Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-62

Massachusetts Striped Bass Monitoring Report for 2014

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Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
Department of Fish and Game
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Massachusetts
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Commonwealth of Massachusetts
Charles D. Baker, Governor
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Matthew A. Beaton, Secretary
Department of Fish and Game
George N. Peterson, Jr., Commissioner
Massachusetts Division of Marine Fisheries
David E. Pierce, Director

Summary: During 2014, the Massachusetts commercial fishery for striped bass sold about 56,058 fish weighing 1,138,507 pounds and kept approximately 4,560 fish for personal consumption. Total losses due to commercial harvesting (including release mortality) were 66,968 fish weighing 1,267,217 pounds. The recreational fishery harvested about 253,877 striped bass weighing over 4.0 million pounds. Total losses due to recreational fishing (including release mortality) were 412,522 fish weighing over 4.8 million pounds. Combined losses (including scientific losses) were 479,489 fish weighing over 6.0 million pounds, which reflects a 4% decrease in numbers lost and a 3% increase in weight lost compared to 2013 (502,522 fish; 5.9 million pounds). The majority of losses, 86% by number and 79% by weight, was attributed to the recreational fishery.

Introduction

This report summarizes the commercial and recreational striped bass fisheries conducted in Massachusetts during 2014. Data sources used to characterize the state fisheries come from monitoring programs of the Massachusetts Division of Marine Fisheries (*MarineFisheries*, the Division) and National Marine Fisheries Service (NOAA Fisheries), which are considered to be essential elements of the long-term management approach described in Section 3 of the Atlantic States Marine Fisheries Commission's (ASMFC) Fisheries Management Report No. 41 (Amendment #6 to the Interstate Fishery management Plan for Atlantic Striped Bass (IFMP)).

Commercial Fishery in 2014

Season: June 23–September 2, 2014. Landings were permitted on Monday and Thursday only.
Sold: 1,138,507 pounds (against a harvest quota of 1,155,100 pounds).
Allowable Gear Type: Hook and line.
Minimum Size: 34 inches total length.
Trip Limit: 15 fish per day for fishers with a commercial lobster or boat permit and a striped bass endorsement; 2 fish per day for fishers with a commercial individual or rod & reel permit and a striped bass endorsement.

Licensing, Reporting, and Estimation of Landings To purchase striped bass directly from fishermen, fish dealers are required to obtain special authorization from *MarineFisheries* in addition to standard seafood dealer permits. Dealer reporting requirements included weekly reporting to the Division or SAFIS program of all striped bass purchases. If sent to Division, all landings information is entered into SAFIS by Division personnel. Primary buyers of striped bass must affix a valid, *MarineFisherie*s-issued Striped Bass ID Tag to each striped bass at the place of primary purchase and prior to transit.

Following the close of the season, dealers are also required to provide a written transcript consisting of purchase dates, number of fish, pounds of fish, and names and permit numbers of fishermen from whom they purchased. *MarineFisheries* personnel review dealer transactions and correct entries before calculating total landings.

Fishermen must have a *MarineFisheries* commercial fishing permit (of any type) and a special striped bass fishing endorsement to sell their catch. They are required to file monthly trip level reports, which include the name of the dealer(s) that they sell to and information describing their catch composition and catch rates.

Landings The landings used here come from the SAFIS program. Commercial dealers bought 1,138,507 pounds (56,058 fish) of striped bass in 2014 (Table 1). Most striped bass were sold in Barnstable, Bristol, and Essex counties of Massachusetts. Commercial fishers kept approximately an additional 4,560 fish weighing approximately 68,806 pounds for personal consumption.

Size Composition Information from biological sampling, catch reports, and voluntary logs is used to characterize disposition of the catch, catch weight, and size composition by catch category. Data from 3,648 fish sampled from the 2014 commercial harvest and 2000 Division diet study were used to construct a length-weight equation to estimate weight-at-size for individual bass. The following geometric regression was derived:

Table 1. Attributes of the Massachusetts striped bass commercial fishery, 1990-2014.

		Purchased			
Year	Season (Fishing Days)	Pounds 000s	Number 000s	Dealer Permits	Fishing Permits
1990	93	160.6	6.3	95	1,498
1991	59	234.8	10.4	92	1,739
1992	39	239.2	11.3	135	1,861
1993	35	262.6	13.0	152	2,056
1994	24	199.6	10.4	150	2,367
1995	57	782.0	41.2	161	3,353
1996	42	696.8	38.3	179	3,801
1997	42	785.9	44.8	173	5,500
1998	28	822.0	45.3	180	5,540
1999	40	788.2	40.8	167	3,578
2000	36	779.7	40.2	137	3,283
2001	29	815.0	40.2	164	4,219
2002	21	924.9	44.9	132	4,598
2003	21	1,055.4	55.7	151	4,867
2004	19	1,206.3	60.6	130	4,376
2005	22	1,104.7	59.5	162	4,159
2006	26	1,312.1	69.9	136	3,980
2007	22	1,040.3	54.3	160	3,906
2008	34	1,160.1	61.1	167	3,821
2009	27	1,138.3	59.3	178	4,020
2010	24	1,224.4	60.3	178	3,951
2011	18	1,163.8	58.5	189	3,965
2012	17	1,219.7	61.5	186	3,965
2013	16	1,004.5	58.5	187	4,016
2014	21	1,138.5	56.1	189	3,896

$$\log_{10}(W) = -3.455 + 3.001 * \log_{10}(L),$$
$$RMS = 0.0027$$

where *W* equals weight in pounds, *L* equals total length in inches, and *RMS* is the residual mean square error. This equation was used to estimate the arithmetic average weight for a given length by back-transforming the predicted weight as follows:

$$W = 10^{(-3.455 + 3.001 * \log_{10}(L) + RMS/2)}$$

Size composition of the commercial catch by category of disposition is presented in Appendix* Tables A1a (numbers of fish) and A1b (pounds of fish). About 45% of all fish caught had lengths >34 inches.

Age and Sex Composition Eight hundred and four fish were sampled from the 2014 commercial harvest for length, sex, and scale samples. Age composition of harvest fish was estimated from a sub-sample of 587 fish. The age composition of fish released and consumed was estimated from length data reported in commercial angler logs, and an age-length key was developed from samples collected from the recreational fishery. Age was determined from scales and sex was determined by visual inspection of gonadal tissue. Age of harvested fish ranged from 7 to over 22 years, and 99.7% were females. About 76% of the sub-sample consisted of individuals from the 2002–2005 year classes (ages 9–12) (Figure 1). Peak numbers-at-age of the total catches (harvest plus releases plus consumed) were from the 2003 and 2004 year-classes.

Estimates of Total Catch and Harvest Rates Estimates of harvest rates (pounds of fish harvested per hour) for the commercial fishery were developed in order to provide an index that may be indicative of fishing success. In 2011,

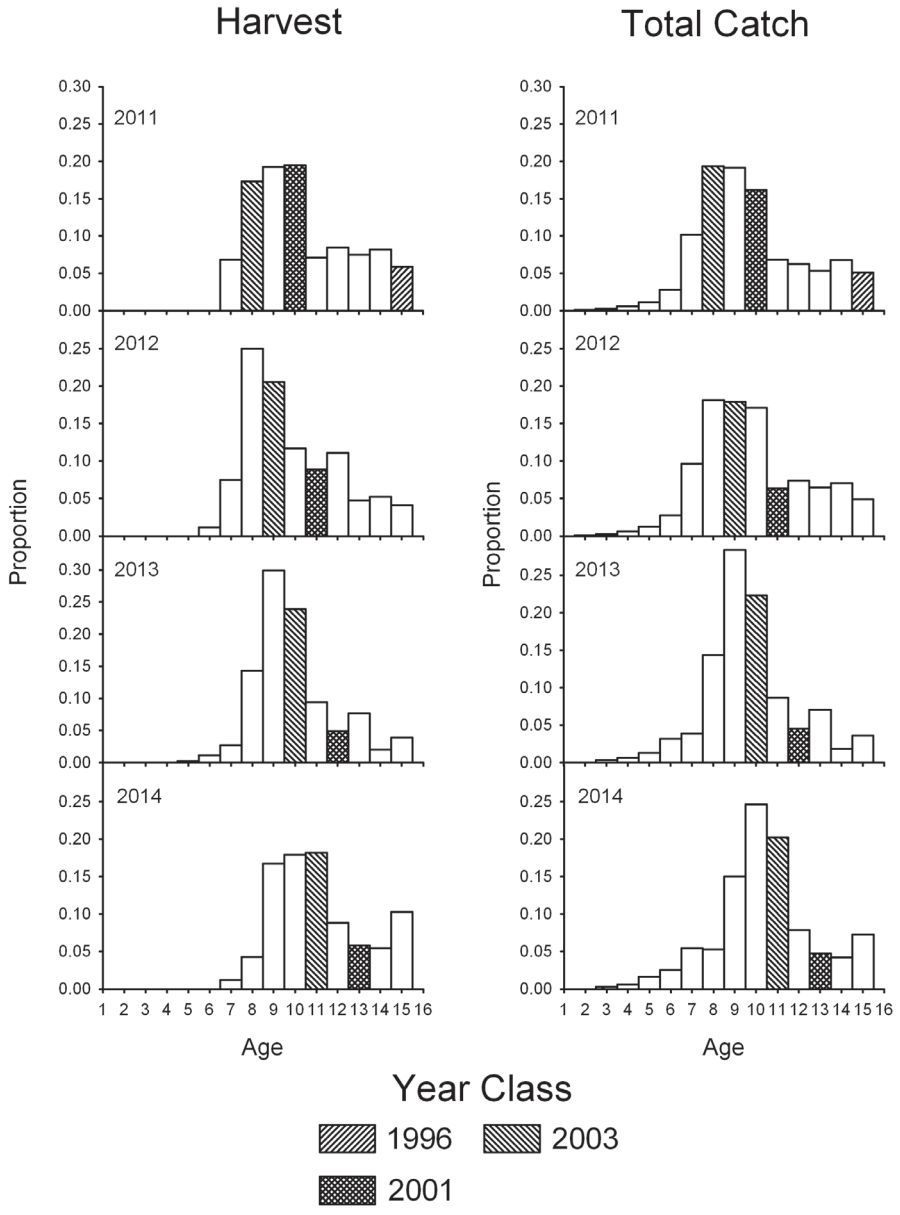

Figure 1. Age composition (proportion) of the harvest and total catches from the Massachusetts commercial fishery. The large 1996, 2001, and 2003 Chesapeake Bay year-classes are highlighted.

*Tables marked with an "A" preceeding the table number can be found in the Appendix.

*MarineFisherie*s switched to trip-level reporting. Significant information has been lost due to the generalization of the report to cover all fisheries in Massachusetts. The only information now available is daily total hours fished, pounds of fish sold and consumed, and area fished. This information was used under a generalized linear model (GLM) framework to generate standardized indices (Hilborn and Walter 1992). Each record represented the summarization of a permit's pounds harvested and hours fished by year, month, and area fished reduced to 4 regions (Cape Cod Canal, Southern Massachusetts, Cape Cod Bay, and Northern Massachusetts). Only data from July and August were used to constrain analyses to the most recent duration of the fishing season. The harvest rates for each record was calculated by dividing the total pounds caught by the total number of hours fished. The harvest rate was standardized using the GLM model

$$\ln(y) = a + \sum_{i=1}^{n} b_i X_i + e$$

where y is the observed total catch or harvest rate, a is the intercept, b_i is the slope coefficient of the ith factor, X_i is the ith categorical variable, and e is the error term. Any variable not significant at $\alpha = 0.05$ with type-II (partial) sum of squares was dropped from the initial GLM model and the analysis was repeated. First-order interactions were not considered in the analyses. The back-transformed geometric mean for each year was estimated by

$$\hat{y} = \exp^{(LSM)}$$

where *LSM* is the least-squares natural log mean of each year.

Results of the GLM analyses of harvest rates are shown in Table A2. Although factors were significant, the variables accounted for only about 10% of the total variation in harvest rates.

Harvest rates steadily increased after 1999, peaked in 2004, dropped through 2008, increased slightly through 2010, then dramatically increased in 2011, remained at high levels in 2012 and dropped through 2014 (Figure 2a). The dramatic increase in harvest rates for 2011 and 2012 is attributed to large increases in harvest rates by fishers working in waters south of Cape Cod (Figure 2b). The reason for the increase was due to atypical, large concentrations of striped bass (likely attracted to large aggregations of sand lance in the area) off Cape Cod—particularly Chatham—in 2011, 2012, and 2013. These large concentrations likely increased the vulnerability of striped bass to capture. In addition, the large 2003 year-class became nearly fully-recruited to the Massachusetts fishery (Figure 1). The drop in harvest rate in 2014 was likely due to the absence of the large aggregations off Chatham and weak year-classes moving through the fishery.

Characterization of Other Losses Release mortality was estimated by using a hook-release mortality rate of 9% applied against the released fish in Tables A1a and b. Total losses due to release mortality were 6,349 fish weighing approximately 59,904 pounds.

Recreational Fishery in 2014

Season: All year
Daily Bag Limit: Two fish per person
Allowable Gear Type: Hook and Line
Minimum Size: 28 inches total length

Licensing and Reporting Requirements: A recreational fishing permit is required in Massachusetts state waters.

Harvest levels: Harvest (A+B1) and total catch (A+B1+B2) estimates (Table 2) were provided by NOAA Fisheries Marine Recreational Information Program (MRIP). In 2011, new estimation methods were applied to data collected since 2004, but only small changes (range: -9.1 to 10.1%) were observed for Massachusetts data.

The MRIP estimate of total catch (including fish released alive) in 2014 was 2,016,595 striped bass, which is a 2.2% increase compared to the 2013 estimate. The estimate of total harvest in 2014 was 253,877 fish, which is a 10% decrease in harvest compared to 2013. Total pounds harvested was over 4.0 million in 2014 (Table 2).

Size Composition The length distributions of harvested and released fish were estimated from biological sampling conducted by the MRIP program in Massachusetts and from the volunteer Sportfish Data Collection Team (SADCT) pro-

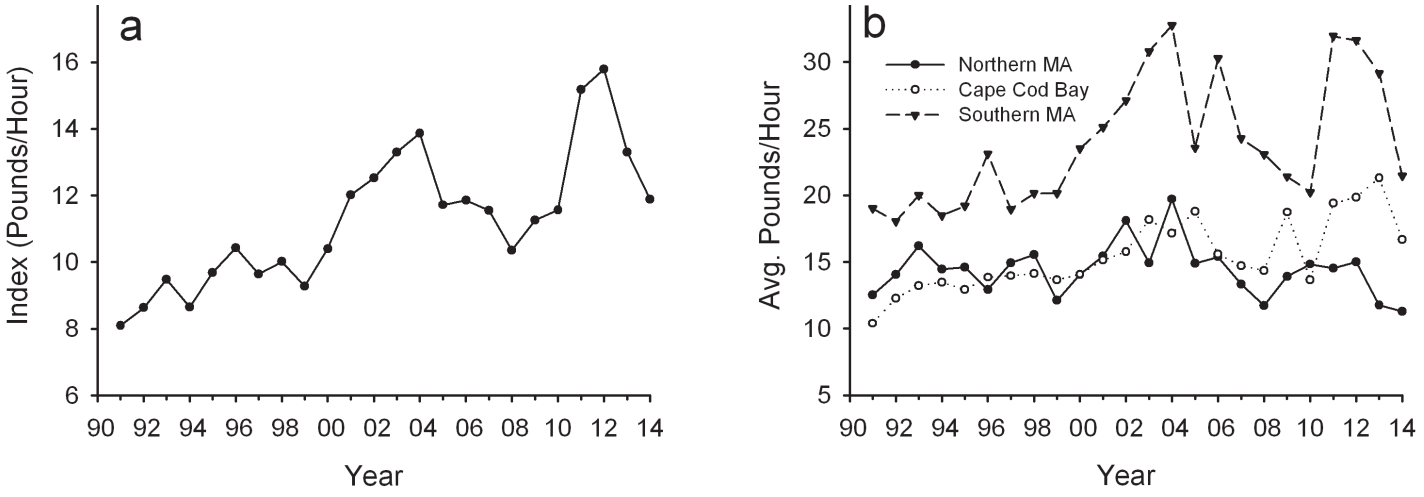

Figure 2. a) Harvest index (stadardized pounds/hour) and b) average harvest rates by area for the Massachusetts commercial striped bass fishery, 1990-2014.

Table 2. MRIP estimates of striped bass harvest, release, and total catch in Massachusetts.

Year	Harvest (A + B1) Numbers	Harvest (A + B1) Weight (lb.)	Released (B2) Numbers	Total (A + B1 + B2) Numbers
1986	29,434	298,816	442,298	471,732
1987	10,807	269,459	93,660	104,467
1988	21,050	421,317	209,632	230,682
1989	13,044	295,227	193,067	206,111
1990	20,515	319,092	339,511	360,026
1991	20,799	440,605	448,735	469,534
1992	57,084	972,116	779,814	836,898
1993	58,511	1,113,446	833,566	892,077
1994	74,538	1,686,049	2,102,514	2,177,052
1995	73,806	1,504,390	3,280,882	3,354,688
1996	68,300	1,291,706	3,269,746	3,338,046
1997	199,373	2,891,970	5,417,751	5,617,124
1998	207,952	2,973,456	7,184,358	7,392,310
1999	126,755	1,822,818	4,576,208	4,702,963
2000	181,295	2,618,216	7,382,031	7,563,326
2001	288,032	3,644,561	5,410,899	5,698,930
2002	308,749	4,304,883	5,718,984	6,027,733
2003	407,100	4,889,035	4,361,710	4,768,810
2004	445,745	6,235,558	4,979,075	5,424,820
2005	340,742	5,119,345	3,988,679	4,329,421
2006	314,988	4,861,391	7,809,777	8,124,765
2007	315,409	5,099,862	5,331,470	5,646,879
2008	377,959	5,720,651	3,649,415	4,027,374
2009	344,401	4,795,791	2,282,601	2,627,002
2010	341,046	4,277,990	1,671,437	2,012,483
2011	255,507	3,504,603	973,192	1,228,699
2012	377,931	5,441,893	989,509	1,367,440
2013	282,179	3,899,919	1,690,888	1,973,058
2014	253,877	4,056,799	1,762,718	2,016,595

gram conducted by the Division. Volunteer recreational anglers were solicited to collect length and scale samples from striped bass that they captured each month (May-October). Each person was asked to collect a minimum of 5 scales from at least 10 fish per month and record the disposition of each fish (released or harvested) and fishing mode. Over 1,300 samples were received from 41 anglers. The size frequencies of measured fish are shown in Figure 3 by disposition and mode. The size frequency of released fishes was used to allocate MRIP release numbers by mode among size classes. Numbers-at-length and weight-at-length data by disposition are summarized in Tables A3a,b.

Age Composition A sub-sample of 477 fish from the SADCT was aged and combined with commercial and tagging samples to produce an age-length key used to convert MRIP and Massachusetts SADCT size distributions into age classes. Recreational samples were selected using a weighted random design based on the total number of striped bass caught in each wave and mode stratum (as determined by MRIP). Recreational harvest and total catches in 2014 catches of striped bass were comprised mostly of the 2003, 2004, 2007, and 2011 year-classes (Figure 4).

Trends in Catch Rates To examine trends in recreational angler catches, standardized catch rates (total number of fish per trip) for striped bass were calculated for all fish caught using a delta-Gamma model (Lo et al. 1992; Stefans-

son 1996) which adjusts trip catches for the effects of year, wave, county, area fished, mode fished, and time spent fishing. A delta-Gamma model was selected as the best approach to estimate year effects after examination of model dispersion (Terceiro 2003) and standardized residual deviance plots (McCullagh and Nelder 1989). In the delta-Gamma model, catch data is decomposed into catch success/failure and positive catch components. Each component is analyzed separately using appropriate statistical techniques. Statistical models are then recombined to obtain year estimates. The catch success/failure was modeled as a binary response to the categorical variables using multiple logistic regression:

$$\text{logit}(p) = \log(p/1-p) = a + \sum_{t=1}^{n} b_t X_t + e$$

where p is the probability of catching a fish, a is the intercept, b_t is the slope coefficient of the tth factor, X_t is the tth categorical variable, and e is the error term. The function *glm* in R was used to estimate parameters, and goodness-of-fit was assessed using partial and empirical probability plots.

Positive catches were modeled assuming a Gamma error distribution with a log link using function *glm* in R:

$$y = \exp^{(a + \sum b_i X_i)}$$

where y is the observed positive catch, b_t and X_t are the same symbols as defined earlier, B is the number of covariates, and e is the Gamma error term. Any variable not significant at α=0.05 dropped from the initial GLM model and the analysis was repeated. First-order interactions were considered in the initial analyses, but it was not always possible to generate annual means by the least-square methods with some interactions included (see Searle et al. 1980); therefore, only main effects were considered.

The annual index of striped bass total catch per trip was estimated by combining the two component models. The estimate in year i from the models is given by

$$\hat{I}_i = \hat{p}_i * \hat{y}_i$$

where p_i and y_i are the predicted annual least-squares responses from the logistic and GLM models. Only data for those anglers who said they targeted striped bass were used in the analyses.

Results of the delta-Gamma model analyses are given in Tables A4a,b for 1986–2013. Standardized catch rates for striped bass in Massachusetts waters increased from 1993 to 1998, declined through 2003, but increased again in 2004 and 2005 (Figure 5). In 2006, catch rates jumped dramatically as the large 2003 year-class became vulnerable to the

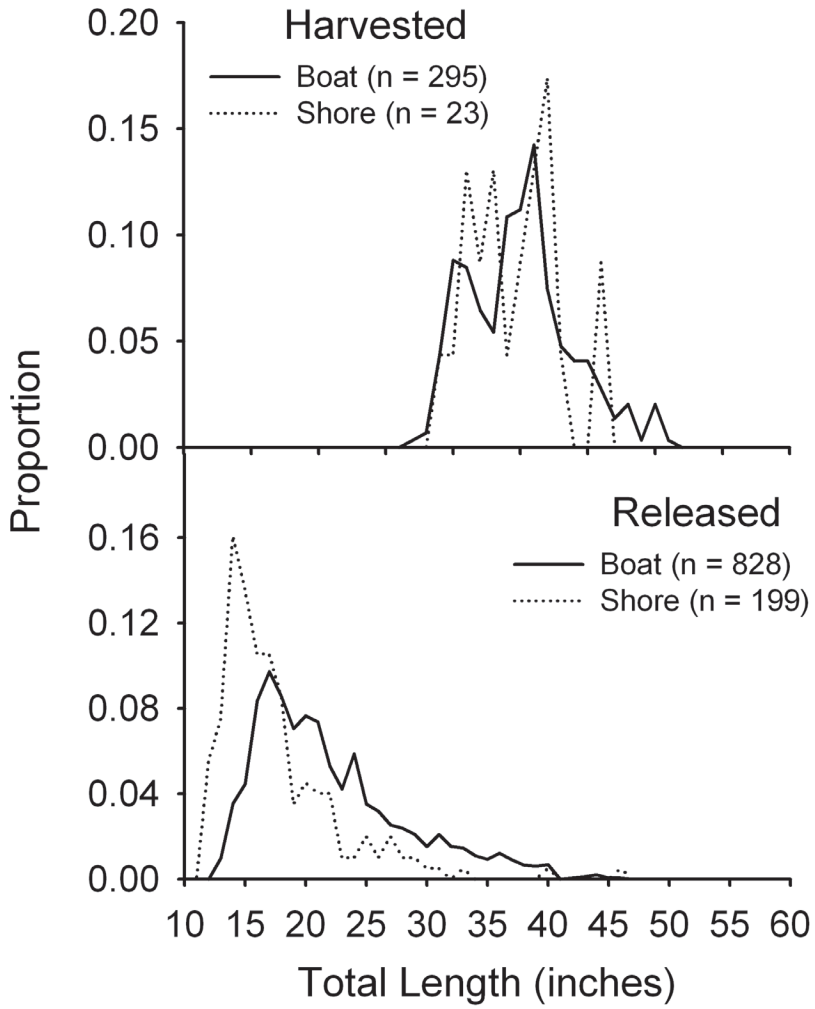

Figure 3. Sizes of striped bass caught by volunteer recreational anglers in 2014 by disposition and fishing mode.

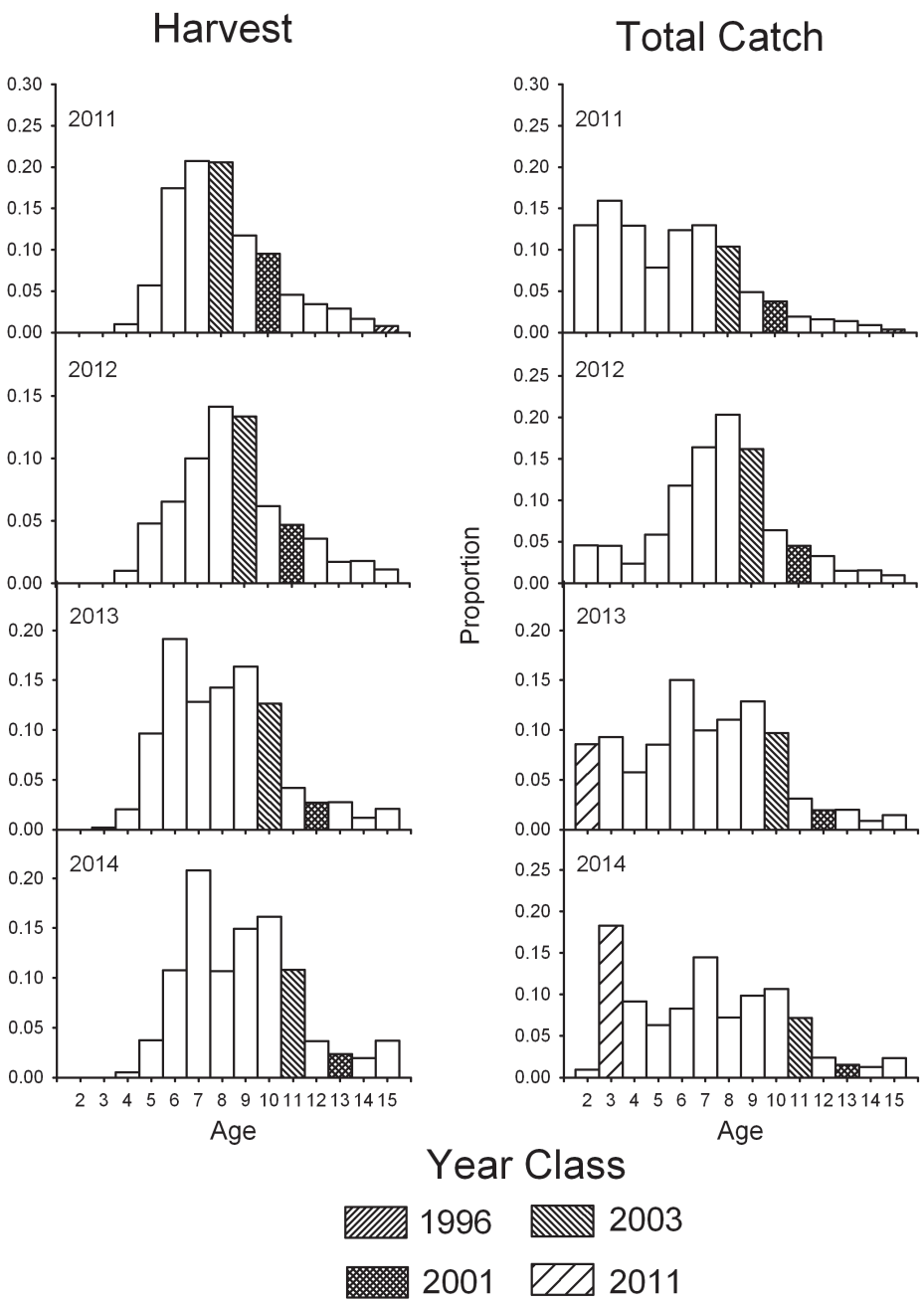

Figure 4. Age composition (proportion) of harvest and total catches from the Massachusetts recreational fishery. The large 1996, 2001, 2003, and 2011 Chesapeake Bay year-classes are highlighted.

fishery. Catch rates declined through 2011, but began increasing in 2012 as the 2011 year-class became vulnerable to the fishery (Figure 5).

Characterization of Losses

The same methods and rates previously described in the commercial fishery section were used to estimate recreational losses. Losses due to hook-and-release were 158,645 fish (748,248 pounds) (Table 3).

Bycatch in Other Fisheries

During 1994, *MarineFisheries* sea-sampling efforts identified striped bass as by-catch in a Nantucket Sound springtime trawl fishery directed at long-finned squid (*Loligo pealei*). The bycatch estimate was about 3,100 fish (17,600 pounds). Anecdotal information reported also suggested that a single tow could land up to 19,000 pounds. Division personnel sampled this fishery at sea during 1995–2000 and observed only incidental catches of striped bass. Limited sampling and low catch rates make it unreasonable to extrapolate sample information. MarineFisheries will continue to monitor potential sources of striped bass by-catch during 2015.

Estimated Total Losses in 2014

Combined losses were 479,489 fish weighing over 6.0 million pounds, which reflects a 4% decrease in numbers and a 3% increase in weight compared to 2013 (502,522 fish; 5.9 million pounds). The majority of losses, 86% by number and 79% by weight, was attributed to the recreational fishery.

Removals-At-Age Matrix in 2014

The removals (numbers) due to release mortality and harvest by the recreational and commercial fisheries are ap-

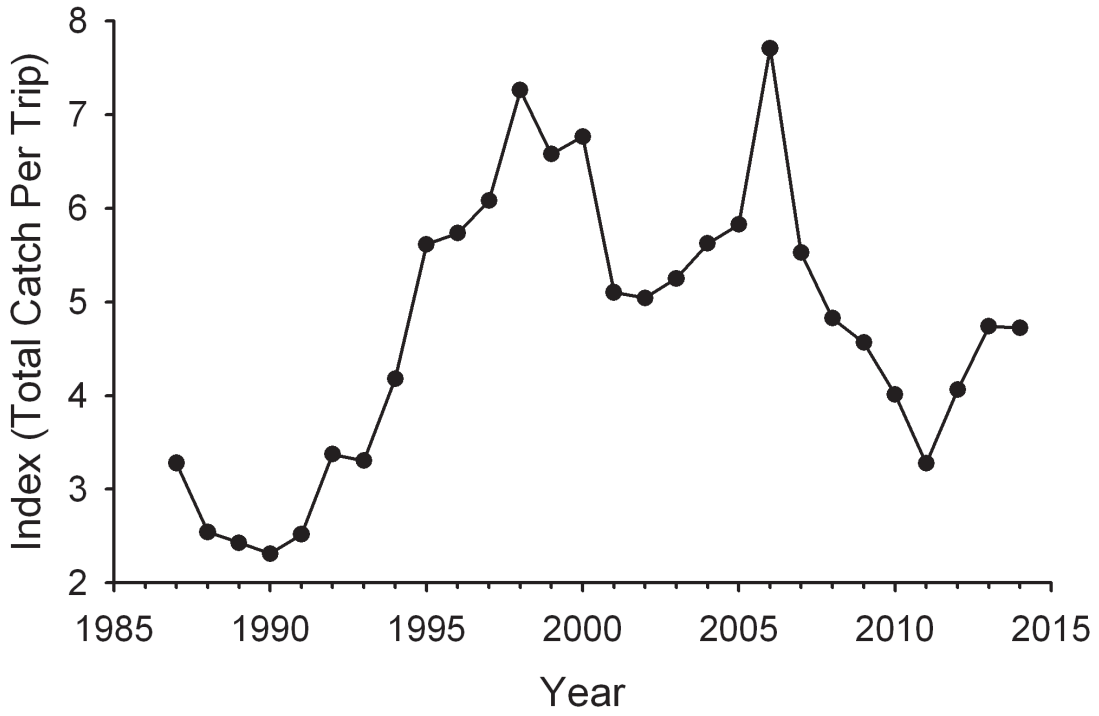

Figure 5. Standardized total catch rates (total number of fish caught per trip) of the recreational fishery for striped bass in Massachusetts waters, 1987-2014.

portioned by age and mortality source in Table 4. The 2011 (age 3), 2007 (age 7), 2004 (age 10), and 2003 (age 11) year-classes incurred the highest losses in 2014 (Figure 6).

Age-Length Relationship

A von Bertalanffy growth model was fitted to age (years) and total length (inches) data from samples collected in the tagging study, the recreational fishery, and commercial fishery from 2014. The resulting equation and predicted relationship are shown in Figure 7.

Required Fishery-Independent Monitoring Programs

Massachusetts Tagging Study

MarineFisheries joined the state-federal coast-wide Cooperative Striped Bass Tagging Study in 1991. The study's primary objective has been to develop an integrated database of tag releases and recoveries that will provide current information related to striped bass mortality and migration rates. The Massachusetts tagging effort has focused on the tag and release of large fish that reach coast-wide legal sizes. To accomplish this job, *MarineFisheries* contracts several select charter boat captains to take Division personnel on board to tag and release their catch during regularly scheduled fishing trips. Fish are caught in fall by trolling artificial baits in shoal areas around Nantucket Island (Figure 8). Floy internal anchor tags provided by the U.S. Fish and Wildlife Service (USFWS) are used. Total length of each fish is recorded. Scales are removed from each fish for aging. The release data are made available to the Annapolis, Maryland office of the USFWS, which coordinates regional tagging programs of state-federal participants.

Summary statistics compiled since the start of this study are shown in Table 5. Striped bass in2011–2014 were recovered from coastal waters in North Carolina through Maine (Figure 9).

Table 3. Estimates of striped bass losses occurring in Massachusetts waters during 2013.

FISHERY	NUMBER	POUNDS	MEAN WEIGHT
Commercial			
Harvest*	60,619	1,207,313	19.9
Release Mortality	6,349	59,904	9.4
Recreational			
Harvest	253,877	4,056,799	16.0
Release Mortality	158,645	748,248	4.7
Total	**479,489**	**6,072,264**	

*includes fish taken for personal consumption

Table 4. Massachusetts striped bass removals-at-age matrix of 2014 by source.

	Recreational		Commercial		
Age	**Release Mortality**	**Harvest**	**Release Mortality**	**Harvest***	**Total**
2	3,899	0	7	0	3,905
3	75,425	0	210	0	75,635
4	36,378	1,351	412	0	38,141
5	16,655	9,453	966	142	27,216
6	6,985	27,303	1,261	440	35,989
7	7,003	52,762	1,998	1,670	63,434
8	2,674	27,157	653	2,909	33,393
9	2,932	37,885	439	9,631	50,887
10	3,049	40,920	249	16,262	60,481
11	2,050	27,441	150	13,407	43,049
12	661	9,264	3	5,281	15,209
13	307	6,000	0	3,202	9,509
14	218	4,976	0	2,809	8,004
15	197	4,157	0	2,577	6,931
16 and over	212	5,207	0	2,289	7,708

*includes fish taken for personal consumption

Planned Management Programs in 2015

Regulations

Massachusetts' recreational bag limit will be reduced to 1 fish per day and the minimum size limit will remain at 28 inches total length, respectively. For the commercial fishery, minimum size limit will remain at 34 inches and the quota will be 869,813 pounds due to the recent conservation measures passed by the ASMFC management board. The commercial fishery quota will be monitored using SAFIS. The commercial season will not open until June 24, 2015. Harvesting will be allowed only on Monday and Thursday with a daily bag limit of 2 fish for those with rod-reel or individual permits, or 15 fish for those with boat permits.

Monitoring Programs

All monitoring programs will continue in 2015.

Acknowledgements

The collection and quality of striped bass data would suffer greatly without the efforts of many Division employees. Staff of the Fisheries Statistics section collected, entered, and compiled all commercial data. Erich Druskat provided the summarized data. Jennifer Stritzel-Thomson and Kim Trull coordinated the SADCT program. Whitney Sargent entered the SADCT data. Scott Elzey, Elise Koob, Collin Farrell, and Kim Trull prepared scale samples. John Boardman aged all scale samples. John Boardman, Nick Buchan, and

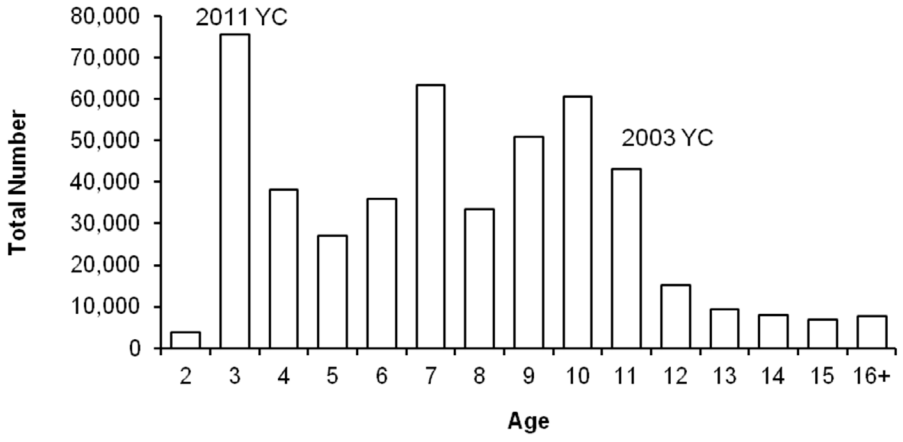

Figure 6. Total number of striped bass removals in 2014 by age. The 2003 and 2011 year-classes are indicated.

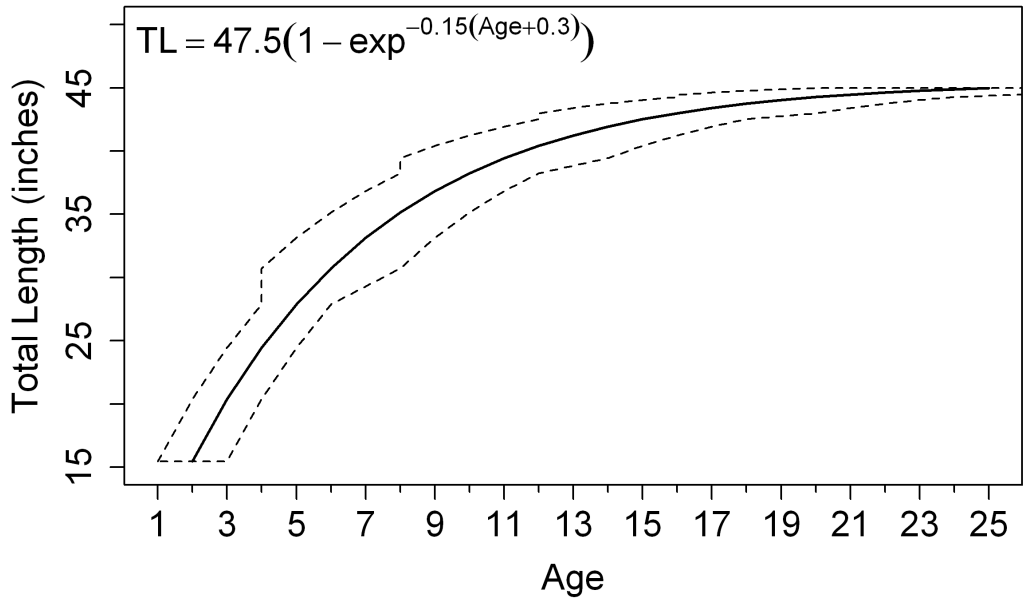

Figure 7. Mean length-age (in years) relationship (solid line) for striped bass captured in Massachusetts during 2014. Dotted lines represent the minimum and maximum ages found at a given length.

Table 5. Massachusetts tag summary statistics. SD = standard deviation.

Year	Trips	Boats	Number Tagged	Average Length (mm)	Average Length (in.)	SD (mm)	SD (in.)	Length Range			
								Minimum (mm)	Minimum (in.)	Maximum (mm)	Maximum (in.)
1991	17	4	388	817	32.2	106.4	4.2	534	21.0	1,300	51.2
1992	29	3	899	798	31.4	125.9	5.0	524	20.6	1,267	49.9
1993	15	2	678	784	30.9	125.0	4.9	515	20.3	1,210	47.6
1994	13	2	377	735	28.9	93.2	3.7	548	21.6	1,028	40.5
1995	11	2	449	767	30.2	110.2	4.3	470	18.5	1,178	46.4
1996	8	2	203	748	29.4	64.1	2.5	541	21.3	1,077	42.4
1997	10	2	321	773	30.4	114.7	4.5	485	19.1	1,090	42.9
1998	12	2	382	797	31.4	93.8	3.7	597	23.5	1,055	41.5
1999	16	2	471	777	30.6	95.5	3.8	594	23.4	1,108	43.6
2000	25	4	1,095	752	29.6	102.6	4.0	510	20.1	1,204	47.4
2001	14	3	456	786	30.9	102.5	4.0	503	19.8	1,110	43.7
2002	12	3	239	764	30.1	103.6	4.1	487	19.2	1,060	41.7
2003	15	3	655	825	32.5	92.1	3.6	602	23.7	1,204	47.4
2004	25	7	784	707	27.8	193.1	7.6	316	12.4	1,164	45.8
2005	19	4	752	726	28.6	210.5	8.3	299	11.8	1,114	43.9
2006	11	4	390	813	32.0	94.2	3.7	565	22.2	1,114	43.9
2007	16	3	530	848	33.4	105.2	4.1	600	23.6	1,225	48.2
2008	13	2	456	821	32.3	104.6	4.1	530	20.9	1,202	47.3
2009	15	3	501	840	33.1	101.8	4.0	572	22.5	1,146	45.1
2010	13	3	329	825	32.5	84.0	3.3	668	26.3	1,095	43.1
2011	15	3	504	831	32.7	91.9	3.6	580	22.8	1,174	46.2
2012	15	3	643	852	33.5	87.7	3.5	524	20.6	1,203	47.4
2013	15	3	487	854	33.6	92.2	3.63	617	24.3	1,145	45.1
2014	15	3	455	876	34.5	98.9	3.89	536	21.1	1,203	47.4

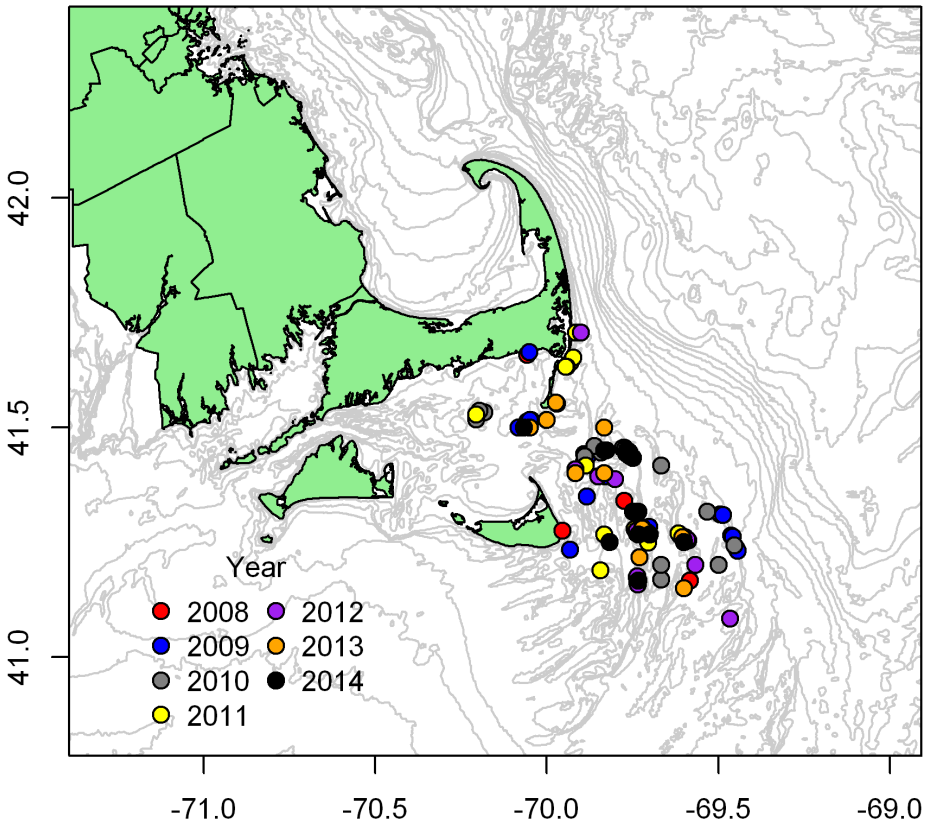

Figure 8. Map of *MarineFisheries* fall tagging locations during 2008–2014.

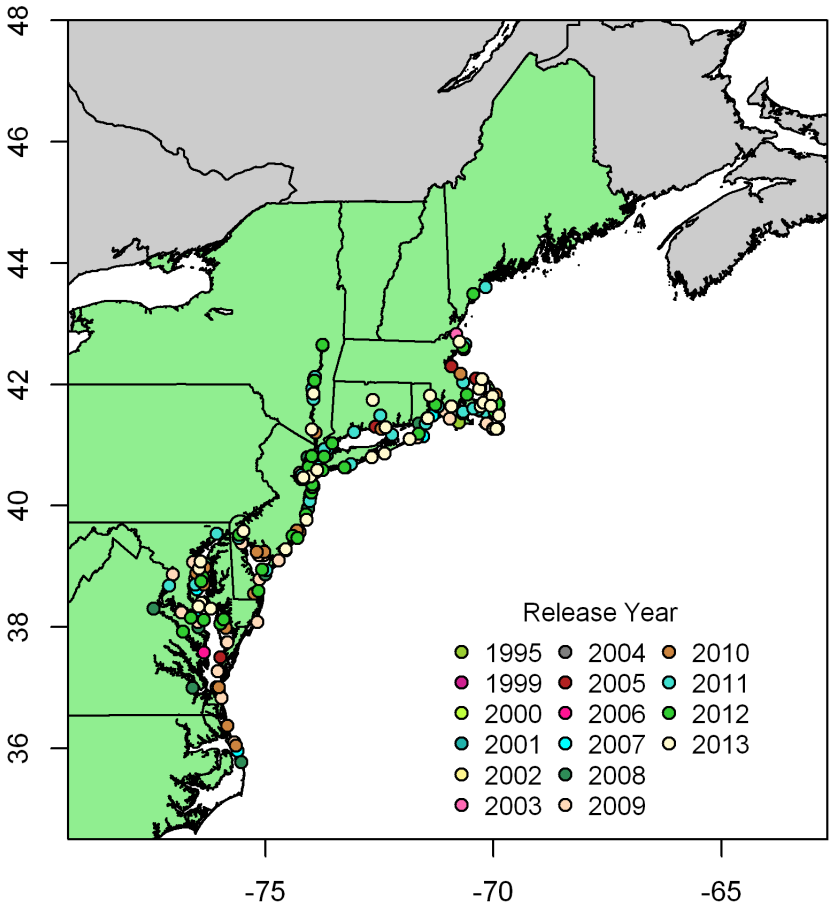

Figure 9. Map of recovery locations, 2011–2014, of *MarineFisheries* tagged striped bass by release year.

Brad Schondelmeier conducted the commercial sampling of stripers. Paul Caruso and John Boardman also coordinated and conducted the USFWS cooperative tagging study. Funding for this effort was provided by the Massachusetts Division of Marine Fisheries and Sportfish Restoration Funds Grants F-57-R and F-48-R.

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Appendix

Table A1a. Estimated size distribution of the Massachusetts commercial striped bass catch (numbers of fish) in 2014.

TL (in.)	Harvested*	Released	Total	Percent	Cumulative Percent
11	0	0	0	0.00	0.00
12	0	0	0	0.00	0.00
13	0	0	0	0.00	0.00
14	0	153	153	0.12	0.12
15	0	51	51	0.04	0.16
16	0	409	409	0.31	0.47
17	0	613	613	0.47	0.93
18	0	306	306	0.23	1.17
19	0	511	511	0.39	1.56
20	0	868	868	0.66	2.22
21	0	306	306	0.23	2.45
22	0	817	817	0.62	3.08
23	0	409	409	0.31	3.39
24	0	3,116	3,116	2.38	5.76
25	0	1,635	1,635	1.25	7.01
26	0	2,758	2,758	2.10	9.11
27	0	4.035	4,035	3.08	12.19
28	158	7,304	7,462	5.69	17.88
29	290	5,159	5,449	4.15	22.03
30	343	9,245	9,588	7.31	29.34
31	316	8,785	9,102	6.94	36.28
32	544	14,149	14,693	11.20	47.49
33	1,138	7,560	8,698	6.63	54.12
34	4,356	1,430	5,786	4.41	58.53
35	6,817	51	6,868	5.24	63.76
36	8,347	817	9,164	6.99	70.75
37	8,223	0	8,223	6.27	77.02
38	6,851	51	6,902	5.26	82.28
39	6,056	0	6,056	4.62	86.90
40	4,483	0	4,483	3.42	90.32
41	2,665	0	2,665	2.03	92.35
42	2,246	0	2,246	1.71	94.06
43	2,622	0	2,622	2.00	96.06
44	2,036	0	2,036	1.55	97.61
45	3,128	0	3,128	2.39	100.00
Total	**60,619**	**70,539**	**131,158**		
Average Size	**38.0**	**29.4**	**33.3**		

*includes fish taken for personal consumption

Table A1b. Estimated weight distribution by size of the Massachusetts commercial striped bass catch (pounds) in 2014.

TL (in.)	Harvested*	Released	Total	Percent	Cumulative Percent
11	0	0	0	0.00	0.00
12	0	0	0	0.00	0.00
13	0	0	0	0.00	0.00
14	0	149	149	0.01	0.01
15	0	61	61	0.00	0.01
16	0	594	594	0.03	0.04
17	0	1,070	1,070	0.06	0.10
18	0	635	635	0.03	0.13
19	0	1,244	1,244	0.07	0.20
20	0	2,468	2,468	0.13	0.33
21	0	1,008	1,008	0.05	0.39
22	0	3,091	3,091	0.17	0.55
23	0	1,766	1,766	0.09	0.65
24	0	15,303	15,303	0.82	1.47
25	0	9,074	9,074	0.49	1.95
26	0	17,225	17,225	0.92	2.87
27	0	28,222	28,222	1.51	4.38
28	1,234	56,976	58,210	3.11	7.50
29	2,513	44,711	47,224	2.53	10.02
30	3,288	88,707	91,995	4.92	14.94
31	3,349	93,013	96,362	5.16	20.10
32	6,340	164,768	171,108	9.15	29.95
33	14,534	96,552	111,086	5.94	35.20
34	60,845	19,979	80,823	4.32	39.52
35	103,881	778	104,659	5.60	45.12
36	138,414	13,553	151,966	8.13	53.25
37	148,046	0	148,046	7.92	61.17
38	133.629	996	134,626	7.20	68.37
39	127,695	0	127,695	6.83	75.20
40	101,982	0	101,982	5.46	80.66
41	65,301	0	65,301	3.49	84.15
42	59,152	0	59,152	3.16	87.32
43	74,103	0	74,103	3.96	91.28
44	61,664	0	61,664	3.30	94.58
45	101,343	0	101,343	5.42	100.00
Total	**1,207,313**	**661,945**	**1,869,259**		
Average Weight	**19.9**	**9.4**	**14.3**		

*includes fish taken for personal consumption

Table A2. Results of the GLM analyses of total catch rates (pounds/hour) for the commercial striped bass fishery, 1991–2014. Analysis of Deviance Table (Type III tests).

Reponse: Pounds/Hour

	SS	Df	F	Pr(>F)	
YEAR	1419	23	0.759	<2.20e-16	***
AREA	2489	2	1225.146	<2.20e-16	***
Residuals	57386	56498			

Coefficients:

	Estimate	SE	t	Pr(>|t|)	
(Intercept)	1.93230	0.02615	73.900	<2.00eE-16	***
YEAR1992	0.06418	0.03522	1.822	0.0684	.
YEAR1993	0.15758	0.03508	4.492	7.08eE-06	***
YEAR1994	0.06597	0.03502	1.884	0.0596	.
YEAR1995	0.17934	0.03131	5.728	1.02e-08	***
YEAR1996	0.25350	0.05098	4.973	6.62e-07	***
YEAR1997	0.17485	0.03029	5.773	7.85e-08	***
YEAR1998	0.21303	0.03088	6.900	5.27e-12	***
YEAR1999	0.13649	0.03155	4.326	1.52e-05	***
YEAR2000	0.25033	0.03207	7.805	6.06e-15	***
YEAR2001	0.39528	0.03214	12.299	<2.00e-16	***
YEAR2002	0.43604	0.03163	13.784	<2.00e-16	***
YEAR2003	0.49623	0.02921	16.990	<2.00e-16	***
YEAR2004	0.53794	0.03526	15.258	<2.00e-16	***
YEAR2005	0.36973	0.03193	11.581	<2.00e-16	***
YEAR2006	0.38168	0.03018	12.645	<2.00e-16	***
YEAR2007	0.35532	0.03065	11.591	<2.00e-16	***
YEAR2008	0.24609	0.03063	8.035	9.51e-16	***
YEAR2009	0.33017	0.03038	10.868	<2.00e-16	***
YEAR2010	0.35724	0.03254	10.978	<2.00e-16	***
YEAR2011	0.62838	0.03659	17.172	<2.00e-16	***
YEAR2012	0.66812	0.03309	20.191	<2.00e-16	***
YEAR2013	0.49651	0.03383	14.675	<2.00e-16	***
YEAR2014	0.38444	0.03235	11.884	<2.00e-16	***
AREACCB	0.03307	0.01255	2.636	0.0084	**
AREASMA	0.44333	0.01114	39.782	<2.00e-16	***

Table A3a. Estimated size distribution of the Massachusetts recreational striped bass catch (numbers of fish) in 2014.

TL (in.)	Harvested	Released	Total	Percent	Cumulative Percent
9	0	0	0	0.00	0.00
10	0	0	0	0.00	0.00
11	0	0	0	0.00	0.00
12	0	13,842	13,842	0.69	0.69
13	0	33,809	33,809	1.68	2.36
14	0	93,777	93,777	4.65	7.01
15	0	101,289	101,289	5.02	12.04
16	0	152,878	152,878	7.58	19.62
17	0	173,361	173,361	8.60	28.21
18	0	150,705	150,705	7.47	35.69
19	0	115,497	115,497	5.73	41.41
20	0	127,220	127,220	6.31	47.72
21	0	121,470	121,470	6.02	53.75
22	0	90,048	90,048	4.47	58.21
23	0	66,557	66,557	3.30	61.51
24	161	91,272	91,433	4.53	66.05
25	2,846	58,197	61,043	3.03	69.07
26	0	50,739	50,739	2.52	71.59
27	833	43,375	44,208	2.19	73.78
28	5,992	38,605	44,597	2.21	75.99
29	17,623	34,412	52,035	2.58	78.57
30	23,682	23.235	46,917	2.33	80.94
31	23,340	32,767	56,107	2.78	83.72
32	17,661	23,295	40,956	2.03	85.75
33	23,682	23,235	46,917	2.33	88.08
34	22,994	16,577	39,571	1.96	90.04
35	22,565	13,975	36,540	1.81	91.85
36	22,563	18,243	40,806	2.02	93.87
37	15,384	13,839	29,223	1.45	95.32
38	13,598	10,143	23,741	1.18	96.50
39	6,770	9,147	15,917	0.79	97.29
40	9,776	11,575	21,351	1.06	98.35
41	6,041	0	6,041	0.30	98.65
42	4,958	784	5,742	0.28	98.93
43	2,319	1,568	3,887	0.19	99.12
44	3,299	3,136	6,435	0.32	99.44
45	3,224	784	4,008	0.20	99.64
46	387	2,042	2,429	0.12	99.76
47	576	0	576	0.03	99.79
48	0	0	0	0.00	99.79
49	3,496	0	3,496	0.17	99.96
50	0	0	0	0.00	99.96
51	0	0	0	0.00	99.96
52	716	0	716	0.04	100.00
53	0	0	0	0.00	100.00
54	0	0	0	0.00	100.00
55	0	0	0	0.00	100.00
56	0	0	0	0.00	100.00
Total	**253,878**	**1,762,718**	**2,016,596**		
Average Size	**34.5**	**21.3**	**23.0**		

Table A3b. Estimated size distribution of the Massachusetts recreational striped bass catch (pounds) in 2014.

TL (in.)	Harvested	Released	Total	Percent	Cumulative Percent
9	0	0	0		
10	0	0	0	0.00	0.00
11	0	0	0	0.00	0.00
12	0	8,812	8,812	0.07	0.07
13	0	27,369	27,369	0.23	0.30
14	0	94,821	94,821	0.78	1.08
15	0	125,977	125,977	1.04	2.11
16	0	230,777	230,777	1.90	4.01
17	0	313,916	313,916	2.58	6.60
18	0	323,957	323,957	2.67	9.26
19	0	292,011	292,011	2.40	11.66
20	0	375,178	375,178	3.09	14.75
21	0	414,707	414,707	3.41	18.16
22	0	353,492	353,492	2.91	21.07
23	0	298,562	298,562	2.46	23.53
24	819	465,210	466,029	3.83	27.36
25	16,389	335,288	351,677	2.89	30.25
26	0	328,835	328,835	2.71	32.96
27	6,045	314,821	320,867	2.64	35.60
28	48,492	312,513	361,005	2.97	38.57
29	158,459	309,507	467,966	3.85	42.42
30	229,697	244,485	474,182	3.90	46.32
31	256,368	360,015	616,383	5.07	51.39
32	213,373	281,531	494,904	4.07	55.46
33	313,801	307,973	621,774	5.12	60.58
34	333,241	240,317	573,558	4.72	65.30
35	356,755	221,010	577,765	4.75	70.05
36	388,191	313,959	702,150	5.78	75.83
37	287,357	258,578	545,935	4.49	80.32
38	275,158	205,311	480,469	3.95	84.27
39	148,091	200,161	348,252	2.87	87.14
40	230,747	273,288	504,034	4.15	91.28
41	153,554	0	153,554	1.26	92.55
42	135,461	21.429	156,890	1.29	93.84
43	68,016	45,994	114,010	0.94	94.78
44	103,658	98,559	202,218	1.66	96.44
45	108,347	26,359	134,706	1.11	97.55
46	13,879	73,335	87,214	0.72	98.26
47	22,052	0	22,052	0.18	98.45
48	0	0	0	0.00	99.69
49	151,721	0	151,721	1.25	99.69
50	0	0	0	0.00	100.00
51	0	0	0	0.00	100.00
52	37,128	0	37,128	0.31	100.00
53	0	0	0	0.00	100.00
54	0	0	0	0.00	100.00
55	0	0	0	0.00	100.00
56	0	0	0	0.00	100.00
Total	**4,056,799**	**8,098,058**	**12,154,857**		
Average Weight	**16.0**	**4.6**	**6.0**		

Table A4a. Results of the Gamma regression analysis of MRFSS striped bass catch positive checks. Analysis of Deviance Table (Type III tests).

Response: tot_fish

	LR Chisq	Df	Pr(>Chisq)	
year	516.71	27	< 2.2e-16	***
area_x	45.78	2	1.147e-10	***
mode_fx	457.77	2	< 2.2e-16	***
wave	361.76	3	< 2.2e-16	***
cnty	124.44	7	< 2.2e-16	***
ffdays12c	633.49	12	< 2.2e-16	***
hours	1019.48	11	< 2.2e-16	***

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.303370	0.230672	1.315	0.188470	
year1988	-0.181857	0.255272	-0.712	0.476221	
year1989	-0.251795	0.248870	-1.012	0.311666	
year1990	-0.244707	0.239850	-1.020	0.307620	
year1991	-0.104308	0.239247	-0.436	0.662985	
year1992	0.102215	0.232605	0.439	0.660350	
year1993	-0.057871	0.231736	-0.250	0.802800	
year1994	0.015863	0.229267	0.069	0.944838	
year1995	0.236861	0.228503	1.037	0.299942	
year1996	0.248238	0.228778	1.085	0.277905	
year1997	0.311809	0.228270	1.366	0.171963	
year1998	0.398271	0.227821	1.748	0.080446	.
year1999	0.342344	0.228092	1.501	0.133395	
year2000	0.386899	0.228516	1.693	0.090451	.
year2001	0.147935	0.228311	0.648	0.517021	
year2002	0.125360	0.228816	0.548	0.58790	
year2003	0.190011	0.228779	0.831	0.406240	
year2004	0.240286	0.229374	1.048	0.294845	
year2005	0.250818	0.229653	1.092	0.274773	
year2006	0.482476	0.228743	2.109	0.034934	*
year2007	0.213069	0.229327	0.929	0.352844	
year2008	0.118980	0.230643	0.516	0.605957	
year2009	0.75997	0.230156	0.330	0.741253	
year2010	0.13029	0.231488	0.056	0.955115	
year2011	-0.148042	0.232318	-0.637	0.523976	
year2012	-0.144397	0.232600	-0.621	0.534739	
year2013	-0.073918	0.229513	-0.322	0.747407	
year2014	-0.016028	0.230839	-0.069	0.944645	
area_x2	-0.045818	0.025583	-1.791	0.073317	.
area_x5	0.094942	0.017627	5.386	7.27e-08	***
mode_fx6	0.354270	0.033342	10.625	<2e-16	***
mode_fx7	0.497365	0.022281	22.322	<2e-16	***
wave4	-0.299167	0.017026	-17.571	<2e-16	***
wave5	-0.180747	0.021598	-8.369	<2e-16	***

Table A4a continued.

						Year	LSMeans
wave6	1.216784	0.230030	5.290	1.24e-07	***	1987	5.754
cnty19	-0.111916	0.069411	-1.612	0.106898		1988	4.797
cnty21	-0.007236	0.041254	-0.175	0.860757		1989	4.473
cnty23	-0.031969	0.025530	-1.252	0.210509		1990	4.505
cnty25	-0.316704	0.061835	-5.122	3.05e-07	***	1991	5.184
cnty5	-0.124524	0.037237	-3.344	0.000827	***	1992	6.373
cnty7	-0.301171	0.048459	-6.215	5.22e-10	***	1993	5.430
cnty9	0.098442	0.019573	5.030	4.95e-07	***	1994	5.846
ffdays12c10	0.058098	0.024232	2.398	0.016513	*	1995	7.291
ffdays12c20	0.192345	0.024747	7.772	8.01e-15	***	1996	7.375
ffdays12c30	0.200039	0.028668	6.978	3.08e-12	***	1997	8.569
ffdays12c40	0.341172	0.035071	9.728	<2e-16	***	1998	8.103
ffdays12c50	0.379940	0.030840	12.320	<2e-16	***	1999	8.472
ffdays12c60	0.411124	0.042422	9.691	<2e-16	***	2000	6.671
ffdays12c70	0.459751	0.052802	8.707	<2e-16	***	2001	6.522
ffdays12c80	0.504077	0.073758	6.834	8.44e-12	***	2002	6.958
ffdays12c90	0.534762	0.085012	6.290	3.22e-10	***	2003	6.958
ffdays12c100	0.564982	0.033201	17.017	<2e-16	***	2004	7.317
ffdays12c150	0.609985	0.057292	10.647	<2e-16	***	2005	7.394
ffdays12c200	0.616517	0.059839	10.303	<2e-16	***	2006	9.321
hours2	0.126400	0.046474	2.720	0.006537	**	2007	7.120
hours3	0.334840	0.043843	7.637	2.30e-14	***	2008	6.481
hours4	0.481667	0.043260	11.134	<2e-16	***	2009	6.208
hours5	0.618613	0.044100	14.028	<2e-16	***	2010	5.829
hours6	0.684097	0.044694	15.306	<2e-16	***	2011	4.962
hours7	0.883289	0.048963	18.040	<2e-16	***	2012	4.980
hours8	0.879984	0.051732	17.010	<2e-16	***	2013	5.344
hours9	0.880823	0.069697	12.638	<2e-16	***	2014	5.662
hours10	1.053290	0.079159	13.306	<2e-16	***		
hours11	1.211763	0.161885	7.485	7.38e-14	***		
hours12	1.083964	0.095056	11.403	<2e-16	***		

Table A4b. Results of the logistic regression analysis of MRFSS striped bass success/failure. Analysis of Deviance Table (Type III tests).

Response: p

	LR Chisq	Df	Pr(>Chisq)	
year	2107.3	27	< 2.2e-16	***
area_x	236.6	2	< 2.2e-16	***
mode_fx	4193.4	2	< 2.2e-16	***
wave	499.0	3	< 2.2e-16	***
cnty	514.2	7	< 2.2e-16	***
ffdays12c	1013.7	12	< 2.2e-16	***
hours	2826.6	11	< 2.2e-16	***

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.62422	0.24879	-14.567	<2e-16	***
year1988	-0.16119	0.27150	-0.594	0.552720	
year1989	-0.11105	-.26827	-0.414	0.678921	
year1990	-0.22980	0.25741	-0.893	0.371990	
year1991	-0.33847	0.25617	-1.321	0.186411	
year1992	-0.16503	0.25045	-0.659	0.509938	
year1993	0.15877	0.24963	0.636	0.524768	
year1994	0.63703	0.24771	2.572	0.010121	*
year1995	0.92543	0.24701	3.747	0.000179	***
year1996	0.96701	0.24744	3.908	9.30e-05	***
year1997	0.94695	0.24671	3.838	0.000124	***
year1998	1.42961	0.24666	5.796	6.79e-09	***
year1999	1.18097	0.24676	4.786	1.70e-06	***
year2000	1.09573	0.24727	4.431	9.37e-06	***
year2001	0.89615	0.24675	3.632	0.000281	***
year2002	0.94302	0.24762	3.808	0.000140	***
year2003	0.84039	0.24733	3.398	0.000679	***
year2004	0.91920	0.24874	3.695	0.000220	***
year2005	1.03086	0.24918	4.137	3.52e-05	***
year2006	1.28155	0.24812	5.165	2.40e-07	***
year2007	0.95947	0.24894	3.854	0.000116	***
year2008	0.78808	0.25011	3.151	0.001628	**
year2009	0.74164	0.24919	2.976	0.002918	**
year2010	0.50745	0.25071	2.024	0.042964	*
year2011	0.38057	0.25125	1.515	0.129841	
year2012	1.20578	0.25592	4.712	2.46e-06	***
year2013	1.77625	0.25168	7.058	1.69e-12	***
year2014	1.33542	0.25376	5.262	1.42e-07	***
area_x2	-0.02391	0.03308	-0.723	0.469902	
area_x5	0.31244	0.02213	14.120	<2e-16	***
mode_fx6	2.55062	0.04539	56.190	<2e-16	***
mode_fx7	1.14688	0.02487	46.112	<2e-16	***
wave4	-0.38606	0.02257	-17.108	<2e-16	***
wave5	-0.53109	0.02683	-19.795	<2e-16	***
wave6	2.90247	0.74660	3.888	0.000101	***

Table A4b continued.

cnty19	-0.40307	0.08039	-5.014	5.33e-07	***
cnty21	0.11174	0.05255	2.126	0.033469	*
cnty23	-0.14196	0.03110	-4.564	5.02e-06	***
cnty25	0.11583	0.07546	1.535	0.124809	
cnty5	-0.28109	0.04590	-6.124	9.14e-10	***
cnty7	-0.16175	0.05814	-2.782	0.005398	**
cnty9	0.38723	0.02439	15.877	<2e-16	***
ffdays12c10	0.12425	0.02959	4.199	2.69e-05	***
ffdays12c20	0.39486	0.03095	12.759	<2e-16	***
ffdays12c30	0.48007	0.03627	13.237	<2e-16	***
ffdays12c40	0.58555	0.04561	12.838	<2e-16	***
ffdays12c50	0.71788	0.04046	17.744	<2e-16	***
ffdays12c60	0.67696	0.05527	12.248	<2e-16	***
ffdays12c70	0.833561	0.07102	11.765	<2e-16	***
ffdays12c80	0.81326	0.10020	8.117	4.79e-16	***
ffdays12c90	0.65944	0.10903	6.048	1.46e-09	***
ffdays12c100	0.90447	0.04444	20.353	<2e-16	***
ffdays12c150	0.93313	0.07635	12.221	<2e-16	***
ffdays12c200	0.87689	0.08233	10.650	<2e-16	***
hours2	0.62887	0.04710	13.353	<2e-16	***
hours3	1.03253	0.04503	22.928	<2e-16	***
hours4	1.31489	0.04482	29,334	<2e-16	***
hours5	1.48585	0.04672	31.806	<2e-16	***
hours6	1.72972	0.04864	35.563	<2e-16	***
hours7	1.88274	.05824	32.329	<2e-16	***
hours8	1.84459	0.06203	29.739	<2e-16	***
hours9	2.16253	0.09823	22.015	<2e-16	***
hours10	2.19895	0.11290	19.477	<2e-16	***
hours11	1.61002	0.21620	7.447	9.56e-14	***
hours12	2.25640	0.13567	16.631	<2e-16	***

Year	LSMeans
1987	0.570
1988	0.530
1989	0.543
1990	0.513
1991	0.486
1992	0.529
1993	0.608
1994	0.715
1995	0.770
1996	0.777
1997	0.774
1998	0.847
1999	0.812
2000	0.799
2001	0.765
2002	0.773
2003	0.753
2004	0.769
2005	0.788
2006	0.827
2007	0.776
2008	0.745
2009	0.736
2010	0.688
2011	0.660
2012	0.816
2013	0.887
2014	0.834