64	0.23	0.20	0.63	0.14	0.32

Table 10 continued.

New York OHS

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988	0.83	0.01	0.15	0.83	0.02	0.15	0.83	0.01	0.15
1989	0.83	0.01	0.15	0.83	0.02	0.15	0.83	0.01	0.15
1990	0.80	0.06	0.15	0.80	0.06	0.15	0.80	0.06	0.15
1991	0.80	0.06	0.15	0.80	0.06	0.15	0.80	0.06	0.15
1992	0.80	0.06	0.15	0.80	0.06	0.15	0.80	0.06	0.15
1993	0.80	0.06	0.15	0.80	0.06	0.15	0.80	0.06	0.15
1994	0.80	0.06	0.15	0.80	0.06	0.15	0.80	0.06	0.15
1995	0.78	0.09	0.15	0.77	0.10	0.15	0.79	0.08	0.15
1996	0.78	0.09	0.15	0.77	0.10	0.15	0.79	0.08	0.15
1997	0.78	0.09	0.15	0.77	0.10	0.15	0.79	0.08	0.15
1998	0.65	0.09	0.33	0.68	0.10	0.28	0.63	0.08	0.37
1999	0.65	0.09	0.33	0.68	0.10	0.28	0.63	0.08	0.37
2000	0.66	0.08	0.33	0.68	0.10	0.28	0.64	0.07	0.37
2001	0.66	0.08	0.33	0.68	0.10	0.28	0.64	0.07	0.37
2002	0.66	0.08	0.33	0.68	0.10	0.28	0.64	0.07	0.37
2003	0.65	0.09	0.33	0.67	0.12	0.28	0.64	0.07	0.37
2004	0.65	0.09	0.33	0.67	0.12	0.28	0.64	0.07	0.37
2005	0.65	0.09	0.33	0.67	0.12	0.28	0.64	0.07	0.37
2006	0.65	0.09	0.33	0.67	0.12	0.28	0.64	0.07	0.37
2007	0.67	0.07	0.33	0.69	0.09	0.28	0.65	0.06	0.37
2008	0.67	0.07	0.33	0.69	0.09	0.28	0.65	0.06	0.37

Table 10 continued.

North Carolina

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988	0.79	0.02	0.21	0.79	0.02	0.21	0.79	0.02	0.21
1989	0.79	0.02	0.21	0.79	0.02	0.21	0.79	0.02	0.21
1990	0.73	0.10	0.21	0.72	0.10	0.21	0.73	0.09	0.21
1991	0.72	0.10	0.21	0.72	0.10	0.21	0.72	0.10	0.21
1992	0.72	0.10	0.21	0.72	0.10	0.21	0.72	0.11	0.21
1993	0.72	0.11	0.21	0.72	0.10	0.21	0.72	0.11	0.21
1994	0.72	0.10	0.21	0.72	0.10	0.21	0.72	0.10	0.21
1995	0.69	0.14	0.21	0.69	0.14	0.21	0.70	0.14	0.21
1996	0.70	0.14	0.21	0.70	0.14	0.21	0.70	0.14	0.21
1997	0.69	0.15	0.21	0.69	0.15	0.21	0.69	0.15	0.21
1998	0.69	0.15	0.21	0.69	0.15	0.21	0.69	0.15	0.21
1999	0.70	0.14	0.21	0.70	0.14	0.21	0.70	0.14	0.21
2000	0.56	0.12	0.45	0.58	0.16	0.39	0.56	0.09	0.48
2001	0.56	0.12	0.45	0.58	0.16	0.39	0.56	0.10	0.48
2002	0.56	0.12	0.45	0.58	0.16	0.39	0.56	0.10	0.48
2003	0.55	0.14	0.45	0.56	0.18	0.39	0.55	0.11	0.48
2004	0.55	0.14	0.45	0.56	0.18	0.39	0.55	0.12	0.48
2005	0.56	0.13	0.45	0.57	0.18	0.39	0.55	0.11	0.48
2006	0.56	0.14	0.45	0.56	0.18	0.39	0.55	0.11	0.48
2007	0.55	0.14	0.45	0.56	0.18	0.39	0.55	0.11	0.48
2008	0.55	0.15	0.45	0.56	0.19	0.39	0.54	0.12	0.48

Table 10 continued.

Producer programs

Hudson River

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988	0.83	0.04	0.14	0.83	0.04	0.15	0.83	0.04	0.14
1989	0.81	0.04	0.14	0.81	0.04	0.15	0.81	0.04	0.14
1990	0.77	0.10	0.14	0.77	0.10	0.15	0.77	0.10	0.14
1991	0.77	0.10	0.14	0.77	0.10	0.15	0.77	0.10	0.14
1992	0.77	0.10	0.14	0.77	0.10	0.15	0.77	0.10	0.14
1993	0.77	0.10	0.14	0.77	0.10	0.15	0.77	0.10	0.14
1994	0.77	0.10	0.14	0.77	0.10	0.15	0.77	0.10	0.14
1995	0.71	0.19	0.14	0.71	0.18	0.15	0.71	0.19	0.14
1996	0.71	0.19	0.14	0.71	0.19	0.15	0.71	0.19	0.14
1997	0.71	0.19	0.14	0.70	0.20	0.15	0.71	0.19	0.14
1998	0.71	0.19	0.14	0.70	0.20	0.15	0.71	0.19	0.14
1999	0.71	0.19	0.14	0.71	0.19	0.15	0.71	0.19	0.14
2000	0.76	0.12	0.14	0.76	0.13	0.15	0.77	0.11	0.14
2001	0.76	0.12	0.14	0.75	0.13	0.15	0.77	0.11	0.14
2002	0.70	0.12	0.23	0.74	0.14	0.16	0.67	0.11	0.28
2003	0.68	0.14	0.23	0.71	0.17	0.16	0.67	0.11	0.28
2004	0.68	0.14	0.23	0.71	0.18	0.16	0.67	0.11	0.28
2005	0.68	0.14	0.23	0.71	0.18	0.16	0.67	0.11	0.28
2006	0.69	0.14	0.23	0.71	0.18	0.16	0.67	0.11	0.28
2007	0.69	0.14	0.23	0.71	0.18	0.16	0.67	0.11	0.28
2008	0.69	0.14	0.23	0.71	0.17	0.16	0.67	0.11	0.28

Table 10 continued.

Delaware River

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988									
1989									
1990									
1991									
1992									
1993									
1994									
1995									
1996									
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									

Table 10 continued.

Maryland Ches. Bay

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987	0.82	0.00	0.20	0.82	0.00	0.20	0.82	0.00	0.20
1988	0.81	0.01	0.20	0.81	0.01	0.20	0.81	0.01	0.20
1989	0.82	0.00	0.20	0.82	0.00	0.20	0.82	0.00	0.20
1990	0.76	0.07	0.20	0.76	0.07	0.20	0.76	0.07	0.20
1991	0.72	0.12	0.20	0.72	0.12	0.20	0.72	0.12	0.20
1992	0.68	0.18	0.20	0.68	0.18	0.20	0.68	0.18	0.20
1993	0.69	0.16	0.20	0.69	0.16	0.20	0.69	0.16	0.20
1994	0.70	0.16	0.20	0.70	0.16	0.20	0.70	0.16	0.20
1995	0.65	0.23	0.20	0.65	0.23	0.20	0.64	0.23	0.20
1996	0.66	0.21	0.20	0.66	0.21	0.20	0.66	0.21	0.20
1997	0.63	0.26	0.20	0.63	0.26	0.20	0.63	0.26	0.20
1998	0.61	0.29	0.20	0.61	0.29	0.20	0.61	0.29	0.20
1999	0.52	0.25	0.40	0.52	0.32	0.33	0.52	0.20	0.45
2000	0.54	0.21	0.40	0.54	0.28	0.33	0.54	0.17	0.45
2001	0.56	0.18	0.40	0.57	0.23	0.33	0.55	0.14	0.45
2002	0.58	0.14	0.40	0.60	0.18	0.33	0.57	0.11	0.45
2003	0.55	0.20	0.40	0.56	0.26	0.33	0.54	0.16	0.45
2004	0.57	0.16	0.40	0.58	0.21	0.33	0.56	0.13	0.45
2005	0.58	0.14	0.40	0.60	0.18	0.33	0.57	0.11	0.45
2006	0.57	0.17	0.40	0.58	0.21	0.33	0.56	0.14	0.45
2007	0.60	0.12	0.40	0.62	0.15	0.33	0.58	0.10	0.45
2008	0.59	0.13	0.40	0.61	0.17	0.33	0.57	0.11	0.45

Table 10 continued.

Virginia Rap. River

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988									
1989									
1990	0.62	0.07	0.40	0.63	0.04	0.41	0.62	0.08	0.39
1991	0.62	0.08	0.40	0.62	0.07	0.41	0.62	0.08	0.39
1992	0.61	0.09	0.40	0.59	0.11	0.41	0.62	0.08	0.39
1993	0.61	0.09	0.40	0.60	0.10	0.41	0.62	0.08	0.39
1994	0.61	0.10	0.40	0.58	0.13	0.41	0.62	0.09	0.39
1995	0.59	0.12	0.40	0.58	0.14	0.41	0.60	0.11	0.39
1996	0.60	0.11	0.40	0.61	0.08	0.41	0.61	0.10	0.39
1997	0.59	0.12	0.40	0.59	0.12	0.41	0.61	0.11	0.39
1998	0.49	0.12	0.59	0.49	0.16	0.54	0.48	0.11	0.62
1999	0.49	0.13	0.59	0.48	0.19	0.54	0.48	0.11	0.62
2000	0.51	0.09	0.59	0.52	0.10	0.54	0.50	0.08	0.62
2001	0.50	0.10	0.59	0.50	0.14	0.54	0.49	0.08	0.62
2002	0.50	0.10	0.59	0.51	0.13	0.54	0.49	0.08	0.62
2003	0.49	0.11	0.59	0.50	0.15	0.54	0.49	0.09	0.62
2004	0.49	0.12	0.59	0.49	0.17	0.54	0.49	0.09	0.62
2005	0.50	0.11	0.59	0.51	0.12	0.54	0.49	0.09	0.62
2006	0.49	0.11	0.59	0.50	0.16	0.54	0.49	0.09	0.62
2007	0.50	0.11	0.59	0.51	0.13	0.54	0.49	0.09	0.62
2008	0.49	0.11	0.59	0.50	0.15	0.54	0.49	0.09	0.62

Table 11. Comparison in the effect of three temporal reporting rate scenarios, constant at 0.43, declining from 0.43 to 0.33 and rising from 0.43 to 0.53, on survival (S), fishing mortality (F) and natural mortality (M) for striped bass greater than 28 inches.

Coastal programs

Massachusetts

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988									
1989									
1990									
1991									
1992	0.83	0.08	0.10	0.84	0.07	0.10	0.83	0.08	0.10
1993	0.83	0.08	0.10	0.84	0.08	0.10	0.83	0.08	0.10
1994	0.83	0.08	0.10	0.84	0.08	0.10	0.83	0.08	0.10
1995	0.75	0.18	0.10	0.75	0.18	0.10	0.75	0.17	0.10
1996	0.75	0.18	0.10	0.75	0.18	0.10	0.75	0.18	0.10
1997	0.75	0.18	0.10	0.75	0.18	0.10	0.75	0.18	0.10
1998	0.75	0.18	0.10	0.75	0.18	0.10	0.75	0.18	0.10
1999	0.72	0.18	0.14	0.75	0.19	0.10	0.70	0.18	0.18
2000	0.76	0.13	0.14	0.76	0.17	0.10	0.75	0.10	0.18
2001	0.76	0.13	0.14	0.77	0.16	0.10	0.75	0.10	0.18
2002	0.76	0.13	0.14	0.76	0.16	0.10	0.75	0.10	0.18
2003	0.78	0.11	0.14	0.78	0.14	0.10	0.76	0.09	0.18
2004	0.78	0.11	0.14	0.78	0.14	0.10	0.76	0.09	0.18
2005	0.78	0.11	0.14	0.78	0.14	0.10	0.76	0.09	0.18
2006	0.78	0.11	0.14	0.78	0.14	0.10	0.76	0.09	0.18
2007	0.80	0.08	0.14	0.81	0.11	0.10	0.78	0.07	0.18
2008	0.80	0.08	0.14	0.81	0.11	0.10	0.78	0.07	0.18

Table 11 continued.

New Jersey

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988									
1989	0.92	0.00	0.07	0.92	0.00	0.07	0.92	0.00	0.07
1990	0.82	0.11	0.07	0.82	0.11	0.07	0.82	0.11	0.07
1991	0.63	0.38	0.07	0.63	0.38	0.07	0.63	0.38	0.07
1992	0.92	0.00	0.07	0.92	0.00	0.07	0.92	0.00	0.07
1993	0.83	0.10	0.07	0.83	0.10	0.07	0.83	0.10	0.07
1994	0.88	0.05	0.07	0.87	0.05	0.07	0.88	0.05	0.07
1995	0.83	0.11	0.07	0.83	0.11	0.07	0.83	0.11	0.07
1996	0.75	0.21	0.07	0.75	0.21	0.07	0.75	0.21	0.07
1997	0.76	0.19	0.07	0.76	0.19	0.07	0.76	0.19	0.07
1998	0.67	0.32	0.07	0.67	0.32	0.07	0.67	0.32	0.07
1999	0.76	0.19	0.07	0.76	0.19	0.07	0.76	0.19	0.07
2000	0.80	0.16	0.07	0.80	0.16	0.07	0.80	0.16	0.07
2001	0.78	0.18	0.07	0.78	0.18	0.07	0.78	0.18	0.07
2002	0.80	0.15	0.07	0.80	0.15	0.07	0.80	0.15	0.07
2003	0.65	0.19	0.23	0.66	0.25	0.15	0.64	0.16	0.29
2004	0.65	0.19	0.23	0.67	0.25	0.15	0.64	0.15	0.29
2005	0.63	0.22	0.23	0.64	0.29	0.15	0.62	0.18	0.29
2006	0.67	0.16	0.23	0.69	0.21	0.15	0.65	0.13	0.29
2007	0.64	0.20	0.23	0.66	0.26	0.15	0.63	0.16	0.29
2008	0.61	0.25	0.23	0.61	0.33	0.15	0.61	0.20	0.29

Table 11 continued.

New York OHS

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988	0.84	0.03	0.13	0.88	0.04	0.07	0.88	0.04	0.07
1989	0.84	0.03	0.13	0.88	0.04	0.07	0.88	0.04	0.07
1990	0.76	0.13	0.13	0.79	0.16	0.07	0.79	0.16	0.07
1991	0.76	0.13	0.13	0.79	0.16	0.07	0.79	0.16	0.07
1992	0.76	0.13	0.13	0.79	0.16	0.07	0.79	0.16	0.07
1993	0.76	0.13	0.13	0.79	0.16	0.07	0.79	0.16	0.07
1994	0.76	0.13	0.13	0.79	0.16	0.07	0.79	0.16	0.07
1995	0.69	0.24	0.13	0.70	0.28	0.07	0.70	0.28	0.07
1996	0.69	0.24	0.13	0.70	0.28	0.07	0.70	0.28	0.07
1997	0.69	0.24	0.13	0.70	0.28	0.07	0.70	0.28	0.07
1998	0.69	0.24	0.13	0.70	0.28	0.07	0.70	0.28	0.07
1999	0.69	0.24	0.13	0.70	0.28	0.07	0.70	0.28	0.07
2000	0.73	0.17	0.13	0.75	0.21	0.07	0.76	0.20	0.07
2001	0.73	0.17	0.13	0.75	0.21	0.07	0.76	0.20	0.07
2002	0.73	0.17	0.13	0.75	0.21	0.07	0.76	0.20	0.07
2003	0.72	0.19	0.13	0.71	0.27	0.07	0.76	0.20	0.07
2004	0.52	0.19	0.46	0.57	0.27	0.28	0.50	0.20	0.49
2005	0.52	0.19	0.46	0.57	0.27	0.28	0.50	0.20	0.49
2006	0.52	0.19	0.46	0.57	0.27	0.28	0.50	0.20	0.49
2007	0.52	0.19	0.46	0.57	0.27	0.28	0.50	0.21	0.49
2008	0.51	0.21	0.46	0.55	0.30	0.28	0.49	0.22	0.49

Table 11 continued.

North Carolina

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988	0.81	0.05	0.15	0.81	0.05	0.16	0.81	0.05	0.15
1989	0.81	0.0	0.15	0.81	0.04	0.16	0.81	0.05	0.15
1990	0.77	0.09	0.15	0.77	0.09	0.16	0.77	0.10	0.15
1991	0.78	0.08	0.15	0.78	0.07	0.16	0.78	0.09	0.15
1992	0.75	0.13	0.15	0.74	0.13	0.16	0.75	0.12	0.15
1993	0.75	0.13	0.15	0.74	0.13	0.16	0.75	0.12	0.15
1994	0.76	0.11	0.15	0.75	0.12	0.16	0.76	0.11	0.15
1995	0.72	0.17	0.15	0.71	0.17	0.16	0.72	0.17	0.15
1996	0.74	0.15	0.15	0.74	0.14	0.16	0.73	0.15	0.15
1997	0.70	0.20	0.15	0.69	0.21	0.16	0.71	0.19	0.15
1998	0.71	0.18	0.15	0.70	0.19	0.16	0.72	0.18	0.15
1999	0.72	0.17	0.15	0.72	0.17	0.16	0.72	0.17	0.15
2000	0.67	0.10	0.29	0.71	0.09	0.25	0.65	0.11	0.32
2001	0.63	0.16	0.29	0.66	0.17	0.25	0.62	0.16	0.32
2002	0.65	0.14	0.29	0.68	0.13	0.25	0.63	0.14	0.32
2003	0.64	0.15	0.29	0.64	0.19	0.25	0.64	0.12	0.32
2004	0.63	0.16	0.29	0.63	0.21	0.25	0.64	0.13	0.32
2005	0.64	0.15	0.29	0.64	0.19	0.25	0.64	0.12	0.32
2006	0.64	0.16	0.29	0.63	0.21	0.25	0.64	0.12	0.32
2007	0.62	0.19	0.29	0.59	0.26	0.25	0.63	0.15	0.32
2008	0.60	0.21	0.29	0.57	0.30	0.25	0.62	0.16	0.32

Table 11 continued.

Producer programs

Hudson River

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988	0.83	0.09	0.09	0.83	0.09	0.09	0.83	0.09	0.09
1989	0.82	0.09	0.09	0.82	0.09	0.09	0.82	0.09	0.09
1990	0.76	0.16	0.09	0.77	0.15	0.09	0.76	0.16	0.09
1991	0.77	0.16	0.09	0.77	0.16	0.09	0.77	0.16	0.09
1992	0.77	0.16	0.09	0.77	0.16	0.09	0.77	0.16	0.09
1993	0.77	0.16	0.09	0.76	0.16	0.09	0.77	0.16	0.09
1994	0.77	0.16	0.09	0.77	0.16	0.09	0.77	0.16	0.09
1995	0.70	0.25	0.09	0.71	0.25	0.09	0.70	0.25	0.09
1996	0.70	0.25	0.09	0.70	0.26	0.09	0.70	0.25	0.09
1997	0.70	0.25	0.09	0.69	0.26	0.09	0.70	0.25	0.09
1998	0.70	0.25	0.09	0.70	0.26	0.09	0.70	0.25	0.09
1999	0.70	0.25	0.09	0.70	0.26	0.09	0.70	0.25	0.09
2000	0.77	0.17	0.09	0.75	0.19	0.09	0.78	0.15	0.09
2001	0.71	0.17	0.17	0.74	0.21	0.09	0.69	0.15	0.22
2002	0.71	0.17	0.17	0.73	0.21	0.09	0.69	0.15	0.22
2003	0.68	0.20	0.17	0.70	0.26	0.09	0.68	0.16	0.22
2004	0.69	0.20	0.17	0.69	0.27	0.09	0.68	0.16	0.22
2005	0.68	0.20	0.17	0.70	0.26	0.09	0.68	0.16	0.22
2006	0.68	0.20	0.17	0.69	0.27	0.09	0.68	0.16	0.22
2007	0.69	0.20	0.17	0.70	0.26	0.09	0.68	0.16	0.22
2008	0.69	0.20	0.17	0.70	0.26	0.09	0.68	0.16	0.22

Table 11 continued.

Delaware River

Year	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
	S	F	M	S	F	M	S	F	M
1987									
1988									
1989									
1990									
1991									
1992									
1993									
1994									
1995									
1996									
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									

Table 11 continued.

Maryland Ches. Bay

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987	0.84	0.03	0.14	0.84	0.03	0.14	0.84	0.03	0.14
1988	0.84	0.03	0.14	0.84	0.03	0.14	0.84	0.03	0.14
1989	0.84	0.03	0.14	0.84	0.03	0.14	0.84	0.03	0.14
1990	0.75	0.13	0.14	0.75	0.13	0.14	0.75	0.13	0.14
1991	0.75	0.13	0.14	0.75	0.13	0.14	0.75	0.13	0.14
1992	0.75	0.13	0.14	0.75	0.13	0.14	0.75	0.13	0.14
1993	0.75	0.13	0.14	0.75	0.13	0.14	0.75	0.13	0.14
1994	0.75	0.13	0.14	0.75	0.13	0.14	0.75	0.13	0.14
1995	0.67	0.25	0.14	0.67	0.25	0.14	0.67	0.25	0.14
1996	0.67	0.25	0.14	0.67	0.25	0.14	0.67	0.25	0.14
1997	0.67	0.25	0.14	0.67	0.25	0.14	0.67	0.25	0.14
1998	0.67	0.25	0.14	0.67	0.25	0.14	0.67	0.25	0.14
1999	0.67	0.25	0.14	0.67	0.25	0.14	0.67	0.25	0.14
2000	0.75	0.14	0.14	0.73	0.17	0.14	0.77	0.12	0.14
2001	0.65	0.14	0.28	0.67	0.17	0.22	0.64	0.12	0.32
2002	0.65	0.14	0.28	0.67	0.17	0.22	0.64	0.12	0.32
2003	0.66	0.14	0.28	0.67	0.18	0.22	0.65	0.11	0.32
2004	0.66	0.14	0.28	0.67	0.18	0.22	0.65	0.11	0.32
2005	0.66	0.14	0.28	0.67	0.18	0.22	0.65	0.11	0.32
2006	0.66	0.14	0.28	0.67	0.18	0.22	0.65	0.11	0.32
2007	0.66	0.13	0.28	0.67	0.17	0.22	0.65	0.11	0.32
2008	0.66	0.13	0.28	0.67	0.17	0.22	0.65	0.11	0.32

Table 11 continued.

Virginia Rap. River

	lambda = 0.43			lambda 0.43 →0.33			lambda 0.43→0.53		
Year	S	F	M	S	F	M	S	F	M
1987									
1988									
1989									
1990	0.66	0.14	0.26	0.66	0.14	0.26	0.67	0.14	0.25
1991	0.66	0.14	0.26	0.66	0.14	0.26	0.67	0.14	0.25
1992	0.66	0.14	0.26	0.66	0.14	0.26	0.67	0.14	0.25
1993	0.66	0.14	0.26	0.66	0.14	0.26	0.67	0.14	0.25
1994	0.66	0.14	0.26	0.66	0.14	0.26	0.66	0.14	0.25
1995	0.62	0.22	0.26	0.61	0.22	0.26	0.62	0.22	0.25
1996	0.62	0.22	0.26	0.61	0.22	0.26	0.62	0.22	0.25
1997	0.62	0.22	0.26	0.61	0.22	0.26	0.62	0.22	0.25
1998	0.62	0.22	0.26	0.61	0.22	0.26	0.62	0.22	0.25
1999	0.62	0.22	0.26	0.61	0.22	0.26	0.62	0.22	0.25
2000	0.69	0.12	0.26	0.68	0.12	0.26	0.69	0.11	0.25
2001	0.69	0.12	0.26	0.68	0.12	0.26	0.69	0.11	0.25
2002	0.69	0.12	0.26	0.68	0.12	0.26	0.69	0.12	0.25
2003	0.67	0.13	0.26	0.65	0.16	0.26	0.69	0.12	0.25
2004	0.52	0.13	0.52	0.55	0.16	0.43	0.50	0.11	0.57
2005	0.52	0.13	0.52	0.55	0.16	0.43	0.50	0.11	0.57
2006	0.52	0.13	0.52	0.55	0.16	0.43	0.50	0.11	0.57
2007	0.52	0.14	0.52	0.55	0.17	0.43	0.50	0.12	0.57
2008	0.50	0.17	0.52	0.53	0.20	0.43	0.49	0.14	0.57