Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-64

Massachusetts Striped Bass Monitoring Report for 2015

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Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
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Massachusetts Division of Marine Fisheries

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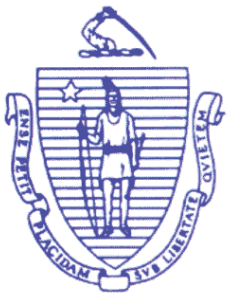

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Ronald Amidon, Commissioner
Massachusetts Division of Marine Fisheries
David E. Pierce, Director

Summary: During 2015, the Massachusetts commercial fishery for striped bass sold about 42,250 fish weighing 865,753 pounds and kept approximately 724 fish for personal consumption. Total losses due to commercial harvesting (including release mortality) were 47,801 fish weighing 923,251 pounds. The recreational fishery harvested about 170,770 striped bass weighing over 2.7 million pounds. Total losses due to recreational fishing (including release mortality) were 309,918 fish weighing over 3.7 million pounds. Combined were 357,720 fish weighing over 4.6 million pounds, which reflects a 25% decrease in numbers lost and a 23% decrease in weight lost compared to 2014 (479,489 fish; 6.0 million pounds). The majority of losses, 86% by number and 80% by weight, was attributed to the recreational fishery. The decreases were due to changes in coast-wide regulations.

Introduction

This report summarizes the commercial and recreational striped bass fisheries conducted in Massachusetts during 2015. Data sources used to characterize the state fisheries come from monitoring programs of the Massachusetts Division of Marine Fisheries (DMF) and National Marine Fisheries Service (NMFS), 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 2015

Season: June 25–August 21, 2015. Landings were permitted on Monday and Thursday only .

Sold: 865,753 pounds (against a harvest quota of 869,813 pounds). The 2015 quota reduction was mandated by the ASMFC.

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 the DMF in addition to standard seafood dealer permits. Dealer reporting requirement included weekly reporting to the DMF or SAFIS system of all striped bass purchases. If sent to DMF, all landings information is entered into SAFIS by DMF personnel. 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. DMF personnel review dealer transactions and correct entries before calculating total landings.

Table 1. Attributes of the Massachusetts striped bass commercial fishery, 1990-2015.

		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	1055.4	55.7	151	4,867
2004	19	1206.3	60.6	130	4,376
2005	22	1104.7	59.5	162	4,159
2006	26	1312.1	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	56.1	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
2015	17	865.7	42.2	160	3,864

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 865,753 pounds (42,250 fish from count of commercial tags used) of striped bass in 2015 (Table 1). Most striped bass were sold in Barnstable, Bristol, Essex and Plymouth counties of Massachusetts. Commercial fishers kept an additional 724 fish weighing approximately 13,000 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 688 fish sampled from the 2015 commercial harvest and 2000 DMF diet study were used to construct a length-weight equation to estimate weight-at-size for individual bass. The following geometric regression was derived:

$$\log_{10}(W) = -3.449 + 2.996 * \log_{10}(L),$$
$$RMS = 0.0027$$

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:

$$W = 10^{(-3.49 + 2.996 * \log_{10}(L) + RMS/2)}$$

Size composition of the commercial catch by category of disposition is presented in Appendix Tables 1A (numbers of fish) and 1B (pounds of fish). About 42% of all fish caught had lengths ≥34 inches.

Age and Sex Composition.. Six hundred and eighty-eight fish sampled from the 2015 commercial harvest were used to sex and age the harvested fish. Age composition of harvest fish was estimated from a sub-sample of 519 fish. The age composition of released and consumed fish was estimated from length data reported in past angler logs. Age was determined from scales and sex was determined by visual inspection of gonadal tissue (Sykes Method). Age of harvested fish ranged from 6 to 18 years. About 80% of the sub-sample consisted of individuals from the 2002-2007 year classes (ages 8-13) (Figure 1). Peak numbers-at-age of the total removals (harvest plus dead releases plus consumed) were from the 2004 and 2005 year-classes (Figure 1).

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, *MarineFisheries* 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 MA, Cape Cod Bay, North MA). Only data from July-August were used to constraint 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 Appendix Tables 2. Although factors were significant, the variables accounted for only about 8% of the total variation in harvest rates.

Harvest rates steadily increased after 1999, peaked in 2004, dropped through 2008, increased slightly through 2010 and then dramatically increased in 2011 and remained at high levels in

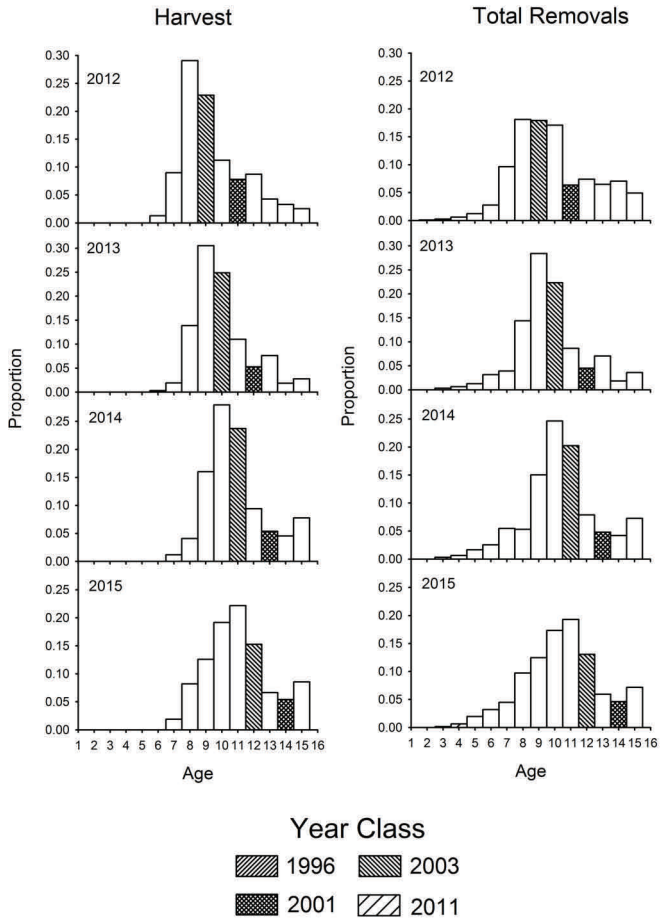

Figure 1. Age composition (proportion) of harvest and total removals (harvest plus dead releases plus consumed) from the Massachusetts commercial fishery. The large 1996, 2001, 2003 and 2011 Chesapeake Bay year-classes are high-

2012, dropped through 2014 and increased 2015 (Figure 2A). The dramatic increase in harvest rates for 2011 and 2012 is attributed to large increases in harvest rates by fishers in Cape Cod Bay and southern Massachusetts (Figure 2B). The reason for the increase was due to atypical, large concentrations of striped bass (likely attracted to large aggregations of sand lance of sand lance in the area) off Cape Cod, particularly off Chatham in 2011 and 2012. These large aggregations likely increased the vulnerability of striped bass to capture. In 2015, catch rates in Cape Cod Bay and northern Massachusetts increased substantially likely the result of a shift in distribution of aggregated striped bass.

Characterization of Other Losses. Release mortality was estimated by using a hook-release mortality rate of 9% applied against the released fish in Appendix Tables 1A and 1B. Total losses due to release mortality were 4,828 fish weighing approximately 44,218 pounds.

Recreational Fishery in 2015

Season: None

Daily Bag Limit: One 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 MA state waters.

Harvest levels: Harvest (A+B1) and total catch (A+B1+B2) estimates (Table 2) were provided by the NMFS MRIP. The MRIP estimates of total catch (including fish released alive) in 2015 was 1,716,864 striped bass, which is a 14.9% decrease compared to the 2014 estimate (Table 2). The estimate of total harvest in 2015 was 170,770 fish, which is a 33.0% decrease in harvest compared to 2014. Total pounds harvested was over 2.7 million in 2015 (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) angler program 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 in 2015. 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 Appendix Tables 3A and 3B.

Age Composition. A sub-sample of 833 fish from the volunteer angler survey was aged and combined with commercial and tagging samples to produce an age-length key used to convert the MRIP and MA volunteer angler 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 2015 catches of striped bass were comprised mostly of the 2010 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; Stefansson, 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 and then the statistical models are recombined to obtain year estimates. The catch success/failure was modeled as a binary response to the categorical variables using multiple logistic regression:

$$\text{logit}(p) = \log(p/1-p) = a + \sum_{i=1}^{n} b_i X_i + e$$

where p is the probability of catching a fish, 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. 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

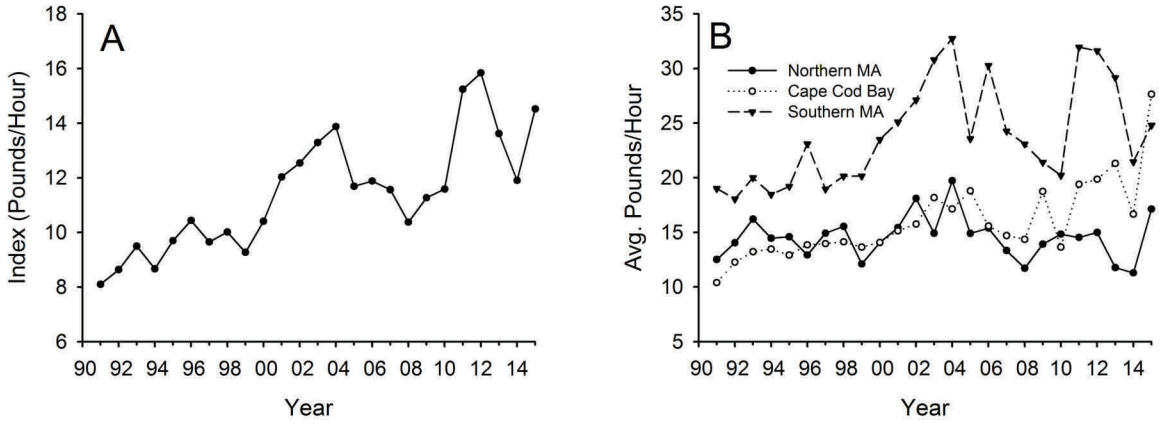

Figure 2. A) Harvest index (standardized pounds/hour) and B) average harvest rates by area for the Massachusetts commercial striped bass fishery, 1990-2015.

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

	Harvest (A+B1)		Released (B2)	Total (A+B1+B2)
Year	Numbers	Weight (lbs)	Numbers	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	282,170	3,899,919	1,690,888	1,973,058
2014	253,877	4,056,799	1,762,718	2,016,595
2015	170,770	2,701,724	1,546,094	1,716,864

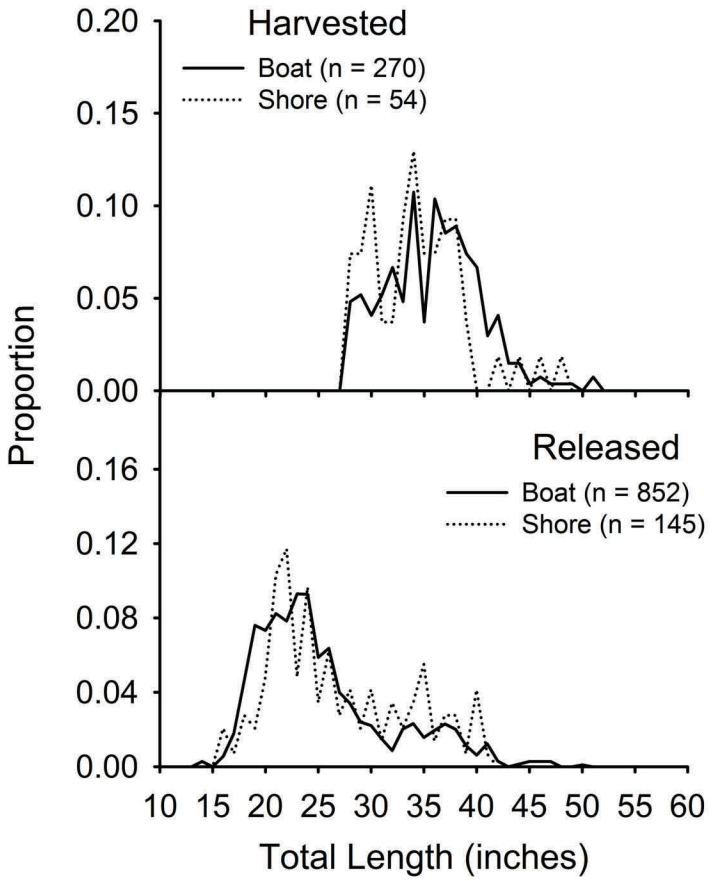

Figure 3. Sizes of striped bass caught by volunteer recreational anglers in 2015 by disposition and fishing mode.

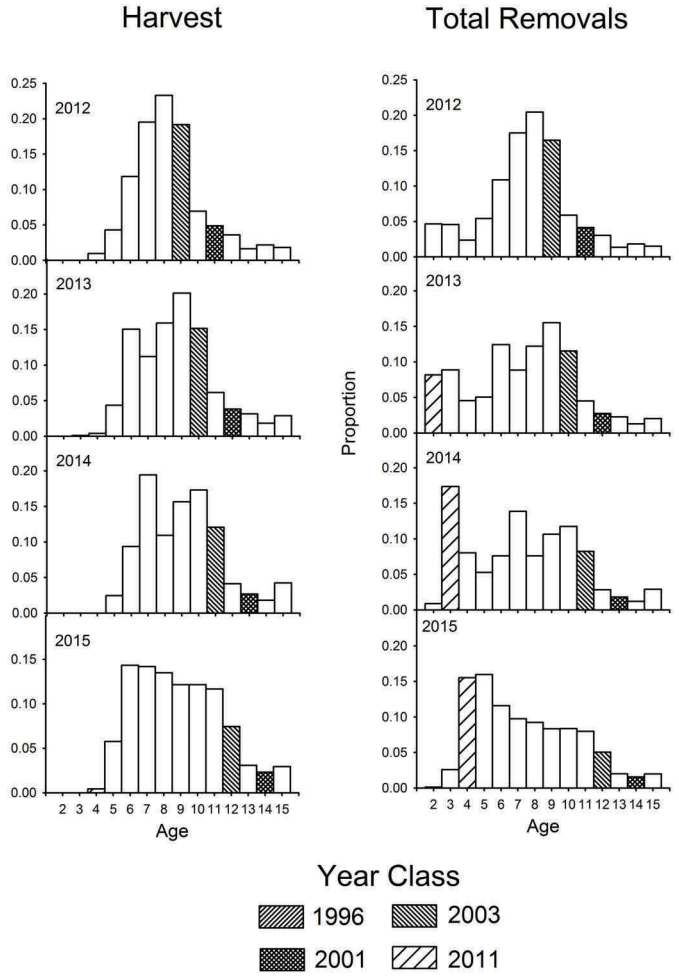

Figure 4. Age composition (proportion) of harvest and total removals (harvest plus dead releases) from the Massachusetts recreational fishery. The large 1996, 2001

Gamma error distribution with a log link using function *glm* in *R:*

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

where y is the observed positive catch, b_i ,and X_i are the same symbols as defined earlier, 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 responses from the least-squares mean estimates 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 Appendix Tables 4A and 4B for 1986-2015. Standardized catch rates for striped bass in Massachusetts waters increased from 1993 to 1998, declined through 2003, but increased in 2004 and 2005 (Fig. 5). In 2006, catch rates jumped dramatically as the large 2003 year-class became vulnerable to the fishery. Catch rates declined through 2011, but began increasing in 2012 as the 2011 year-class became vulnerable to the fishery (Fig. 5). Total catch rates dropped slightly since

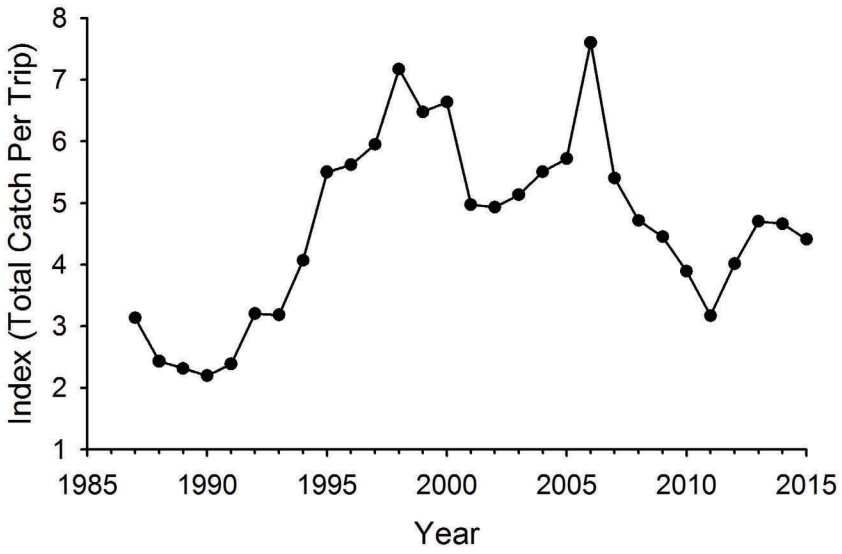

Figure 5. Standardized total catch rates (total number of fish caught per trip) of the recreational fishery for striped bass in Massachusetts waters, 1987-2015.

2013.

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 139,148 fish (about 1 million 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 was also reported which 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 2016.

Estimated Total Losses in 2015

Total estimated loss of striped bass during 2015 was 357,720 fish weighing over 4.6 million pounds pounds (Table 3), which reflects a 25% decrease in numbers lost and a 23% decrease in weight compared to 2014 (479,489 fish; 6.0 million

Table 3. Estimates of striped bass losses occurring in Massachusetts waters during 2015.

FISHERY	NUMBER	POUNDS	MEAN WT.
Commercial			
Harvest*	42,974	879,033	20.5
Release Mortality	4,828	44,218	9.2
Recreational			
Harvest	170,770	2,701,724	15.8
Release Mortality	139,148	1,025,819	7.4
Total	357,720	4,650,794	

* includes fish taken for personal consumption

Table 4. Massachusetts striped bass removals-at-age matrix of 2015 by source.

	Recreational		Commercial		
Age	Release Mortality	Harvest	Release Mortality	Harvest*	Total
2	440	0	7	0	446
3	8334	0	74	0	8,409
4	46502	491	306	2	47,301
5	38499	7,135	903	31	46,568
6	12491	25,470	1,352	166	39,479
7	6075	23,825	986	1155	32,041
8	4593	19,192	472	4177	28,434
9	5893	25,132	284	5667	36,976
10	6198	23,590	272	8017	38,077
11	5040	20,555	138	9078	34,811
12	3407	14,185	30	6206	23,828
13	469	3,912	0	2831	7,212
14	370	3,117	0	2210	5,697
15	175	563	0	1460	2,198
16+	663	3,604	0	1974	6,241

* includes fish taken for personal consumption

pounds). The decreases were due mostly to ASMFC mandated coast-wide regulation changes. The majority of losses, 86% by number and 80% by weight, was attributed to combined losses in the recreational fishery.

Removals-At-Age Matrix in 2015

The removals (numbers) due to release mortality and harvest by the recreational and commercial fisheries are apportioned by age and mortality source in Table 4. The 2011 (age 4), 2010 (age 5) and 2005 (age 10) year-classes incurred the highest losses in 2015 (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 2015. The resulting equation and predicted relationship are shown in Figure 7.

Required Fishery-Independent Monitoring Programs

Massachusetts Tagging Study

DMF joined the Striped Bass Cooperative State-

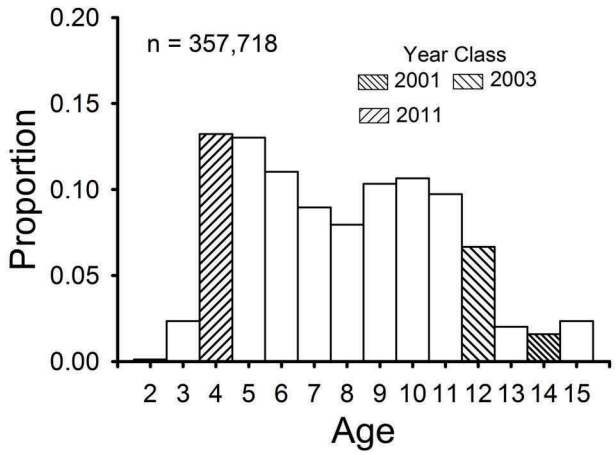

Figure 6. Proportion of striped bass removals in 2015 by age. The 2001, 2003 and 2011 year-classes are indicated.

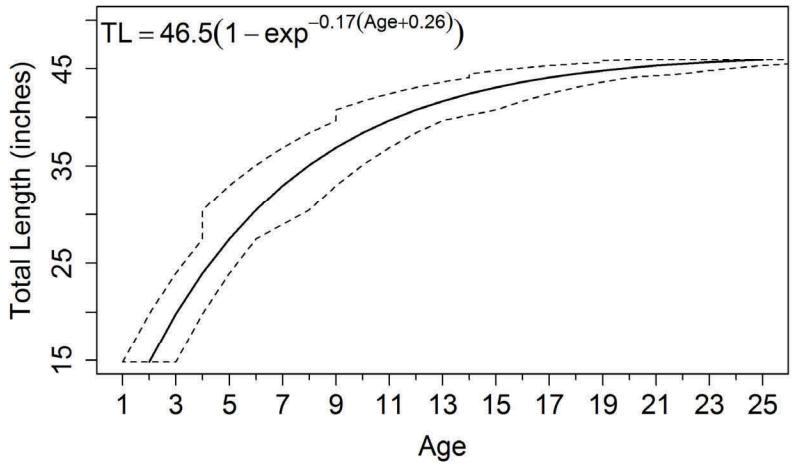

Figure 7. Mean length-age relationship (solid line) for striped bass captured in Massachusetts. Dotted lines represent the minimum and maximum ages found at a given length.

Federal Coast-wide 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, DMF contracts several select charter boat captains to take DMF 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 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 recaptured in 2012-2015 were reported from coastal waters in North Carolina through Maine

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

			Number	Ave.	Ave.	SD	SD	Length Range			
Year	Trips	Boats	Tagged	Length (mm)	Length (in)	(mm)	(in)	Min (mm)	Min (in)	Max (mm)	Max (in)
1991	17	4	388	817	32.2	106.4	4.2	534	21.0	1300	51.2
1992	29	3	899	798	31.4	125.9	5.0	524	20.6	1267	49.9
1993	15	2	678	784	30.9	125.0	4.9	515	20.3	1210	47.6
1994	13	2	377	735	28.9	93.2	3.7	548	21.6	1028	40.5
1995	11	2	449	767	30.2	110.2	4.3	470	18.5	1178	46.4
1996	8	2	203	748	29.4	64.1	2.5	541	21.3	1077	42.4
1997	10	2	321	773	30.4	114.7	4.5	485	19.1	1090	42.9
1998	12	2	382	797	31.4	93.8	3.7	597	23.5	1055	41.5
1999	16	2	471	777	30.6	95.5	3.8	594	23.4	1108	43.6
2000	25	4	1095	752	29.6	102.6	4.0	510	20.1	1204	47.4
2001	14	3	456	786	30.9	102.5	4.0	503	19.8	1110	43.7
2002	12	3	239	764	30.1	103.6	4.1	487	19.2	1060	41.7
2003	15	3	655	825	32.5	92.1	3.6	602	23.7	1204	47.4
2004	25	7	784	707	27.8	193.1	7.6	316	12.4	1164	45.8
2005	19	4	752	726	28.6	210.5	8.3	299	11.8	1114	43.9
2006	11	4	390	813	32.0	94.2	3.7	565	22.2	1114	43.9
2007	16	3	530	848	33.4	105.2	4.1	600	23.6	1225	48.2
2008	13	2	456	821	32.3	104.6	4.1	530	20.9	1202	47.3
2009	15	3	501	840	33.1	101.8	4.0	572	22.5	1146	45.1
2010	13	3	329	825	32.5	84.0	3.3	668	26.3	1095	43.1
2011	15	3	504	831	32.7	91.9	3.6	580	22.8	1174	46.2
2012	15	3	643	852	33.5	87.7	3.5	524	20.6	1203	47.4
2013	15	3	487	854	33.6	92.2	3.63	617	24.3	1145	45.1
2014	15	3	455	876	34.5	98.8	3.89	536	21.1	1203	47.4
2015	15	3	348	857	33.7	90.9	3.58	597	23.5	1063	41.9

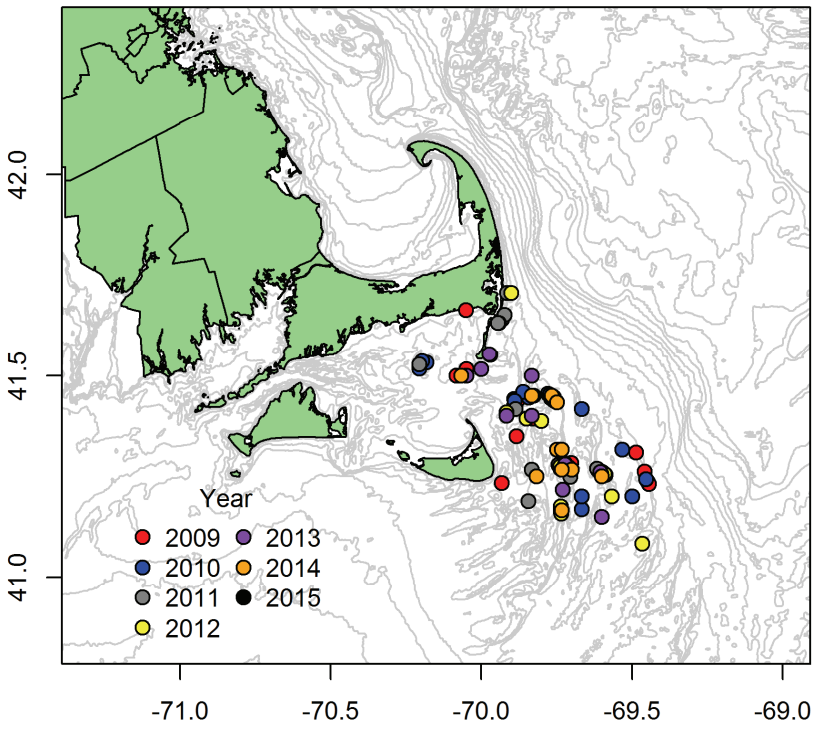

Figure 8. Map of DMF fall tagging locations during 2009-2015.

(Figure 9).

Planned Management Programs in 2016

Regulations

Massachusetts' recreational bag and minimum size limits will remain at 1 fish per day and 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. The commercial fishery quota will be monitored using the SAFIS system. All monitoring programs will continue in 2016.

Acknowledgements

The collection and quality of striped bass data would suffer greatly without the efforts of many DMF employees. Staff of the Fisheries Statistics section collected, entered, and compiled all commercial data. Kim Trull coordinated the volunteer recreational angler data collection program, entered scale envelope data, and prepared data for analysis. Scott Elzey, Elise Koob, Collin Farrell and Kim Trull prepared and aged scale samples. John Boardman, Nick Buchan, and Nicole Ward conducted the commercial sampling of stripers. 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.

Literature Cited

Hilborn, R. and C. J. Walters. 1992.Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. 570 p. Chapman and Hall, Inc., New York, NY.

Lo, N. C., L. D. Jacobson, and J. L. Squire. 1992. Indices of relative abundance from fish spotter data based on the delta-lognormal models. Can.

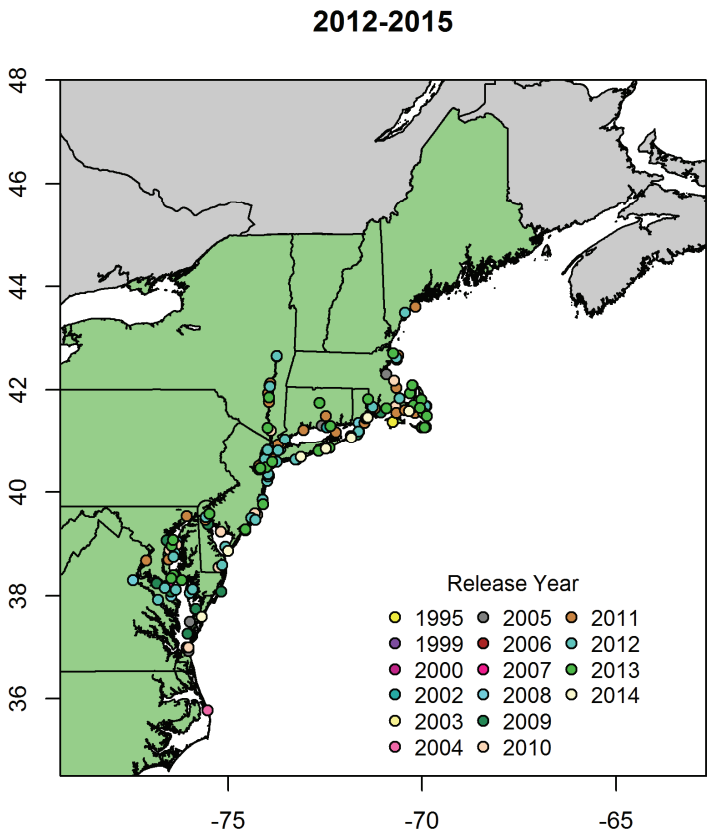

Figure 9. Map of recovery locations from 2012-2015 of *MarineFisheries* tagged striped bass by release year.

J. Fish. Aquat. Sci. 49:2525-2526.

McCullagh, P. and J. A. Nelder. 1989. Generalized linear models, 511 p. Chapman and Hall, London.

Searle, S. R., F. M. Speed, and G. A. Milliken . 1980. Population marginal means in the linear model: an alternative to least-squares means. Am. Stat. 34:216-221.

Stefánsson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES Journal of Marine Science 53: 577–588.

Terceiro, M. 2003. The statistical properties of recreational catch rate data for some fish stocks off the northeast US coast. Fish. Bull. 101: 653-672.

Appendix Table 1A. Estimated size distribution of the Massachusetts commercial striped bass catch (numbers of fish) in 2015.

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	117	117	0.12	0.12
15	0	39	39	0.04	0.16
16	0	311	311	0.32	0.48
17	0	466	466	0.48	0.96
18	0	233	233	0.24	1.21
19	0	388	388	0.40	1.61
20	0	660	660	0.68	2.29
21	0	233	233	0.24	2.53
22	0	621	621	0.64	3.18
23	0	311	311	0.32	3.50
24	0	2,369	2,369	2.45	5.95
25	0	1,243	1,243	1.29	7.24
26	0	2,097	2,097	2.17	9.41
27	0	3,068	3,068	3.18	12.58
28	25	5,554	5,579	5.77	18.36
29	46	3,923	3,969	4.11	22.47
30	54	7,030	7,085	7.33	29.80
31	50	6,681	6,731	6.97	36.77
32	136	10,759	10,896	11.28	48.04
33	364	5,749	6,113	6.33	54.37
34	2,143	1,088	3,231	3.34	57.71
35	3,658	39	3,697	3.83	61.54
36	5,085	621	5,706	5.91	67.45
37	5,104	0	5,104	5.28	72.73
38	6,026	39	6,064	6.28	79.01
39	5,716	0	5,716	5.92	84.92
40	3,926	0	3,926	4.06	88.99
41	3,070	0	3,070	3.18	92.16
42	1,908	0	1,908	1.97	94.14
43	1,117	0	1,117	1.16	95.30
44	1,174	0	1,174	1.22	96.51
45	3,371	0	3,371	3.49	100.00
Total	42,974	53,640	96,614		
Avg. Size	38.6	29.4	33.5		

* includes fish taken for personal consumption

Appendix Table 1B. Estimated weight distribution by size of the Massachusetts commercial striped bass catch (pounds) in 2015.

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	111	111	0.01	0.01
15	0	46	46	0.00	0.01
16	0	443	443	0.03	0.04
17	0	796	796	0.06	0.10
18	0	472	472	0.03	0.14
19	0	926	926	0.07	0.20
20	0	1,835	1835	0.13	0.34
21	0	750	750	0.05	0.39
22	0	2,298	2298	0.17	0.56
23	0	1,313	1313	0.10	0.66
24	0	11,372	11372	0.83	1.49
25	0	6,742	6742	0.49	1.98
26	0	12,795	12795	0.93	2.91
27	0	20,959	20959	1.53	4.44
28	192	42,306	42498	3.10	7.54
29	391	33,193	33584	2.45	9.99
30	511	65,844	66355	4.84	14.84
31	520	69,029	69549	5.08	19.91
32	1,556	122,262	123818	9.04	28.95
33	4,554	71,633	76187	5.56	34.51
34	29,297	14,820	44117	3.22	37.73
35	54,534	577	55112	4.02	41.75
36	82,490	10,050	92541	6.75	48.50
37	89,887	0	89887	6.56	55.06
38	114,938	739	115677	8.44	63.50
39	117,850	0	117850	8.60	72.10
40	87,323	0	87323	6.37	78.47
41	73,525	0	73525	5.37	83.84
42	49,121	0	49121	3.58	87.42
43	30,866	0	30866	2.25	89.68
44	34,753	0	34753	2.54	92.21
45	106,722	0	106722	7.79	100.00
Total	879,033	491,312	1,370,344		
Avg. Weight	20.5	9.2	14.2		

* includes fish taken for personal consumption

Appendix Table 2. Results of the GLM analyses of total catch rates (pounds/hour) for the commercial striped bass fishery, 1991-2015.

```
    Analysis of Deviance Table (Type III tests)

   Response: Pounds/Hour
              SS    Df        F    Pr(>F)
YEAR       1565    24   64.058 < 2.2e-16 ***
AREA       2424     2 1190.863 < 2.2e-16 ***
Residuals 59621 58574
```

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	1.92476	0.02613	73.658	< 2e-16	***
YEAR1992	0.06488	0.03526	1.840	0.0657	.
YEAR1993	0.15927	0.03512	4.535	5.78e-06	***
YEAR1994	0.06749	0.03505	1.925	0.0542	.
YEAR1995	0.18094	0.03134	5.773	7.82e-09	***
YEAR1996	0.25404	0.05103	4.978	6.43e-07	***
YEAR1997	0.17571	0.03032	5.795	6.87e-09	***
YEAR1998	0.21305	0.03091	6.893	5.51e-12	***
YEAR1999	0.13546	0.03158	4.289	1.80e-05	***
YEAR2000	0.25041	0.03211	7.799	6.34e-15	***
YEAR2001	0.39538	0.03217	12.290	< 2e-16	***
YEAR2002	0.43703	0.03167	13.801	< 2e-16	***
YEAR2003	0.49563	0.02924	16.952	< 2e-16	***
YEAR2004	0.53827	0.03529	15.251	< 2e-16	***
YEAR2005	0.36672	0.03196	11.475	< 2e-16	***
YEAR2006	0.38298	0.03022	12.675	< 2e-16	***
YEAR2007	0.35664	0.03069	11.622	< 2e-16	***
YEAR2008	0.24744	0.03066	8.071	7.10e-16	***
YEAR2009	0.33040	0.03041	10.864	< 2e-16	***
YEAR2010	0.35778	0.03258	10.983	< 2e-16	***
YEAR2011	0.63221	0.03663	17.259	< 2e-16	***
YEAR2012	0.67109	0.03312	20.259	< 2e-16	***
YEAR2013	0.50039	0.03387	14.774	< 2e-16	***
YEAR2014	0.38484	0.03238	11.884	< 2e-16	***
YEAR2015	0.58367	0.03314	17.614	< 2e-16	***
AREACCB	0.05825	0.01232	4.727	2.29e-06	***
AREASMA	0.44362	0.01100	40.326	< 2e-16	***

Year	LSMEANS
1991	8.10
1992	8.64
1993	9.50
1994	8.67
1995	9.71
1996	10.44
1997	9.66
1998	10.03
1999	9.28
2000	10.41
2001	12.03
2002	12.54
2003	13.30
2004	13.88
2005	11.69
2006	11.88
2007	11.57
2008	10.38
2009	11.27
2010	11.59
2011	15.25
2012	15.85
2013	13.36
2014	11.90
2015	14.52

Appendix Table 3A. Estimated size distribution of the Massachusetts recreational striped bass catch (numbers of fish) in 2015.

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	0	0	0.00	0.00
13	0	0	0	0.00	0.00
14	0	2,832	2,832	0.16	0.16
15	0	0	0	0.00	0.16
16	0	16,615	16,615	0.97	1.13
17	0	21,746	21,746	1.27	2.40
18	0	62,037	62,037	3.61	6.01
19	0	88,295	88,295	5.14	11.16
20	0	100,122	100,122	5.83	16.99
21	0	138,557	138,557	8.07	25.06
22	0	141,721	141,721	8.25	33.31
23	0	120,081	120,081	6.99	40.31
24	0	145,387	145,387	8.47	48.77
25	0	78,009	78,009	4.54	53.32
26	0	97,622	97,622	5.69	59.00
27	1,124	55,131	56,255	3.28	62.28
28	7,291	56,537	63,828	3.72	66.00
29	8,787	35,364	44,151	2.57	68.57
30	11,388	44,446	55,834	3.25	71.82
31	16,846	22,566	39,412	2.30	74.12
32	12,468	27,032	39,500	2.30	76.42
33	15,724	31,484	47,208	2.75	79.17
34	16,911	41,759	58,670	3.42	82.59
35	11,447	45,147	56,594	3.30	85.88
36	11,993	27,040	39,033	2.27	88.16
37	11,043	37,935	48,978	2.85	91.01
38	11,712	35,019	46,731	2.72	93.73
39	10,525	15,204	25,729	1.50	95.23
40	6,781	28,218	34,999	2.04	97.27
41	2,701	16,167	18,868	1.10	98.37
42	3,179	2,974	6,153	0.36	98.72
43	3,470	0	3,470	0.20	98.93
44	1,974	1,416	3,390	0.20	99.12
45	540	2,890	3,430	0.20	99.32
46	1,831	2,890	4,721	0.27	99.60
47	599	2,890	3,489	0.20	99.80
48	1,258	0	1,258	0.07	99.88
49	393	0	393	0.02	99.90
50	0	963	963	0.06	99.95
51	786	0	786	0.05	100.00
52	0	0	0	0.00	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	170,770	1,546,094	1,716,864		
Avg. Size	34.8	25.9	26.8		

Appendix Table 3B. Estimated size distribution of the Massachusetts recreational striped bass catch (pounds) in 2015.

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	0	0	0.00	0.00
13	0	0	0	0.00	0.00
14	0	2,773	2,773	0.02	0.02
15	0	0	0	0.00	0.02
16	0	24,274	24,274	0.17	0.19
17	0	38,097	38,097	0.27	0.46
18	0	128,985	128,985	0.91	1.38
19	0	215,860	215,860	1.53	2.91
20	0	285,434	285,434	2.02	4.93
21	0	457,181	457,181	3.24	8.17
22	0	537,555	537,555	3.81	11.99
23	0	520,357	520,357	3.69	15.68
24	0	715,697	715,697	5.08	20.75
25	0	433,974	433,974	3.08	23.83
26	0	610,799	610,799	4.33	28.16
27	7,876	386,236	394,111	2.80	30.96
28	56,963	441,681	498,644	3.54	34.50
29	76,257	306,900	383,157	2.72	37.21
30	109,394	426,952	536,346	3.80	41.02
31	178,529	239,147	417,675	2.96	43.98
32	145,318	315,064	460,381	3.27	47.24
33	200,961	402,391	603,352	4.28	51.52
34	236,355	583,649	820,004	5.82	57.34
35	174,502	688,252	862,754	6.12	63.46
36	198,926	448,518	647,443	4.59	68.05
37	198,847	683,067	881,914	6.25	74.30
38	228,422	683,008	911,431	6.46	80.77
39	221,902	320,537	542,439	3.85	84.62
40	154,227	641,784	796,010	5.65	90.26
41	66,141	395,932	462,073	3.28	93.54
42	83,690	78,286	161,976	1.15	94.69
43	98,018	0	98,018	0.70	95.38
44	59,738	42,849	102,587	0.73	96.11
45	17,465	93,543	111,008	0.79	96.90
46	63,285	99,910	163,196	1.16	98.06
47	22,102	106,560	128,661	0.91	98.97
48	49,400	0	49,400	0.35	99.32
49	16,409	0	16,409	0.12	99.43
50	0	42,740	42,740	0.30	99.74
51	36,998	0	36,998	0.26	100.00
52	0	0	0	0.00	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	2,701,724	11,397,989	14,099,713		
Avg. Weight	15.8	7.4	8.2		

Appendix Table 4A. Results of the Gamma regression analysis of MRFSS striped bass catch positive catches.

```
Analysis of Deviance Table (Type III tests)

Response: tot_fish
          LR Chisq  Df  Pr(>Chisq)
year         549.07 28  < 2.2e-16 ***
area_x        45.84  2  1.113e-10 ***
mode_fx      461.37  2  < 2.2e-16 ***
wave         398.87  3  < 2.2e-16 ***
cnty         133.42  7  < 2.2e-16 ***
ffdays12c    632.66 12  < 2.2e-16 ***
hours       1065.58 11  < 2.2e-16 ***

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    0.30577    0.23011   1.329  0.18392
year1988      -0.17101    0.25479  -0.671  0.50211
year1989      -0.24863    0.24840  -1.001  0.31689
year1990      -0.24192    0.23940  -1.011  0.31225
year1991      -0.09897    0.23890  -0.414  0.67869
year1992       0.10451    0.23217   0.450  0.65260
year1993      -0.05113    0.23130  -0.221  0.82506
year1994       0.02109    0.22883   0.092  0.92657
year1995       0.24261    0.22807   1.064  0.28745
year1996       0.25259    0.22835   1.106  0.26868
year1997       0.31517    0.22784   1.383  0.16659
year1998       0.40240    0.22739   1.770  0.07680 .
year1999       0.34749    0.22766   1.526  0.12694
year2000       0.39028    0.22808   1.711  0.08707 .
year2001       0.14915    0.22788   0.654  0.51280
year2002       0.12865    0.22839   0.563  0.57324
year2003       0.19428    0.22835   0.851  0.39489
year2004       0.24428    0.22895   1.067  0.28600
year2005       0.25407    0.22923   1.108  0.26771
year2006       0.48652    0.22831   2.131  0.03311 *
year2007       0.21461    0.22890   0.938  0.34846
year2008       0.12337    0.23021   0.536  0.59204
year2009       0.07941    0.22972   0.346  0.72960
year2010       0.01744    0.23105   0.075  0.93984
year2011      -0.14346    0.23188  -0.619  0.53613
year2012      -0.13943    0.23216  -0.601  0.54813
year2013      -0.07081    0.22907  -0.309  0.75722
year2014      -0.01246    0.23040  -0.054  0.95687
year2015      -0.04384    0.22962  -0.191  0.84859
area_x2       -0.04447    0.02539  -1.751  0.07987 .
area_x5        0.09352    0.01727   5.414 6.22e-08 ***
mode_fx6       0.35897    0.03251  11.042  < 2e-16 ***
mode_fx7       0.49359    0.02201  22.427  < 2e-16 ***
wave4         -0.31048    0.01667 -18.627  < 2e-16 ***
wave5         -0.18681    0.02131  -8.765  < 2e-16 ***
wave6          1.20961    0.22958   5.269 1.38e-07 ***
cnty19        -0.11450    0.06922  -1.654  0.09809 .
cnty21        -0.01047    0.04070  -0.257  0.79692
cnty23        -0.02572    0.02496  -1.030  0.30282
cnty25        -0.29257    0.06074  -4.817 1.47e-06 ***
cnty5         -0.12498    0.03682  -3.394  0.00069 ***
cnty7         -0.30002    0.04807  -6.242 4.39e-10 ***
cnty9          0.10947    0.01911   5.729 1.02e-08 ***
ffdays12c10    0.05484    0.02370   2.314  0.02069 *
ffdays12c20    0.19208    0.02437   7.882 3.35e-15 ***
ffdays12c30    0.20457    0.02824   7.244 4.48e-13 ***
ffdays12c40    0.33964    0.03455   9.830  < 2e-16 ***
ffdays12c50    0.37219    0.03044  12.227  < 2e-16 ***
ffdays12c60    0.41243    0.04186   9.853  < 2e-16 ***
ffdays12c70    0.45213    0.05212   8.675  < 2e-16 ***
```

Appendix 4A cont'd.

```
ffdays12c80   0.49268    0.07258   6.788 1.16e-11 ***
ffdays12c90   0.52448    0.08438   6.216 5.19e-10 ***
ffdays12c100  0.56267    0.03278  17.167  < 2e-16 ***
ffdays12c150  0.60249    0.05658  10.649  < 2e-16 ***
ffdays12c200  0.55837    0.05627   9.923  < 2e-16 ***
hours2        0.13150    0.04573   2.876  0.00403 **
hours3        0.33697    0.04309   7.821 5.46e-15 ***
hours4        0.47710    0.04250  11.225  < 2e-16 ***
hours5        0.61099    0.04336  14.091  < 2e-16 ***
hours6        0.69326    0.04391  15.788  < 2e-16 ***
hours7        0.87643    0.04812  18.212  < 2e-16 ***
hours8        0.89281    0.05080  17.574  < 2e-16 ***
hours9        0.87688    0.06845  12.811  < 2e-16 ***
hours10       1.05473    0.07861  13.417  < 2e-16 ***
hours11       1.33016    0.15615   8.518  < 2e-16 ***
hours12       1.07862    0.09296  11.603  < 2e-16 ***
```

Year	LSMeans
1987	5.771682
1988	4.864453
1989	4.501173
1990	4.531442
1991	5.227839
1992	6.407554
1993	5.484004
1994	5.894700
1995	7.356436
1996	7.430170
1997	7.910045
1998	8.631026
1999	8.169850
2000	8.527083
2001	6.700017
2002	6.564081
2003	7.009341
2004	7.368708
2005	7.441204
2006	9.388467
2007	7.153334
2008	6.529498
2009	6.248687
2010	5.873211
2011	5.000322
2012	5.020517
2013	5.377102
2014	5.700211
2015	5.524125

Appendix Table 4B. 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        2134.1    28  < 2.2e-16 ***
area_x       253.2    2   < 2.2e-16 ***
mode_fx     4119.3    2   < 2.2e-16 ***
wave         551.3    3   < 2.2e-16 ***
cnty         526.6    7   < 2.2e-16 ***
ffdays12c   1023.2    12  < 2.2e-16 ***
hours       2864.9    11  < 2.2e-16 ***

   Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)  -3.57734    0.24783 -14.435  < 2e-16 ***
year1988     -0.17216    0.27071  -0.636 0.524812
year1989     -0.11387    0.26738  -0.426 0.670207
year1990     -0.23104    0.25657  -0.901 0.367850
year1991     -0.34568    0.25534  -1.354 0.175805
year1992     -0.17160    0.24961  -0.687 0.491772
year1993      0.15245    0.24879   0.613 0.540026
year1994      0.62871    0.24687   2.547 0.010874 *
year1995      0.91550    0.24616   3.719 0.000200 ***
year1996      0.95813    0.24659   3.885 0.000102 ***
year1997      0.93774    0.24586   3.814 0.000137 ***
year1998      1.42058    0.24581   5.779 7.50e-09 ***
year1999      1.17121    0.24591   4.763 1.91e-06 ***
year2000      1.08344    0.24642   4.397 1.10e-05 ***
year2001      0.88655    0.24591   3.605 0.000312 ***
year2002      0.93072    0.24678   3.771 0.000162 ***
year2003      0.83245    0.24648   3.377 0.000732 ***
year2004      0.91362    0.24789   3.686 0.000228 ***
year2005      1.02738    0.24832   4.137 3.51e-05 ***
year2006      1.27813    0.24727   5.169 2.35e-07 ***
year2007      0.95829    0.24808   3.863 0.000112 ***
year2008      0.78340    0.24925   3.143 0.001672 **
year2009      0.73330    0.24834   2.953 0.003148 **
year2010      0.50308    0.24985   2.014 0.044055 *
year2011      0.37831    0.25038   1.511 0.130802
year2012      1.20813    0.25504   4.737 2.17e-06 ***
year2013      1.76699    0.25084   7.044 1.86e-12 ***
year2014      1.33253    0.25291   5.269 1.37e-07 ***
year2015      1.20294    0.25087   4.795 1.63e-06 ***
area_x2      -0.01250    0.03287  -0.380 0.703645
area_x5       0.32130    0.02178  14.752  < 2e-16 ***
mode_fx6      2.46721    0.04412  55.916  < 2e-16 ***
mode_fx7      1.14317    0.02470  46.276  < 2e-16 ***
wave4        -0.40790    0.02222 -18.355  < 2e-16 ***
wave5        -0.55071    0.02654 -20.754  < 2e-16 ***
wave6         2.47688    0.62605   3.956 7.61e-05 ***
cnty19       -0.39114    0.07977  -4.903 9.42e-07 ***
cnty21        0.11973    0.05217   2.295 0.021737 *
cnty23       -0.15658    0.03061  -5.116 3.13e-07 ***
cnty25        0.12352    0.07454   1.657 0.097517 .
cnty5        -0.30277    0.04552  -6.651 2.92e-11 ***
cnty7        -0.18353    0.05763  -3.185 0.001449 **
cnty9         0.37564    0.02400  15.651  < 2e-16 ***
ffdays12c10   0.11983    0.02915   4.111 3.94e-05 ***
ffdays12c20   0.38286    0.03062  12.505  < 2e-16 ***
ffdays12c30   0.46912    0.03589  13.071  < 2e-16 ***
ffdays12c40   0.57259    0.04517  12.676  < 2e-16 ***
ffdays12c50   0.71265    0.04013  17.757  < 2e-16 ***
ffdays12c60   0.66995    0.05477  12.232  < 2e-16 ***
ffdays12c70   0.83246    0.07048  11.811  < 2e-16 ***
ffdays12c80   0.79969    0.09922   8.060 7.65e-16 ***
ffdays12c90   0.64966    0.10852   5.987 2.14e-09 ***
```

Appendix Table 4B cont'd.

ffdays12c100	0.90122	0.04412	20.427	< 2e-16	***
ffdays12c150	0.92507	0.07586	12.195	< 2e-16	***
ffdays12c200	0.88557	0.07901	11.208	< 2e-16	***
hours2	0.62332	0.04655	13.390	< 2e-16	***
hours3	1.01388	0.04447	22.799	< 2e-16	***
hours4	1.31427	0.04427	29.690	< 2e-16	***
hours5	1.46652	0.04615	31.778	< 2e-16	***
hours6	1.72557	0.04806	35.908	< 2e-16	***
hours7	1.85810	0.05746	32.335	< 2e-16	***
hours8	1.83208	0.06123	29.921	< 2e-16	***
hours9	2.16471	0.09732	22.244	< 2e-16	***
hours10	2.16376	0.11213	19.297	< 2e-16	***
hours11	1.65012	0.21262	7.761	8.42e-15	***
hours12	2.26188	0.13469	16.794	< 2e-16	***

Year	Prob
1987	0.5429433
1988	0.5000097
1989	0.5145787
1990	0.4852932
1991	0.4567381
1992	0.5001481
1993	0.5804565
1994	0.6901677
1995	0.7479488
1996	0.7558990
1997	0.7521174
1998	0.8310063
1999	0.7930489
2000	0.7782735
2001	0.7424501
2002	0.7508058
2003	0.7319718
2004	0.7475940
2005	0.7684503
2006	0.8100493
2007	0.7559294
2008	0.7222400
2009	0.7120775
2010	0.6626842
2011	0.6342544
2012	0.7990431
2013	0.8742633
2014	0.8182785
2015	0.7982090